Inaugural Address

Enhancing Timber Production In The Country, Keeping *Melia Dubia* And Bamboo As Flagships

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Hunting and felling of trees for food and shelter is thousands of year old practice. Planting trees and protecting the wild animals is around hundred year old introduction. Unfortunately the newly introduced concept of tree planting is still not very successful.

When we were young, our forests were sufficient to meet the requirement of 33 crore people of India. Rains were plenty. In Malnad region, we never saw the sun for three months during rainy season. Today our population has reached 134 million mark (Feb, 2016) and coupled with this there is drastic reduction in rain fall resulting in severe drought.

135 taluks out of 178 are drought affected in Karnataka. Similar situation we are witnessing happening in other regions also. Despite slow development in R&D sector (Tissue culture, mass propagation; improved varieties; introduction of fast growing exotic species; development of many products to substitute wood), increase in green cover etc., achievements the country has made, we are importing timber from other countries to an extent of Rs.13,000 crores annually.

Recent Paris agreement is compelling us to afforest 50 lakh hectares of forest land to mitigate 275 crore tonnes of carbon. It is under these critical conditions we are meeting here at Coimbatore today.

Now coming to the point, forestry is a dynamic subject. What was economically important at one time, later becomes obsolete like *Lophopetalum wightianum*. What appears to be less important today gains importance later, like wild life, ecology, environment, climate change, etc. In this background we have to be cautiouswhile planning for the next 50 years.

With fifty years of experience, I have developed a hypothesis F= E1, E2, E3, E4.

Where, F= forest of any design

E1=Economical gains,

E2=Employment generation,

E3=Ecological and environmental gains,

E4=Rural poverty.

When the forests flourish, prosperity also flourishes, when forests retreat, poverty gains hold. In this background I request all of you to market your ideas keeping this idea as a strong basis. I am happy that Mr. Prashanth, IFS, Director, IFGTB, Coimbatore invited me to address all of you. I am both a sinner and a sage. I have felled trees for the submersion of Sharavathy project 80,000 acres, Kali project ultimately it came to 2, 00,000 acres, and number of small projects like Harangi, Lakya, Varahi, etc., and also industrial felling's on a big way. Those were the days when **"INDUSTRILISE OR PERISH"** and big projects are **"MODERN TEMPLES"** movements were in circulation. We were inspired by such great thoughts.

Second half of my service was spent in forest and wildlife conservation, and afforestation. I was instrumental in declaring the first "sloth bear sanctuary" at Daroji; "Gudvi bird sanctuary", successfully afforestation of grassy blanks, freeing sandal from draconian outdated law, rising rattan and cane plantations, tending of bamboos in the natural forest, publications, etc., though I was considered as a blue eyedboy of the forestry service, I faced Shaw Commission for putting down smuggling mercilessly, by mafia dons of Western Ghats.

Before moving to my subject of bamboo, I would like to touch on increasing timber production in natural forest. Significant point is that forests are there but hardly we can see giant mature trees; in most of the forests native species are replaced by invasive species *Lantana camara*, *Euphatorium* sp. *Mikania micrantha* etc. Nearly 50% of the forest has no natural regeneration of original forest. On the other hand there is a great pressure from biotic factors like firegrazing, illicit felling, etc.

To bring back natural conditions in forests we have many constrains: do not have quality propagules (seeds, suckers), do not know silviculture methods for number of native species (Brandis- 3500 plus species from India), not mapped area of abundance, accessible to collect the seeds; do not have proper germplasm collection, preservation, seed storage facility forlongterm usage; not very successful in production of quality seedlings; if production is there also no certified seeds/ seedlings , no designated agency and for most of the species we do not have data on availability, utilization. These are essential for sustainable management of forest resources.

What we witnessed in last few decades is, there is an increase in number of personnel working in Forestry sectors - Foresters, Research Scientists, Scholars, number of institutions producing forestry graduates, number of publications etc. but not corresponding increase in quality of forests. Instead there is reduction, encroachment of forest land, overexploitation, man-animal conflict etc. More number of species are being added every year to Rare, Endangered and Threatened List of RED Data Book. For diverting forests for non-forestry works like road construction, industry and for hydroelectric projects, forests are scarified but in turn money is deposited in CAMPA fund. Proportionate planting trees in other area is not happening. Large amount of CAMPA fund is getting accumulated. We are not successful in reaching grass root level in imparting knowledge.

Such information and knowledge should reach farmers and other stake holders. There is an urgent need to strengthen forestry extension – media, training programmes, field visit, helpline number- for timely help- disease management, harvest, storage etc.,

Research Institutes –National and States like IFGTB, Coimbatore; IWST, Bengaluru, Tropica Botanical Garden Research Institute (TBGRI), Trivandrum, Kerala Forest Research Institute (KFRI), Peechi and many Forest Department work in coordinated way- selecting species - 6-12 species each institute- standardization of protocol- nursery and plantation practice- production of quality seedlings. Establishment of nursery - make available enough planting stock, distributing only certified quality planting stock-based on habitat specificity. Duplication of work should be avoided. During multiplication (micro/macro) wider genetic base need to be selected. Collection of seeds, propagules should not be from one locality. For. Eg. If bamboo from one location multiplied and given to farmers in terms of lakhs of seedling and if all comes flowering once future will be bleak. If disease or pest attack occurs, if all are from one genotype, all will be devastated at once. So having different genotype is advantageous, and also to future breeding programme, establishment of permanent plots in major forest types-for long term monitoring about effect of climate change on species composition- phenology etc.When the natural conditions revert to the forests, the growth performance of tree crop also improves.

I would like to mention about my 20 years of post-retirement works, mainly on SILVI-HORTICULTURE. In spite of my struggle in the department, I felt forestry was a losing battle and tried silvi-horticulture studies first, and later introduced this concept to tobacco farmers of Hunsoor and Periyapatna. My motivation was discussing with stake holders, supply of free seedlings and giving advice. The species were Melia dubia, *Grevillea robusta*, *Santalum album*, *Casuarina equisitifolia*, Eucalyptus along with pepper, ginger, *Dolicos* species, chilly, black pepper vines, grafted Jack, etc., My work got a shot in the arm recently by the introduction of **Aranya prothsahayojana** concept by a visionary Forest Minister Mr. Vijayashanker. The farmers got Rs 45 per every surviving seedling in their farms. Today about 20,000 farmers are practicing silvi-horticulture in these two taluks. With the cooperation of the media over 30 article appeared in media, spreading the message to the whole state of Karnataka. I have got more than 6000 calls from farmers in the last six months. Many of the farmers have started silvi-horticulture and many others are on the way. If this practice is continued sincerely, this is bound to make us a surplus country in timber. Today farmers are experimenting and mixing many species and each farmer has become a successful researcher.

I am frequently announcing that with the cooperation of the Govt**. "we can make our farmers, one of the richest in the world"**. We are working in that direction. I will be very happy, if all the participants take this message home and work in that direction. Depending upon the locality factors, suitable tree species have to be selected. Now, coming to Bamboo, the fastest growing plant on land, India occupies a prime position regarding bamboo occurrence in the world. It has nearly 9 million hectares of natural bamboo. China with 4 million hectares earns nearly a billion USD worth of foreign exchange. Even small countries like Thailand, Vietnam, Korea and Philippines earn good foreign exchange from export of bamboo products. This requires serious consideration of the participants and I have suggested some remedial measures as below.

Recommendations

1) There is an urgent need for wiping out the stigma of "poor man's timber, by chemical treatment of bamboo by brochures' method. This is a simple but very effective old research, which is lying mostly in cold storage for a long time, is practiced very little in the field. It is time to take up extension of this knowledge to wider circle of people. We should learn a lesson from this experience. Unless proper extension work is carried out, it is clear from this, where our research stays in the hands of few. We have to learn to convert our valuable research into cow's milk, for wider utilization by all. It is desirable to earmark minimum 2.5% of the project cost for extension purposes compulsorily. This should become one of the guidelines for research.

2) Value addition, industrial production and industrial applications - sophisticated uses. a) Popularizing bamboo as a structural material particularly in buildings, mainly in multipurpose buildings (like barns, storage sheds, cattle sheds, car sheds, residential and office buildings and factories....). Students at engineering colleges should be encouraged to try bamboo buildings during college training itself. Professional Medars who make their living on bamboos should be given training in bamboo house and office building by the engineering colleges. South American

builders are advanced in bamboo buildings and our people should be trained under them.

3) Ecological applications such as fodder to wild animals: for cattle *Dendrocalamus hamiltonii* is said to be good as fodder bamboo. As droughts are becoming frequent all over the country, it is essential for the research institutes to multiply and supply such species to farmers. Popularizing multipurpose bamboo species like *Bambusa tulda*, *B. balcooa*, *Dendrocalamus asper*, *Guadua angustifolia*, *Oxytenanthera stocksii*, which can be used for structures, bamboo shoots, etc.

4) Bamboo charcoal (having high pyrolytic value) is supposed to be a profitable item. State can benefit by manufacturing and exporting it (Bamboo activated charcoal/ bricks). We should keep a target of supporting opening of 100 factories immediately.

5) It is desirable to give training on bamboo shoot processing and producing delicious food products all over the country. This will help in supplementing nutrition and imparting livelihood support.

6) Bamboo should be integrated with rattan cane in the preparation of furniture as a binder. This should be popularized.

7) The use of bamboo for soil and moisture conservation has to be widely extended. Each farmer should have a bamboo clump in his farm and backyard. The bamboo seedlings of suitable species (like less crowned and less spreading,) should be made available at all research stations for farmers.

8) The role of bamboo in carbon trade is still in its infancy. This opportunity should be extensively utilized.

9) The country boast of nearly 9 million hectares of natural bamboo and Lakhs of hectares of bamboo plantations. If the yield is increased even by 50%, there will be a tremendous improvement in the whole economy. There is a need to mark superior mother trees and use this parent plant for multiplication. I have experimented this on *Bambusa bamboos*, the yield can go up by 2-3 times, because of the bigger girth, height and weight of such mother trees. I have gifted plants and seeds of such mother trees to

TERI and IWST, etc. If all of you decide today we can make Indian bamboo, currency of the world. India can become a top exporter in the world. This requires sweat, sacrifice and hard work by all of you as a team. Hope you will join in this crusade.

a) The following remark I am making with pain in my heart, in the background of our nearly failed bamboo missions. Intelligent people headed as CEOs, but they did not have the knowledge of bamboo. They went on harping from the beginning itself that, bamboo should be freed from permits and spent their energies on this unproductive work. They alienated themselves from forest department. They did not have love for bamboos nor humility to take the right advice and decisions and choice. The country has lost precious fifteen years and lot of amount of resources. More than everything, the pioneering effort on an extraordinary, fastest growing plant in the world initiative, was let lose. India should not lose this golden opportunity. Let us have a committee to review the both the Bamboo missions work and list out the success stories and spread it wider. Let us review the drawbacks and take suitable action to rectify the mistake; it is an opportune time to do it.

I strongly feel, that silvi-horticulture is the only way of enriching the individual farmer and the Country, simultaneously.

PLANT AND FLOURISH is the slogan, we should adopt it in this Coimbatore National Workshop on Important Timber Trees of India, 2017.

We should develop the art of working as well knit teams, bigger the involvement of stake holders greater the success. I = WE = TEAM = STAKE HOLDERS (Ex. Rattan work in 1980 s and 1990s in India- expand).

Thank you.

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THE INHERITANCE OF DESIRED TRAITS

Timber trade and forest certification in India

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Abstract

India is a net importer of timber and this import is growing fast to meet the domestic demand and export of value added timber products. While timber imports are liberalised, the exports of unprocessed logs are prohibited as conservation measure to protect India's forests. In the absence of adequate due diligence systems and its implementation mechanisms, India will become a destination for logs harvested illegally and unsustainably. Forest certification offers a voluntary system to the managers of forests including agro forestry, farm forestry and trees outside forests and companies engaged in timber trade to establish credible due diligence systems and thereby support improvement of forest governance besides generating several social, environmental and economic benefits. This paper attempts to address the linkages between India's timber trade and forest certification with special reference to FSC Certification.

Introduction

India is a net importer of timber and this import is growing fast to meet the domestic demand and export of value added timber products. While timber imports are liberalised, the exports of unprocessed logs are prohibited as conservation measure to protect India's forests. In the absence of adequate due diligence systems and its implementation mechanisms, India will become a destination for logs harvested illegally and unsustainably. Forest certification offers a voluntary system to the managers of forests including agro forestry, farm forestry and trees outside forests and companies engaged in timber trade to establish credible due diligence systems and improve governance besides generating several social, environmental and economic benefits. This paper attempts to address the linkages between India's timber trade and forest certification with special reference to FSC Certification.

Forestry is the second largest land use in India next to agriculture. According to India State of Forest Report 2015, India's forest cover is 70.17 million ha (21.34 per cent of total geographical area) and tree cover is 9.26 million ha (2.82 per cent of total geographical area). Forest and tree cover is 79.42 million ha or 24.16 percent of total geographical area. India targets 33 per cent of total geographical area under forests and tree cover. There is an increase of 3775 sq.km (0.38 million ha) in the forest cover of the country as compared to 2013 assessment. However, very dense forests are only 8.59 million ha (2.61 per cent of total geographical area)[2]. (FSI, 2016)

Forest Plantations managed by the Government is the largest domestic source of timber in India (Government of India, 2009). State Forest Development Corporations (SFDCs) set up by the State Forest Departments have established credible systems in harvesting, transporting and marketing of timber. The management of forests is the responsibility of State Forest Department and this is in accordance with the approved forest working plans prepared based on scientific forestry principles. However, the timber originated from forests, including agro forestry, farm forestry areas and trees outside forest areas often lack such management plans. To address this, the Indian industry, in particular paper and pulp sector provide technical and financial support to the farmers(most of them are small holders) to improve management of farm forestry / agro forestry areas in accordance with the best practices. The cooperative societies of these farmers play a significant role in implementing best forest management principles for such areas, including conservation of ecosystem services. National Forest Policy 1988 encouraged such partnerships to increase the supply of timber needed by the industry besides meeting the economic needs of the communities including fuel wood.

Challenges

Deforestation, forest degradation and illegal logging continue to be the challenges that humanity faces today despite global attention to these challenges and introduction of several regulatory and voluntary approaches. The two significant global international initiatives in 2015, the Paris Agreement to address the Climate Change and the adoption of UN Sustainable Development Goals have secured hope and confidence. It is widely acknowledged that the Governments alone cannot implement these initiatives. Therefore, the role of the civil society and private sector are crucial.

In international timber trade, private sector initiatives to support sustainable standards , in particular environmental labelling and certification have made positive contribution to address global challenges in forestry sector. However, the lack of awareness on the benefits of credible forest certification schemes have become a concern. These include the cost of compliance of environmental standards, lack of technology that can be applied locally, lack of awareness on the scope for and limitations of such initiatives.

The World Forest Report 2016 (of FAO) reported that there was a net forest loss of 7 million ha per year in tropical countries in 2000-2010 and net gain in agricultural land of 6 million ha per year[3]. The report identified agriculture as the most significant driver of global deforestation (large scale commercial agriculture-40%; local subsistence agriculture-33%) followed by infrastructure(10%), urban expansion(10%) and mining (7%). One of the key message of the report :

"Where large scale commercial agriculture is the principal driver of land use change, effective regulation of change with appropriate social and environmental safeguards is needed. Private governance initiatives such as voluntary certification schemes and commitments to zero deforestation also have a positive impact." (FAO, 2016)

Increased regulation in the world's leading markets, in particular US Lacey Act amendment in 2008, EU Timber Regulation in 2013, regulations in Australia and Japan to address illegal logging and global deforestation have impacted international trade in timber and timber products. As part of compliance measures with these regulations, the companies/operators in these markets have started asking additional information and documentation from their suppliers in India as well as other countries. This has resulted in increased costs and procedural delays in fulfilling such demand from overseas markets.

Recognition of international forest certification systems by the leading multinational enterprises to address traceability and sustainability in their global supply chains became a driver to the uptake of forest certification in India. However, the local suppliers need to improve their capacity to meet such requirements to access global markets.

Policy Context

India's National Forest Policy 1988 was a major shift from previous policies in several aspects. The earlier forest policies had focused on the sustained production of timber on scientific and business lines for maintaining a sustained supply of wood for industry and large timber for defence, communication and other national purposes[4]. The principal aim of the national forest policy 1988 was " to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which is vital for sustenance of all life forms, human, animal and plant. The derivation of direct economic benefit must be subordinated to this principal aim" (Government of India, 1988)

The Policy stated "As far as possible, a forest based industry should raise the raw material need for meeting its own requirements, preferably by establishment of a direct relationship between the factory and the individuals who can grow the raw material by supporting the individuals with inputs including credit, constant technical advice, and finally harvesting and transport services". To minimise the pressure on India's forests and to meet the industry requirement of timber, the policy recommended import liberalisation of timber.

The National Forest Commission constituted by the Government of India in 2003 made several recommendations in its report submitted in 2006. By recognising the supply constraints of timber in India, the commission noted that felling regulations on private lands may be restricted to "highly restricted tree species" and recommended there should be no restrictions and regulations on the felling and removal of other trees on private holdings. Under Land Ceiling Act, no land ceiling shall be imposed on land under plantation of forest tree species. This will motivate the corporate sector and big farmers to invest in plantations (Government of India, 2006).

Green India Mission (GIM), as part of National Action Plan on Climate Change aims to increase 5 million ha under forest and tree cover and another 5 million ha to improve the quality of forest or tree cover in forest and non forest areas and thereby enhancing carbon sequestration by 100 million tonnes of CO2 equivalent annually.

Draft National Forest Policy -2016, a report prepared by the Indian Institute of Forest Management (IIFM) incorporated several innovative and practical approaches to revise/update the National Forest Policy 1988. For example, among the aims and objectives, the report recommended: "Double the tree cover outside forests by the end of the next decade by incentivizing agro-forestry and farm forestry, facilitating assured returns, with enabling regulations and by promoting the use of wood products." (IIFM,2016). IIFM report recognised the need to encourage forest certification in India. While recommending the policy directions, the report 4.3.7 states:"Mechanisms such as forest and chain of custody certification that promote sustainable management of forest resources should be encouraged through development of appropriate standards and institutional framework."(IIFM,2016). The focus on "promoting sustainable use of wood" rather than "substitution of wood" is a paradigm shift.

The objectives of the National Forest Policy 1988 and subsequent policy interventions have effectively incorporated in other policies, including those related to agriculture, land use practices, trade and investment, finance as well as relevant bilateral, regional and multilateral trade agreements. India's commitment to the implementation of UN Sustainable Development Goals and the Paris Agreement to address climate change supports effective implementation of these policies.

India's growing forest footprint

India with a population of more than 1.3 billion and GDP of USD 2.095 trillion is the sixth largest economy in the world and is growing fast[5]. Increased disposable income of the middle class and the predominance of young working people and implementation of liberalisation policies since 1991 made India as a potential market for trade and investment. India's international trade have crossed USD1 trillion.

The impact of India's economic growth and trade liberalisation put tremendous pressure on forest resources both within the country and overseas. A Chatham House report noticed that about 17 per cent of India's timber imports are illegal origin (Lawson, 2014) India is one of the largest destinations of illegal exports of wood products from several countries[6]. The widening gap between timber demand and supply had adversely affected the development of forest based industries in India (Singh, 1991). A research by the Forest Trends pointed out that many of the countries that source forest products from India have serious concerns about the rapid decline of natural forests, and about their ability to supply products in the future, both for local needs and for exports (EFI, 2014).

The World Bank (2006) Report noted " India is facing serious imbalances between the supply of and demand for wood; and the over harvesting of fuel wood, about 139 million cu.m above the sustainable supply from regulated sources. Much of the log supply deficit is being met through illegal harvesting, putting additional pressure on the remaining high quality dense forests. The supply demand situation underscores the national government's strong support for forest conservation, manifested through efforts to protect existing forests and grow new plantations under Joint Forest Management(JFM)"

Manoharan(2011) concluded that forest conservation measures are not the major limiting factors in timber supply in India. The key determinants of timber supply in the country include GDP growth rate, timber imports, industrial production of wood and whole sale price index of all commodities. Unless India takes the required measures to boost its timber productivity, it will face a severe shortage in timber supply from domestic sources.

The report based on a research supported by the Planning Commission and published by the WWF India recommended that availability of trees outside the forests for timber as well as provisioning of ecosystem services should be promoted by strengthening agro-forestry and farm forestry systems and incentives to growers; development of high yielding tree plantations should be supported, if they are appropriately located and well managed; industry should be encouraged to carry out research in collaboration with relevant universities in India and abroad; promote use of reclaimed wood in the manufacturing of handicrafts, furniture and other timber products; promote imports of timber from certified forests through fiscal and other incentives to the business and industry; safeguard the interests of growers; promote forest certification by providing suitable support (both technical and budgetary) to the State Forest Departments, communities and growers; A significant portion of wood that can be used for timber is currently used for fuel wood. Without compromising the local energy requirements and livelihood timber production can be increased substantially, if the opportunities and policy options are effectively utilised by the forest based industry in India (Manoharan, 2011).

India's Timber Trade

The supply of timber in India is mainly from domestic production and imports. The recycled/reclaimed wood is also contribute to the supply but the volume is limited. The main sources of domestic production of timber in India are (a) Government forests/plantations (b) farm forestry/agro forestry areas (c) private plantations.

Industrial round wood production in India has increased from 41.93 million m3 in 2001 to 49.51 million m3 in 2014. During the period, the imports increased from 2.7 million m3 to 7.3 million m3. (Table 4.1) Three significant

Table 4.1 India's industrial round wood production, exports and imports : 2001-14 (In 1000 m3)

Year	production	Exports	Imports
2001	41930	5.41	2784.76
2002	42691	9.6	2095.77
2003	43448	11.83	2990.54
2004	44206	4.04	3702.21
2005	44966	7.67	3365.31
2006	45723	16.67	3248.91

Year	production	Exports	Imports
2007	46483	9.4	4168.4
2008	47242	11	4171.01
2009	48001	8.86	4902.3
2010	48759	3.63	5299.69
2011	49517	12.87	6341.35
2012	49517	13.25	6527.38
2013	49517	5.78	6530.92
2014	49517	15.38	7367.09

Source: ITTO

product categories have been identified for the analysis. These are HS(44)- wood and articles of wood and wood charcoal; HS(47) -pulp of wood, fibrous cellulosic material and HS(48) paper and paperboard, articles of pulp, paper and board.

Table 4.2 show India's trade in select forest products. In 2015, the import of wood (HS44) valued USD 2.434 billion ; pulp (HS47) worth USD1.68 Billion and paper (HS 48) worth USD 2.424 Billion. The exports of wooden products of HS44 was USD 0.428 billion; HS(47) about USD 0.0109 billion and HS (48) about USD1.127 billion.

Table 4.2 Value of India's trade in selected forest products (USD Billion)

Year	wood HS (44)	Wood HS (44)	Pulp HS (47)	Pulp HS (47)	Paper HS (48)	Paper HS (48)	All commodities	
	Import	Export	Import	Export	Import	Export	Import	Export
2011	2.41	0.22	1.304	0.001	2.454	0.906	462	301
2012	2.606	0.258	1.284	0.0028	2.266	0.93	488	289
2013	2.68	0.351	1.37	0.0015	2.376	1.141	466	336
2014	2.703	0.353	1.656	0.0047	2.61	1.115	459	317
2015	2.434	0.428	1.608	0.0109	2.424	1.127	390	264

Data source : UN COMTRADE

The total import of these three commodities in 2015 valued USD6.46 billion (1.6 percent of India's total imports of all commodities) whereas the export of these valued USD 1.56 billion (0.59 percent of India's total exports of all commodities). (Table 4.3) This does not include exports of wooden furniture (HS 940360) which is USD 0.399 billion in year 2015.

Figure 4.1 shows long term trend of India's industrial round wood production and imports. This was prepared based on FAO data base on forest products. This shows significant increase in imports during the post 1988 period.

Table 4.3: India's import and export of wood, pulp and paper:2011-2015

Year	Import of wood, pulp and paper (Billion USD)	Share of import of all commodities (%)	Export of selected wood products, pulp and paper (In Billion USD)	Share of exports of all commodities (%)
2011	6.168	1.34	1.127	0.37
2012	6.156	1.26	1.1908	0.41
2013	6.426	1.38	1.4935	0.44
2014	6.969	1.52	1.4727	0.46
2015	6.466	1.66	1.5659	0.59

Source: COMTRADE

Figure 4.2 shows the value of India's import of select forest products during 1988-2015. All three categories identified (wood, pulp and paper) have shown significant growth during the period. However, the trend since 2002 shows

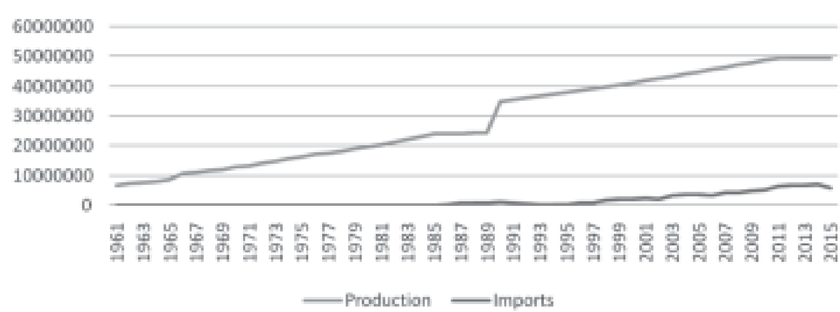
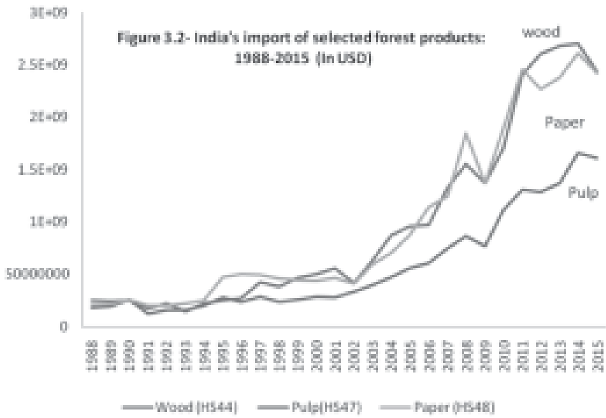


Figure 4.1. India's industrial roundwood - Production and imports : 1961 - 2015 (Quanity - m3)

faster growth and the factors determining such fast growth need to be analysed.



Analysis of international trade data show that India has become one of the world's top importers of timber. Table 4.4 shows the top 15 importers of wood (HS44) in value terms. China with USD 18.62 billion (14.64 per cent of world imports) ranked first followed by USA (USD 18 billion), Japan (USD10 billion). With 1.9 percent of world imports of wood (HS44), India ranked 13 position. If we further analyse the data it is evident that except China (rank 1) and South Korea (rank 8) all top importing countries of wood are developed countries and have implemented stringent regulation to address illegal logging. Further, the forest certification in these markets are also relatively matured when compared to their trade partners in the tropical countries.

While North America, Europe, Japan and Australia are India's leading export market for timber products, the imports of timber are mainly from tropical countries, in particular Malaysia, Myanmar, PNG, Central and Eastern

Table 4.4- World import of wood (HS44) in 2015

Rank	Country	Import value(USD Billion)	Share to world imports (%)
1	China	18.627	14.64
2	USA	18.000	14.15
3	Japan	10.051	7.90
4	Germany	8.025	6.31
5	United Kingdom	6.917	5.44
6	Italy	4.243	3.34
7	France	3.715	2.92
8	Rep. of Korea	3.112	2.45

Rank	Country	Import value(USD Billion)	Share to world imports (%)
9	Netherlands	3.066	2.41
10	Canada	3.009	2.37
11	Belgium	2.727	2.14
12	Austria	2.468	1.94
13	India	2.434	1.91
14	Viet Nam	2.092	1.64
	Others	38.734	30.45
	world	127.219	100.00

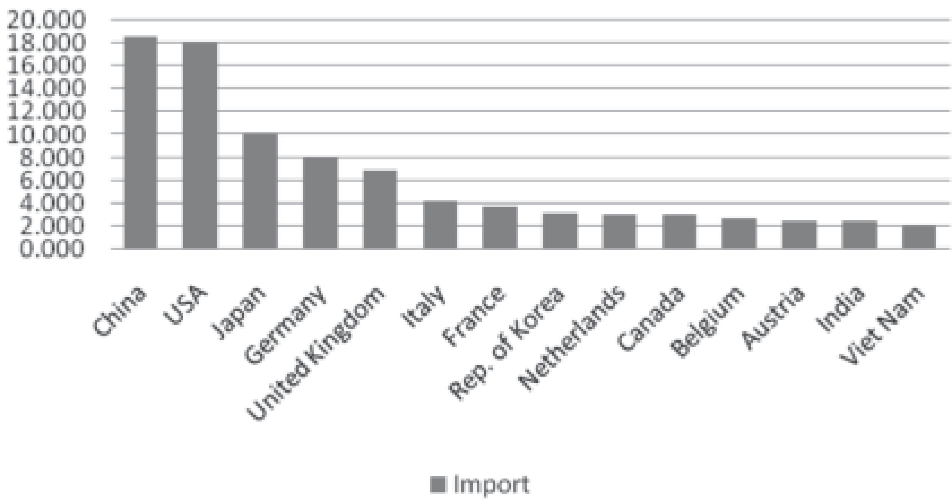


Figure 4.3 - World's top timber importers in 2015 (USD Billion)

Africa, and Latin American countries. The import of wood pulp from Indonesia is also significant. Many of these countries are in the process of voluntary partnership agreements (VPAs) with European Union as part of implementing forest law enforcement governance and trade (FLEGT) action plan. Indonesia is the first country that secured FLEGT licence in 2016. Myanmar's timber export ban in 2014 have affected India, one of the largest export market of Myanmar for timber.

Forest Certification

Forest certification is a market based mechanism to promote responsible management of forests and improve forest governance. Usually forest certification involves two processes: Forest management (FM)certification and Chain of custody (CoC) certification. Forest management unit certification is a process that leads to the issuing of a certificate by an independent party, which verifies that an area of forest/plantation is managed to a defined standard. Chain of Custody certificate (CoC) is a process of tracking wood products from the certified forest to the point of sale to ensure that product originated from a certified forest. (Figure 5.1). The certification system involves development of standards based on credible principles, the development of traceability system and a labeling system through which the consumers can choose the certified product.

Michael Conroy while addressing the challenges of consumer consciousness and direct consumer demand for certification noticed that one of the strongest and most interesting lessons learned in recent years is that certification systems have become most important in business-to-business (B2B) relationships, rather than in business-to- consumer (B2C) transactions. (Conroy,2007).

Forest Certification become a reality in the global market by the establishment of Forest Stewardship Council (FSC) in 1993. FSC is an independent, non-governmental, not-for-profit, membership organization. FSC's ten principles are the basis of the international standards (Box5.1).

Several forest certification schemes have emerged after FSC and these include Programme for Endorsement of Forest Certification (PEFC), Sustainable Forest Initiative (SFI), MTTC (Malaysia) and LEI (Indonesia).

Despite several challenges, the growth of forest certification was impressive. However, the share of developing countries, in particular tropical areas are still low. As of January 2017, area under FSC Certification is 194.75 million ha in

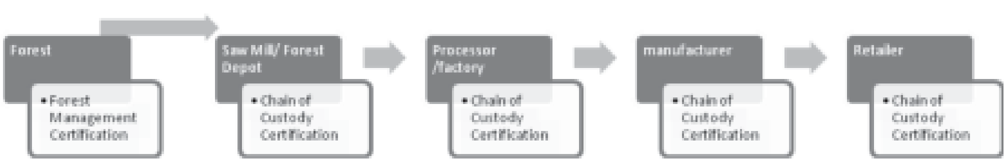


Figure 5.1 : From Forest to Consumer

82 countries and 31,772 Chain of Custody Certificates. Of this 95 million ha are in Europe , 69 million ha from North America (USA, Canada and Mexico). 8.3 million ha from Asia and 7.5 million ha in Africa.13.3 million ha Latin America and Caribbean[1]. The number of chain of custody certificates is 32,000 in 162 countries.

The emergence of FSC in India is a result of the nations response to recognise, promote and make use of credible international standards. In 2007, FSC Certified area was around 644 ha of rubber plantations of New Ambady Estate in Kanyakumari District, Tamil Nadu State and about five FSC Chain of Custody Certificates in Punjab and Gujarat States.

In 2012, the area under FSC Certification has increased to 39,848 ha and number of CoCs becmae 234. In 2016 the area under FSC Certification became 508 million ha and the number of CoCs increased to 351.

Table 5.1 FSC Certification in India:2007-2016

Year	FM (Ha)	CoC (Number)
2007	644	5
2012	39848	234
2016	508216	351

Source: FSC Facts & Figures

Over the period, FSC Certified areas became a reality in several Indian States including Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, Odisha, Tripura, Tamil Nadu and Uttar Pradesh. In 2015, Uttar Pradesh Forest Corporation (UPFC) became the Certificate Holder of largest FSC Certified Area in South Asia.

Forest certification offers several benefits, including economic, social and environment. In the context of India's international timber trade, the certification helps the traders to establish due diligence system and there by securing market access besides generating social and environmental benefits.

The challenges of forest certification include the cost of certification, lack of awareness on the benefits of certification, capacity of small holders and micro, small and medium enterprises to meet the requirements of certification, engaging with multiple government institutions and procedural delays, lack of appropriate technology.

Ministry of Environment and Forests had constituted a National Working Group on Forest Certification in May 2005 with three sub committees on (i)

Box 5.1. FSC 10 Principles

1. Compliance with Laws
2. Workers' Rights and Employment Conditions
3. Indigenous Peoples' Rights
4. Community Relations
5. Benefits from the Forest
6. Environmental Values and Impacts
7. Management Planning
8. Monitoring and Assessment
9. High Conservation Values
10. Implementation of Management Activities

Source: FSC

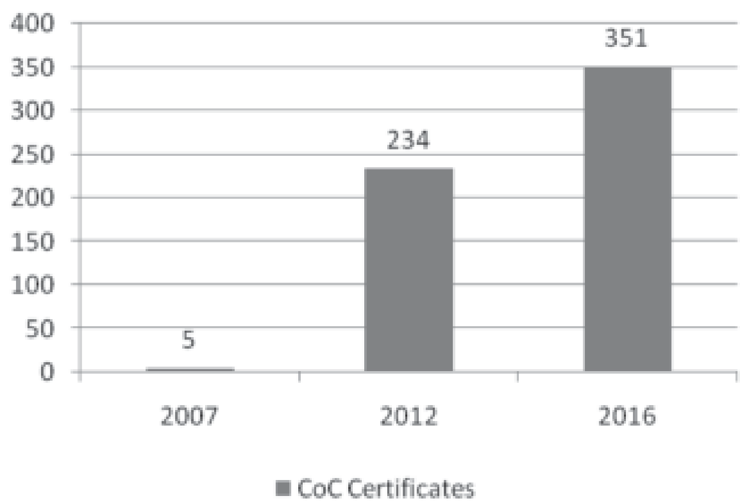


Figure 5.2 Growth in FSC - Chain of custody certificates in India : 2007 - 2016

Table 5.2 FSC Certified Areas in India (As of January 2017)

Sl. No.	Certificate Holder	Certified Area (Ha)	State
1	New Ambadi Estate (P) Ltd	688	Tamil Nadu
2	ITC Limited - PSPD Unit Bhadrachalam	36,112	Telegana
3	Tamil Nadu Newsprint and Papers Limited	2,914	Tamil Nadu
4	International Paper APPM Ltd, Andhra Pradesh	33,635	Andhra Pradesh
5	JK Paper LTD, Unit: JK Paper Mills	4,217	Rayagada, Odisha
6	Uttar Pradesh Forest Corporation, Govternment of Uttar Pradesh(include 13 Forest Divisions in UP)	4,04,104	Uttar Pradesh
7	Tripura Forest Development Plantation Corporation Ltd.Govt. Of Tripura	7,087	Tripura
	Total	4,88,757	

Source : FSC (http://info.fsc.org)

Certification Criteria, (ii) Certification Processes and (iii) Accreditation criteria & processes. The first meeting of three committees were held in October 2007. Later the Ministry constituted a National Forest Certification Committee (NFCC) by merging three committees and appointed Dr Maharaj Muthoo as its Chairperson. The first meeting of NFCC was held in December 2008. NFCC submitted its final report in September 2010 with recommendation to establish Indian Forest Certification Council (IFCC) with a financial support from the Ministry. In 2011 series of stakeholder consultations conducted by the Ministry and prepared a framework to establish Indian Forest Certification Council (IFCC). However, IFFC has not established so far.

Several State Forest Development Corporations have decided to opt for international forest certification schemes in response to the emerging demand for certified timber in India's export markets[1]. Accordingly they have opted for FSC Certification. The Chattisgarh Certification Society, India for forestry and agriculture was established as an autonomous society by the State Government of Chattisgarh in 2003[2] to promote organic certification, forest certification and other certification.

Network for Certification and Forest Certification (NCCF) was formulated in 2014 by the stakeholders and become a member of PEFC International in March 2015 and promoting PEFC certification in India.[3]

WWF- India in coordination with other key stakeholders initiated a leading role to promote forest certification in India in accordance with the WWF position on this subject globally[4]. The awareness and capacity building programmes conducted as part of Global Forest and Trade Network (GFTN) since 2006 has resulted in the uptake of Forest Stewardship Council (FSC) Certification in India. In 2011, FSC International designated a national representative for India.

Conclusion

Forest certification is an opportunity rather than a challenge to promote India's international timber trade. Imports of timber continue to grow fast and therefore there is a legitimate requirement to introduce adequate due diligence system not only to demonstrate India's commitment to address legality and sustainability but also to support the efforts of the supplier countries to address deforestation and illegal logging. Many of these supplier countries are developing and least developed tropical countries. India's export markets for wood products are developed countries where the voluntary sustainability standards such as forest certification are well recognised. Forest certification assures market access of timber products from India to these markets besides other benefits.

There is a need to invest in minimising the cost of certification, in particular to small holders and small and medium enterprises. The awareness on the benefits of forest certification need to be increased. Fiscal incentives to be provided to the Indian industry, particularly small holders.

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A Value Chain on Timber based Industrial Agroforestry - Constraints and Interventions

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Introduction

Timber products are environmentally superior to other variants made from metals, plastics and cement as these are recyclable, energy efficient and reduce greenhouse gases. Existing forest policies, laws and national forestry programmes in various countries across the world were revised to promote sustainable forest management, biodiversity conservation, and to restrict uncontrolled timber logging. However, the unsustainable extraction and illegal trade in timber has resulted in the loss of forests and biodiversity in many countries. Presently the world's forests are depleting at an alarming rate of 16 million ha per annum (FAO, 2012).

India is one of the top producers of tropical logs among ITTO member countries, but the country faces a severe shortage of timber supply from domestic sources to meet its growing demand. The productivity of Indian Forests is 0.5cu.m/ha/annum compared to the world average of 2.0 cu.m./ha/annum. The India State of Forest Report (2011) estimated timber production from government forests to be 3.17 million m^3, and potential timber production from TOFs, including industrial plantations, social and farm forestry to be 42.77 million m^3 (FSI, 2011). The current demand for timber is almost twice the total production and there exists a huge gap in timber supply and demand in India, resulting in the massive import of timber.

Over the past two decades, countries that export timber to India have undergone policy changes with respect to timber extraction, which include a log export ban, and reduce forest exploitation. This shift in forest policies could result in a decline in timber production, thus creating a supply crunch for countries dependent on timber imports. The countries like India which dependent on imports would be most affected, and therefore should revise their existing policies and institutional frameworks in an effort to increase timber production from TOFs through agro and farm forestry to meet growing domestic demand. Under such circumstances, the Forest College and Research Institute of Tamil Nadu Agricultural University has conceived a Value Chain Model for timber supply chain which are furnished in this paper.

Influence of Policies and Acts on Timber Production

After independence, India went through an infrastructural developmental phase in terms of industrial expansion. This expansion included urban development, housing, river valley projects and improved communications through an expanding transport network, which relied directly on timber (GoI, 1976; Balaji, 2002).The domestic demand for forest products also increased significantly due to increase in population and the associated urbanization.

The National Forest Policy (1952) was enunciated to provide an approach for balanced and complementary land use, and recommended a national target of 33% forest cover for the total geographical area.In line with this new forest policy, the subsequent 5-year plans in the 1960s and the 1970s promoted commercial schemes for the cultivation of fast growing species to address the increasing timber demand (GoI, 2012b). Following this period, the increase in industrial round wood production grew steadily, and production of industrial wood doubled from about 4.16 million m^3 in 1955–1956 to about 8.93 million m^3 in 1969–1970; however, demand reached 16 million m3 (Sharma, 1974). This increasing gap in supply and demand led to the exploitation of trees on farmlands and illegal logging from government forests (GoI, 1976).

In 1976, the report of the National Commission on Agriculture (NCA) (GoI, 1976) suggested a revision of the existing forest policy, as well as the formation of a new policy, with a view to maximize forest productivity for meeting the growing demand for industrial raw wood, timber and other forest products for defence, communications and domestic needs.The report further emphasized the concept of promoting social forestry programmes in order to reduce the gap in timber supply and demand.

At the time when India was contemplating an increase in productivity of forests, the world was turning its attention to biodiversity conservation. India was a growing economy during that era but at the same time, it demonstrated its commitment to the protection of the environment at the United Nations Conference on the Human Environment, Stockholm, 1972 (UNEP, 2016). Conservation in India received further prominence with the implementation of the Wildlife Protection Act (WPA) in 1972 (GoI, 1972). Under the provisions of this act, protected areas were constituted where human occupation or resource exploitation is almost stopped. Additionally, the number and size of the protected area network increased consistently, and presently consists of over 16.04 million ha, which is 4.88% of the total geographical area (WII, 2015).

In 1980, the Government of India (GoI) moved a step ahead in its commitment to biodiversity conservation, and enacted the Forest Conservation Act (FCA; 1980) that prohibited state governments from allowing the use of forest lands for any other purposes without prior approval from the central government (GoI, 1980).Furthermore, from 1951 to 1980, about 4.33 million hectares of forest was converted to non-forest, bringing forest loss to about 150,000 ha per annum (Manoharan, 2011).

India's commitment to environmental and biodiversity conservation received greater support from the NFP (1988), which initiated a paradigm shift in the forest management approach from regulatory to participatory (GoI, 1988). The NFP (1988) encouraged afforestation and the planting of TOFs. As per policy, the subsidized supply of raw materials to wood industries ceased. It also encouraged forest-based industries to procure raw materials in order to meet its requirements, and did so through the building of direct relationships with individuals who had both the financial and technical capabilities to produce raw materials.Recognizing the need for people's participation in the NFP (1988), the government of India launched a people-oriented forest management programme, called the Joint Forest Management Programme, in 1990.

Even though the WPA (1972), FCA (1980) and NFP (1988) changed the focus of Indian forestry from one of exploitation to one of protection, they were not able to fully regulate forest logging nationwide. In order to restrict further loss of forest areas due to illegal and uncontrolled felling, the Hon. Supreme Court of India passed its first order (interim order in Writ Petition No. 202, dated 12 December 1996) (Rosencranz et al., 2007), in response to the writ petition filed by T. N. Godavarman in 1995, in which it interpreted the meaning of the word 'forest' for the implementation of the FCA (1980). Prior to this order, the term forest was not clearly defined and some states misinterpreted it, and applied it only to reserve forests instead of all forest areas. However, after the Hon. Supreme Court's order (1996), the act applied to all forests, regardless of ownership or legal status, and suspended tree felling in the entire country. Further, the Hon. Supreme Court ordered all non-forestry activities, such as sawmills and mining operations that had not received official permission from the Central Government, to cease their operations, as well as instructed the state governments to conduct a detailed survey of the timber industry and measure the sustainability of forests with respect to the number of sawmills. These legal prohibitions further adversely affected timber production in the country (Rosencranz et al., 2007; Rosencranz and Lele, 2008).

The transition of Indian forest policies, acts and regulations can be viewed as a shift from production to conservation, which is also advocated by the 1992 UNCED Summit in Rio de Janeiro. Following the Hon. Supreme Court Order (1996), the GoI launched two national programmes, namely, the National Forestry Action Programme (1999) (GoI, 1999) and the National Afforestation Programme (2002) (GoI, 2002), with an aim to increase forest cover and to promote forest conservation (Yasmi et al., 2010).

In 2006, the National Forest Commission's report recommended no requirement for amendment to the present forest policy, and emphasized conservation and management of forests on scientific principles in order to enhance its ecological contribution and productivity (GoI, 2006). All of these acts and programmes collectively reiterated that the primary role of Indian forests was to conserve biodiversity and to maintain ecological sustainability over timber production and thus resulted in widening the gap between timber supply and demand in India (Figure.1). As per the GoI's data, this resulted in a huge decline in the production of industrial roundwood from 24.4 million m3 in 1990, to 1.5 million m3 in 2000.

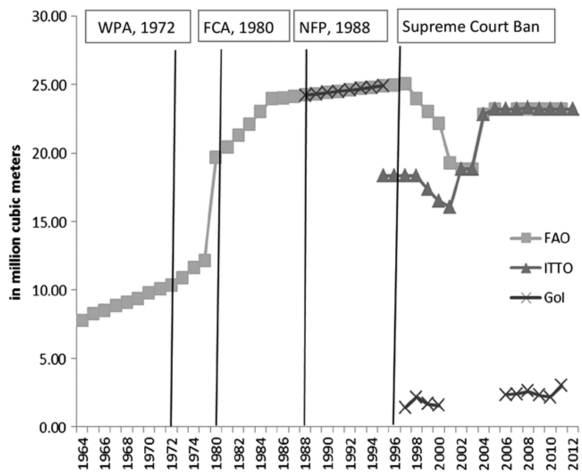


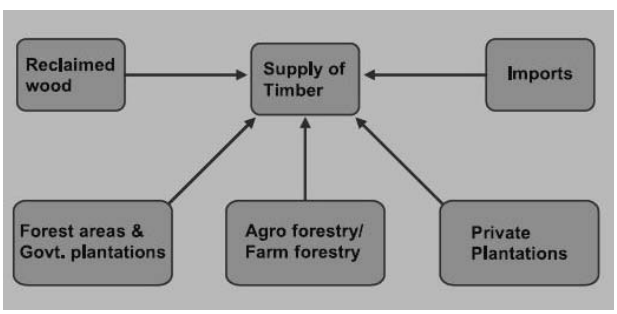
Fig. 1: Industrial roundwood production in India

Source: Indiastat (2015), ITTO (2015) and FAO (2016).

Status of Timber in India

Timber supply and demand

The major sources of domestic production of timber are i) government owned forests and plantations (ii) farm forestry/agroforestry areas and (iii) private plantations or trees outside the forests (TOF). (WWF, 2011).



The FAO and the ITTO are primarily dependent on their corresponding country for data; however, India has been consistently lacking in the provision of reliable data. As a result, data on timber production from the FAO and the

ITTO is mostly based on estimates made from assumed consumption patterns, and therefore this could include timber production from all sources, including TOFs. Furthermore, the similarity in the GoI's production data between 1988 and 1995 is also based on FAO estimates, as quoted in Indiastat from 1988 to 1990. However, the data quoted by the GoI after 1996 is limited to the timber sourced from the Reserve Forest Areas (RFAs). Thus, it is difficult to assign credibility to one particular source as compared to others, as enormous discrepancies in the data exist. This also indicates that the government should attempt to record data on timber production from TOFs, so that comparisons with other sources can be made, and their related discrepancies can be addressed.

The data on timber production between 1988 and 1995 from the GoI and the FAO is similar, and subsequently one may infer with some degree of certainty that the WPA (1972), the FCA (1980) and the NFP (1988), which were drafted to shift the focus of forest management from timber production to conservation, provided no evidence of having impacted the regulation of timber extraction in India. The GoI provides no data on industrial roundwood production between 2000 and 2005; however, there is a positive trend of recovery in timber production (1.58–3.0 million m^3).

The decline in timber production from government forests has been attributed to the growing emphasis on forest conservation (ICFRE, 2010) through policies, acts and regulations; however, this can be ascertained only when there is a robust record keeping of timber production from all sources within the country.

Timber Imports and Exports

India's wood market has long defined the expectations of foreign wood exporters who sensed that a growing economy and a large population in a country with limited forest resources should result in new opportunities for wood suppliers. Instead, Indian industries that would normally consume wood were heavy users of substitutes like concrete and steel. However, starting about ten years ago, Indian imports of wood began to rise, increasing from 42906.65 million rupees in 2003 to 183.89 billion rupees in 2013 (Table.1).

India has long sought to augment its domestic wood supply through the importation of logs. Going back 20 years when imports of value added wood products were effectively banned, logs were one of the only wood-sector products that could be imported. Most timber imports are in the form of logs, whereas the import of sawnwood is in lesser quantities, and veneer and plywood is almost negligible (Pandey and Rangaraju, 2008). Logs enjoy a lower tariff and satisfy the general policy of shifting value addition to India whenever possible. While logs comprised a significant (75 percent) portion of the value of India's wood product imports in 2013, that share is declining as imports diversify to other higher value processed wood products as wood-based projects and applications increase in sophistication and quality.

More than two thirds of log imports come from Malaysia, Myanmar, and New Zealand due to a freight advantage and relatively lower prices. Major log imports from these countries include hardwood species of teak, meranti and mahogany softwood species of ash, maple, cherry, oak, walnut, beech, hemlock and pine. Other major suppliers of logs to India are Cote D'Ivoire, Papua New Guinea, Gabon, Ecuador, Costa Rica, Panama and Cameroon. In 2013, imports from United States were valued at 3677.94 million rupees which included log imports valued at 1362.2 million rupees.

Marketing

Larger design firms are increasing in number to serve both the export and growing domestic market for wood furniture and wood interior items. Rising incomes and real estate development are boosting demand for imported hardwood and softwood lumber varieties for use in building projects as interior decorating materials and furniture. India's smaller "tier- two" and "tier-three" cities are emerging markets, with a growing housing supply and need for interior materials and furnishings. India's first home stores have opened over the past few years, introducing customers to new concepts in home decoration.

Import Tariffs

India has reduced tariffs on wood and wood products to facilitate imports. India's bound tariff rate for wood products is set at 40 percent, while the applied rates of most wood products range from 5 to 15 percent. India has traditionally kept tariffs low on log imports (5 percent) relative to processed wood products in an effort to shift value addition to India and reduce harvesting in India. Despite the preferential tariff structure, logs' share of India's forest product imports has been declining over the past decade. With the increase in real costs for almost all the components of production, i.e. energy, resins, chemicals, and transportation, saw mills are looking to more processed woods or rough sawn lumber as options to save on costs.

Table 1. India's Total Imports of Logs and Wood Products by Category (million rupees)

Category	2007	2008	2009	2010	2011	2012	2013
Logs	74921.0	88066.2	81323.3	90995.0	124709.4	136764.9	138603.9
Other Products	5585.0	7151.6	5380.7	8581.9	10216.5	10965.7	16210.2
Sawn Lumber	1566.5	2247.6	2860.6	3950.4	8922.4	10897.6	12600.4
MDF/HDF	3677.9	3746.1	2792.5	5244.5	5721.2	6266.1	6538.6
Plywood	1634.6	2588.2	2520.1	3541.7	7696.4	6129.9	5516.9
Veneer	1089.8	1566.5	1362.2	1839.0	3133.1	3814.2	4495.3
Particle Board	3065.0	3065.0	2247.6	3677.9	5653.1	4290.9	2996.8
Total	91539.8	108431.1	98487.1	117830.3	166052.2	179129.3	186962.0

Source: Directorate General of Foreign Trade, Ministry of Commerce

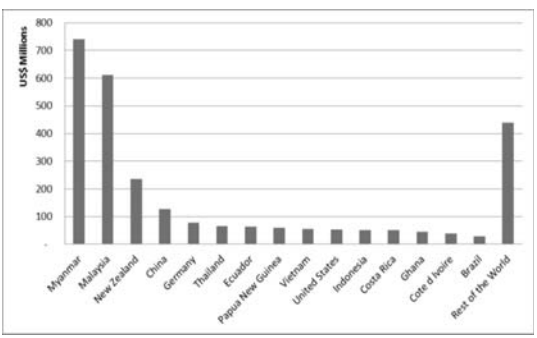


Fig. 2: India's total imports of Logs and Wood Products in 2013 by country

(Source: Dhruv Sood, 2014)

Timber demand

The demand for raw wood by different industries increased from 52 million m^3 in 1998 to 95 million m^3 in 2010, and is projected to increase further to 123 million m^3 in 2015 and 153 million m^3 in 2020 (Table 2). This demand is found to be doubling or tripling in all sectors except for agriculture, where demand is stagnant because of increased mechanisation. The increase in demand for paper and the paper board industry has increased the most since 1998. Similarly, the demand for raw wood in the construction, packaging, plywood and furniture industries is consistently growing (1998–2010), and is projected to increase further due to economic growth and a rise in population. Moreover, it is interesting to mention that timber production from government forest areas caters to 3.35% of the total demand, whereas potential timber production from TOFs fulfils 45% of the total demand (FSI, 2011). This implies that there is a need for enhanced timber production from RFAs and TOFs on a sustainable basis, or through enabling policies and programmes to meet domestic demand and reduce the reliance of India on imports.

Table 2. Total projected demand of raw wood by different industries in India (million m^3)

Industry	1998*	1999*	2000*	2005*	2010*	2015†	2020†
Paper and paper board	4.48	4.48	4.48	8.96	15.4	26.24	35.84
Construction industry	13.6	14.6	15.9	19.4	22.1	26.3	28.5
Packaging	4.36	4.49	4.62	5.54	6.4	7.55	9
Furniture	2.25	2.38	2.52	3.36	4.62	5.9	7.53
Agricultural implements	2.0	2.06	2.12	2.33	2.50	2.50	2.50
Plywood	10.1	10.5	11.0	14.0	17.96	22.9	29.2
Others	15.12	16.04	17.08	20.32	25.91	31.37	40.23
Total	51.91	54.55	57.72	73.91	94.89	122.76	152.8

Source: Indiastat (2015)

* Represents actual demand of timber.
† Represents projected demand of timber.

Role of TOFs in Timber Supply

Trees outside forests (TOFs) became more important after the Hon. Supreme Court Order (1996) took effect, which regulated logging in government forests, and resulted in a sharp decline of timber production and a simultaneous increase in imports. Being one of the top 10 countries in private plantations in the world (Lal, 2000; Carle et al., 2002; FSC, 2012), India has the potential to increase production from farm forestry, private plantations and community forestry through private–public partnerships, in order to meet domestic timber demand (Pandey, 2008). This is evident from the fact that wood-based paper mills, one of the fastest growing sectors in terms of demand, get 80% of their wood from agro farm forestry sources. Furthermore, the Indian paper industry has planted and funded about 657,093 ha plantations on farmlands over the past two decades, which produce 39.42 million tonnes of wood (Kulkarni, 2013). The potential to enhance timber production through TOFs is also recognised by the GoI, as mentioned in the National Forest Commission Report 2006.

(GoI, 2006). The Ministry of Environment, Forests, and Climate Change (MoEF&CC9) also stressed the need for TOF management in the recent National Working Plan Code 201410 (GoI, 2014). The National Agroforestry Policy (2014) is another national initiative by the GoI that recognizes agroforestry as an important source of timber, as well as emphasizes the need to simplify regulations related to the felling and transit of tree species (GoI, 2014).

It is interesting to observe that in spite of a significantly higher area of government RFAs as compared to TOFs, the potential timber production from TOFs is much higher than that from government RFAs. The low timber production from RFAs could be attributed to various reasons, such as a lower number of approved working plans, fewer areas with the potential for timber logging, and an increase in protected areas, as more emphasis was placed on the role of the forest in biodiversity conservation and maintaining ecological balance. However, it may not be appropriate to compare and attribute the difference in timber production between RFAs and TOFs to policy implication because of the unavailability of uniform and comprehensive data from both sources.Trees outside forests (TOFs) contribute one-fourth of the total growing stock of the country, and have become a major source of timber in India.

Even though potential timber production from TOFs is significantly higher as compared to RFAs at the national level, there is significant variation among states in terms of timber production from TOFs. This is due to a difference in policies related to the harvest and transit of TOFs species (GoI, 2012).A state-wide detailed assessment of timber produced outside RFAs can help in understanding the impact of state policies on the production of timber, which will provide further insights into the design, modification, or revision of existing policies, in order to increase timber production from TOFs. Apart from meeting timber demand, TOFs also have a significant role to play in the revival of the rural economy (GoI, 2014). Additionally, the promotion of TOFs should be linked to incentive-based carbon sequestration, which in turn will also act in the mitigation and adaptation of measures related to climate change.

Strategies to Improve Timber Production

Timber still today is the robust raw material required for both domestic and industrial utility. But due to policy and legal compulsion, the availability of timber from reserve forest is restricted which led to massive imports. These imports not only consume huge foreign exchange but create uncertainty in timber availability and associated market prices. To resolve this issue, the Forest College and Research Institute of Tamil Nadu Agricultural University has established a Consortium of Industrial Agroforestry (CIAF) where in timber industry is one of the significant components and conceived a Value Chain Model and addresses the issues in Production, Processing and Consumption systems (Parthiban, 2014) which are discussed.

Constraints identified in Timber PCS

The timber based supply chain in the country has experienced wide range of constraints which are indicated in figure 3. The constraints are categorized as production related, processing related and consumption related issues. The lack of superior genetic resources and silvicultural technology specific to some species are robust issues in promotion of timber plantations. Similarly, absence of quality planting materials coupled with lack of profitable agroforestry models are the major constraints which demanded serious interventions. Though India is housed with wide range of processing industries, the facilities need to be upgraded to be competitive globally. The value addition of timber residues is still one of the major constraints faced by several industries. Above all, the supply chain is highly unorganized and needs serious intervention through institutional arrangements.

Interventions

The Forest College and Research Institute of Tamil Nadu Agricultural University has identified systematic intervention approach to resolve the constraints in Production, Processing and Marketing which are furnished below.

a) Production led Intervention

1. Development of superior genetic resources

The TNAU has prioritized the following timber species viz., Teak (*Tectona grandis*), Mahogony (*Swietenia macrophylla*), Kumil (*Gmelina arborea*), Vengai (*Pterocarpus marsupium*), Rosewood (*Dalbergia latifolia*) and *Albizia lebbeck* for incorporation in timber based agroforestry and initiated systematic tree improvement programme through the provenance, seed source, progeny and clonal tests. Through these tree improvement activities superior genetic resources have been identified and deployed for the promotion of timber species.

2. Production and supply of quality planting material

From the identified genetic resources seedlings and clones have been multiplied and supplied to the tree growers and other stakeholders for the establishment of improved timber plantations.

3. Development of organized plantations

The institute has involved development of organized plantations through block plantations, agroforestry plantations, linear or line plantations and also through sporadic plantations. The Sivlicultural technologies from the site preparation upto harvesting have been development and implemented in association with tree growing farmers.

4. Price Supportive Systems

The Forest College and Research Institute of Tamil Nadu Agricultural University has established the price supportive systems through Consortium of Industrial Agroforestry (CIAF). Accordingly the price supportive systems have been established and disseminated to the farmers through CIAF.

S.No.	Species	Girth Quality	Rate / Tonne(Rs.)
1	*Tectona grandis*	24" inches and above	17000 – 20000
2.	*Dalbergia latifolia*		20000 – 25000
3.	*Pterocarpus marsupium*		12000 –15000
4.	*Swietenia macrophylla*		8500 –12500
5.	*Gmelina arborea*		8500 – 12500
6.	*Albizia lebbeck*		6500 – 8500

a) Processing led interventions

The timber industries associated with CIAF have introduced several interventions to upgrade processing technologies which led to the efficient utilization of timber and reduced conversion loss. The introduction of machinery in each and every stage of conversion and utilization has reduced the processing constraints and improved the product quality and become competitive in the market. The industrial residues generated from timber industries have been successfully value added into briquettes and pellets and thereby ensures the efficient value addition technologies. The residues are also utilized for production of particle board and is gaining significant attractors.

b) Marketing interventions

The Consortium of Industrial Agroforestry has identified and incorporated several timber industries in the Consortium and resolved the issues in marketing. The timber industries are now assuring market prices for various species. For example in case of timber the price mechanism has been assured as Rs. 17000/ tonne for logs with 24" and above girth and Rs. 20000 / tonne in case of logs with 30" and above girth. The timber species growing farmers are now finding direct market mechanism through this approach which will be extended by incorporating more industries in the future.

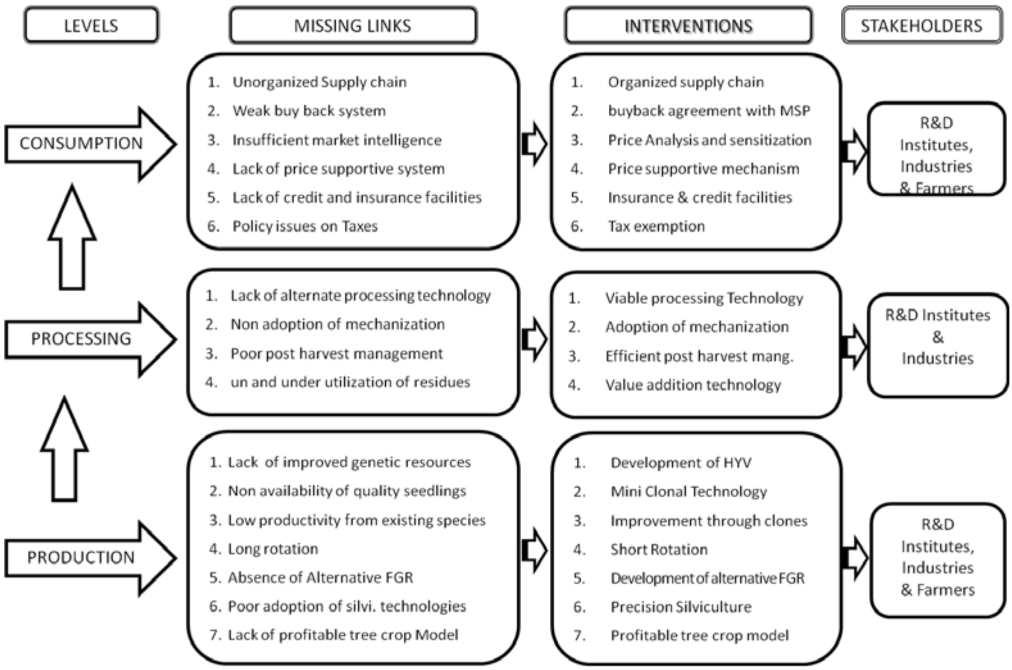


Fig. 3 Timber Value Chain Model

Way Forward

Creation of Database

Through the promotion of timber based agroforestry has intrinsic relationship with traditional farming system, there is no database available either for reference or for commercial timber production. Hence the institutions and organizations involved in promotion of timber plantations should collect and develop a database to estimate the timber availability in the state.

Development of Improved Genetic Resources

The existing genetic resources can be deployed as such for the promotion of timber plantation. However there is a need to develop improved genetic resources in a sustainable manner specific to site and industrial utility. For this purpose, the research institute should evolve long term breeding and improvement strategies for timber species towards incorporation in the operational timber plantation development programmes.

Development of Precision Silvicultural Technology

The tree species in general and timber species in particular have received a little attention in terms of adoption of Sivlicultural technologies. For many species, the density of plantation, spacing, irrigation and fertilization schedules have not been established which demand an organized research intervention. The success evidenced in precision farming of both agriculture and horticulture should be replicated in the tree species particularly the long term timber species for increased timber productivity and reducing the rotation age.

Design and Development of Timber based Multifunctional Agroforestry Model

The organized and unorganized agroforestry practices are prevalent across the land use systems. However the development of functional based agroforestry system will help to improve the productivity and profitability. The identified timber species needs to be tested and evaluated through various agroforestry models and suitable timber based profitable agroforestry models need to be developed for incorporation in agroforestry systems.

Organized supply chain

The timber based supply chain in India in general and in the state of Tamil Nadu in particular is highly unorganized due to massive imports which resulted in uncertainity in price and trade. To resolve this issue, Forest College and Research Institute, Tamil Nadu Agricultural University has established the value added supply chain model through Bi, Tri, Quad partite model contract farming system (Parthiban and Seenivasan, 2017) . This model need to be promoted on a commercial scale by all promoting institutions in order to ensure organized supply chain to eliminate multipartite supply chain.

Timber insurance

A comprehensive insurance plan should be developed for timber species like (*Tectona grandis*), Mahogony (*Swietenia macrophylla*), Vengai (*Pterocarpus marsupium*), Rosewood (*Dalbergia latifolia*) and *Albizia lebbeck* etc. in order to protect them due to unforeseen biotic and abiotic damages. The insurance plan developed earlier for other tree species (Parthiban, 2016) need to be followed for timber species as well.

Price Analysis and Sensitization

The research institute and other institutions involved in promotion of timber based agroforestry should ensure price analysis and sensitization to the tree growing farmers. For this purpose, more timber industries should be identified to collect the database on prices and to analyze through systematic research and development mechanism in order to suggest nominal market price. This will attract more farmers towards timber husbandry.

Summary and Conclusion

India is one of the largest timber producing as well as importing country due to its increasing demand for both domestic and industrial utility. It has been estimated that India demands over 80 million m^3 of wood to meet its multifarious utility. Due to the policy and legal regulations, the timber production from the forests has declined which necessitated massive imports. The imported log not only increases the price but also exhibited varying quality. The National Forest Policy (1988) and the Agroforestry Policy (2014) directed to promote agroforestry in order to meet the timber demand besides augmenting the tree cover in the country. Various institutions and organizations both at state and central levels are involved in promoting timber species in agroforestry. However the role of TNAU in this approach is very significant, because the University has conceived and implemented a Consortium of Industrial Agroforestry which incorporated timber industries as well. The TNAU has developed a value chain based timber agroforestry model wherein the producers, processors, consumers and financial institutions are linked to resolve the issues in Production to Consumption System in timber based agroforestry. Through this approach, technological interventions through incorporation of superior genetic resources, organizational interventions through linkage establishment and marketing interventions through price supportive system have been delivered which attracted several farmers towards timber husbandry. The model needs to be promoted intensively in association with all stakeholders in order to become self reliance in timber production.

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Trends in India's import of timber

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Indian Council of Forestry Research and Education, Dehra Dun

Introduction

India imports timber in mainly two broad categories – Wood in Rough and Sawn Wood. The import statistics are maintained by the Directorate General of Commercial Intelligence and Statistics based at Kolkata. The classification of the imported products follows the Indian Tariff Classification based on Harmonized System (ITCHS) of coding that goes up to 8 digits. The first four digits provide a broad view of classification. Here, the two kinds of products are coded as 4403 (Wood in Rough) and 4407 (Sawn Wood) under the broad category of forest products (Chapter 44).

Wood in Rough

According to the definition of FAO, wood in rough is includes all woody raw material excluding wood chips and particles. The ITC 4 digit classification for the items under this broad commodity head is 4403.

The main species imported as wood in rough (as classified in the DGCIS database) are given below:

Table 1: Classification of imports of wood in rough

Import classification commodity	Commodity as mentioned in recorded	Species / sub-commodities included	Related ITC HS codes
Andaman padauk		*Pterocarous dalbaergioides*	44039901
Beech	Beech wood in rough		44039200
Birch coniferous	Betulla spp		44039926
Coniferous	Coniferous NES		44032090

Import classification commodity	Commodity as mentioned in recorded	Species / sub-commodities included	Related ITC HS codes
	Poles pilling & posts coniferous		44032020
Gurjan		*Dipterocarpus alatus*	44039913
Khair		*Acacia catachu*	44039914
Meranti	Dark red/light red meranti and meranti bakau		44034100
Oak	Oak wood in rough		44039100
Red sanders		*Pterocarpus sautatinus*	44039918
Rosewood		*Dalbergea latifolia*	44039919
Sal		*Shorea robusta*	44039921
Sandalwood		*Santalum albam*	44039922
Semul		*Bombax ceiba*	44039923
Sheesham		*Dalbergia sissoo*	44039927
Teak	Teak wood in rough	*Tectona grandis*	44034910
Walnut		*Juglans rejia*	44039924
White cedar		*Dysozylum malabaricum*	44039928
Others	Bonsom (phoebe goalparensis)	*Phoebe goalparensis*	44039902
	Lampati (duabanga grandiflora)	*Duabanga grandiflora*	44039915
	Laurel (terminalia alata)	*Terminalia alata*	44039916
	Others		44039929
	Others than tropical wood/teak wood rough		44034990
	Sawlogs & veneerlogs in rough w/n	stripd of bark or	44032001
	Sawlogs and veneerlogs		44032010
	Wood trtd wth paint stan creste/othr prsvt		44031000

Table 2: Species – wise average and total imports from 2001 to 2015

species	Average Annual imports	Total imports
Others	732.8823	49836.00
Teak	662.7758	11267.19
Gurjan	247.0435	3705.65
Meranti	182.2540	2916.06
Sal	26.3569	395.35
Andaman Padauk	19.3756	310.01
Coniferous	14.2923	300.14
Beech	16.1729	258.77
Rose Wood	5.4325	81.49
Sandal Wood	4.7828	76.53
Oak	3.0749	49.20
Semul	3.4673	27.74
White cedar	1.8515	11.11
Walnut	0.6134	9.81
Khair	0.5144	3.60
Red Sanders	1.1537	3.46
Birch	0.4470	2.68
Sheesham	0.1140	0.23

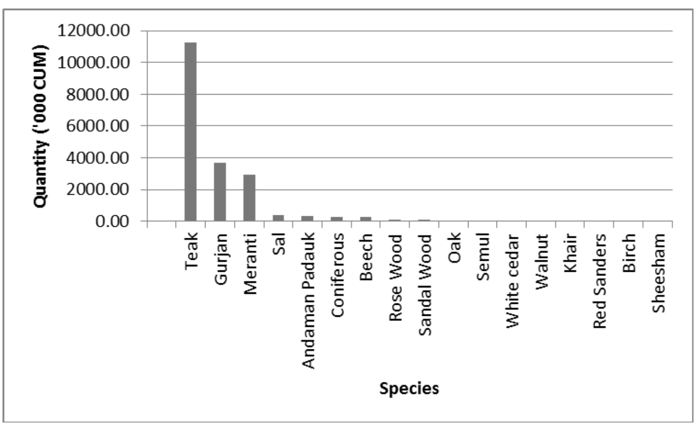

Fig. 1: Total imports of Wood in Rough, species wise from 2001 to 2015

Teak is the preferred import species followed by Gurjan and Meranti. Sal, present in India in large amounts along with Padauk form a minor component of imports.

The annual imports of Wood in Rough, including all sub classifications, are given in the following table:

Table 3: Annual import of wood in rough (in '000 Cubic metres)

year	Total quantity	year	Total quantity
2001	2554.13	2010	4791.01
2002	1662.81	2011	5820.08
2003	2691.57	2012	6391.57
2004	3334.56	2013	6233.41
2005	3302.50	2014	6234.92
2006	3235.00	2015	5693.87
2007	3867.88	2016	4240.22
2008	4113.25	Total	69255.02
2009	5088.24		

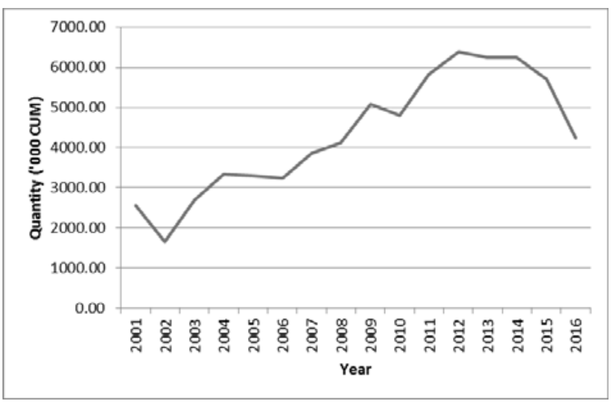

Fig. 2: Import pattern of timber from 2001 to 2015

Wood in rough imports show a steady increase, reaching a peak in 2012 and then a decline Although specific reasons for the decline, which continues till 2016 (data available up to October 2016) are difficult to arrive at, alternatives to wood may have been the reason. These alternatives could be imported or available within the country. A cursory look at import of plywood for 2012,

Table 4. Import of Important timber species

Year	Andaman Padauk	Beech	Coniferous	Gurjan	Meranti	Oak	Rosewood	Sal	Sandal	Teak	Walnut
2001	80.595	1.907	0.384	59.681	4.495	0.321	0.068		0.005	366.178	0.037
2002	117.680	2.034	0.212	43.450	0.056	0.356		60.167	0.139	410.591	0.005
2003	11.817	5.263	0.627	9.245	3.063	1.022	21.162	19.714	29.887	210.762	0.196
2004	67.690	3.948	0.320	141.014	9.063	3.381	31.488	17.173	5.904	624.217	0.260
2005	1.509	6.147	3.999	225.899	49.548	1.625	0.174	11.957	5.397	914.901	0.471
2006	6.093	9.898	65.798	189.078	84.575	1.775	0.509	27.768	0.802	591.673	0.588
2007	0.483	13.678	56.873	208.763	140.712	1.858	1.300	44.624		646.641	1.381
2008	12.631	20.682	31.539	248.001	252.535	5.094	0.963	45.118	0.070	697.767	1.209
2009	0.114	16.105	14.695	242.503	313.079	2.707	0.203	31.784	0.818	583.345	1.739
2010	1.326	15.694	23.020	329.074	239.878	2.336	0.202	33.272	1.313	647.746	0.946
2011	1.954	24.329	12.015	488.552	225.584	2.076	0.222	18.938	0.076	934.268	0.640
2012	0.036	22.915	1.885	507.268	249.760	1.983	3.462	15.200	0.141	996.943	0.638
2013	6.980	43.278	3.905	649.890	308.792	14.371	0.464	17.762	0.655	1003.053	0.280
2014	0.248	26.024	6.134	360.970	424.657	5.247	0.009	15.503	0.651	928.049	0.313
2015	0.682	25.114	12.380	2.264	360.290	3.039	0.100	19.400	0.311	842.702	0.650
2016*	0.172	21.751	14.112		249.977	2.008		16.974	0.469	657.591	0.461

* Data for 2016 is up to October 2016.

2013 and 2014 also shows a decline. (For 2012 the figure is 307.70 thousand CUM, for 2013, 199.97 and for 2014 it is 195.80 thousand CUM). Even in case of Fibre board, the statistics for the period are 192257, 203705 and 168174 tonnes respectively. There is a strong indication of either of two possibilities.

Out of all the species imported and reported, not all have been imported from 2001 onwards. The bulk of imports are constituted by Andaman Padauk, Beech, Gurjan, Meranti, Oak, Rosewood, Sal, Sandal, Teak and Walnut. Coniferous constitutes many sub constituents and cannot be clubbed into a single species. Rest like Birch, Khair, Red Sanders, Semul, Sheesham and White Cedar have shown erratic imports.

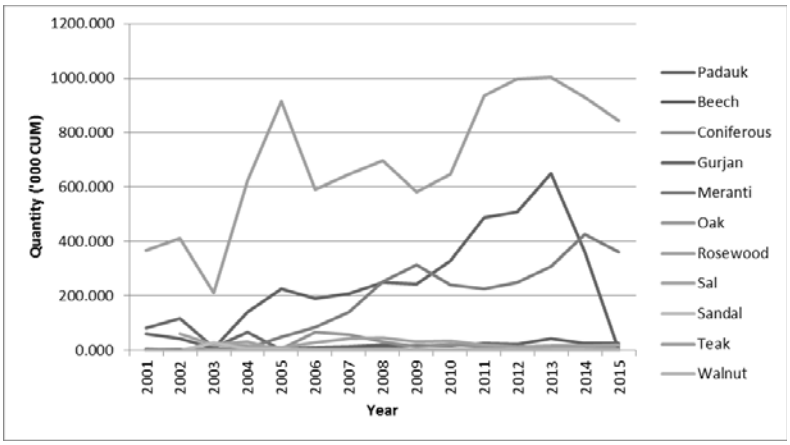

Fig. 3: Annual patterns of imports of important timber species

From the above it is quite evident that major changes have been observed in the imports of Teak, Meranti and Gurjan. Other species have been quite stable over the 15-year interval. The decline seen in the overall imports of wood in rough can be attributed to the decline of import of these three species.

Other species, imports of which have been not so regular, are detailed in the table below.

Table 5. Imports of other species

Year	Birch	Khair	Red Sanders	Semul	Sheesham	White Cedar
2001		0.130	0.080			
2002				3.586		1.214
2003				21.556		8.446
2004	0.033	0.539				
2005		1.329		0.731		
2006			3.364			
2007	0.070			0.226		0.881
2008	0.019			0.321		0.094
2009	0.011	0.754		1.093		0.260
2010			0.017			
2011		0.287		0.062	0.020	
2012		0.282				
2013	0.080			0.163	0.208	0.214
2014	2.469					
2015						
2016*		0.280				

* Data for 2016 is up to October 2016.

It is evident that these species are imported in small quantities and largely based on specific needs of the end users. There are some doubts regarding some species, especially Andaman padauk and Red Sanders. Andaman padauk is largely present in India and mention of it in imports is looked upon with suspicion. Red sanders is also such a case.

Sawn Wood

Sawn wood is defined by FAO as, ‘unplaned, planed, grooved, tongued, etc., sawn lengthwise, or produced by a profile-chipping process (e.g. planks, beams, joists, boards, rafters, scantlings, laths, boxboards, “lumber”, sleepers, etc.) and planed wood which may also be finger jointed, tongued or grooved, chamfered, rabbeted, V-jointed, beaded, etc. Wood flooring is excluded. With few exceptions, sawnwood exceeds 5 mm. in thickness’. The 4 digit ITC HS code for this category is 4407. Annual imports of Sawn wood is given in the table below:

Table 6: Imports of Sawn Wood

Year	Quantity* ('000 cubic metres)	Year	Quantity* ('000 cubic metres)
2001	202.788	2009	159.560
2002	42.097	2010	161.338
2003	69.632	2011	448.534
2004	88.603	2012	498.615
2005	74.802	2013	545.031
2006	60.600	2014	551.378
2007	58.451	2015	734.558
2008	82.980	2016 **	633.631

* Does not include Willow and Others where unit is '000 Kilograms

** Data for 2016 is upto October 2016.

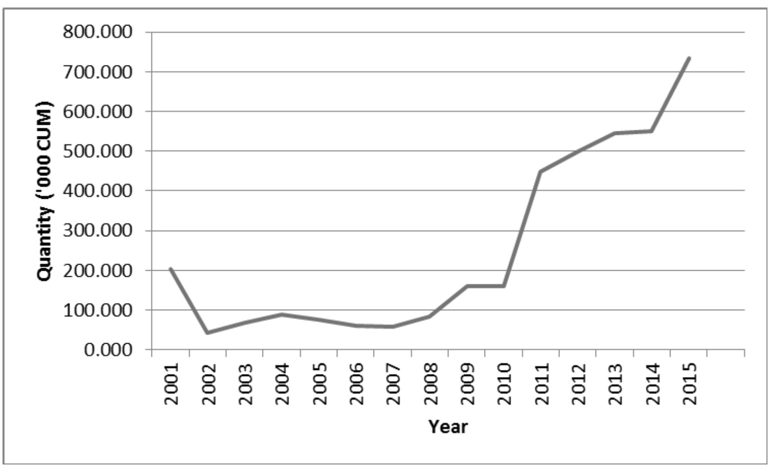

Fig. 4: Annual patterns of imports of sawn wood

From above it is seen that the imports of sawn wood have increased from 2011 onwards and remain on the rise, reaching a sharp peak in 2015. For 2016, the figure has already touched 633.63 x 1000 CUM by the end of October 2016.

The average annual import and total quantity imported from 2001 to 2015 of various sub-classifications of sawn wood is given in the table below:

Table 7: Total imports of various species of Sawn wood from 2001 to 2015

Common name	Average annual Quantity('000 CUM)	Total Quantity ('000 CUM)
Other Coniferous wood articles	58.16088	988.735
Other tropical woods - Sawn, Chipped	55.81363	893.018
Pine	52.21406	887.639
Teak	29.06694	494.138
Beech	29.49375	471.900
Douglas Fir	14.82247	251.982
Willow*	17.75614	248.586
Others*	1.74254	90.612
Birch	2.37993	33.319
Other Tropical woods- Sawn or Chipped	2.86844	25.816
Oak	1.38925	22.228
Meranti	0.25892	3.107
Mahogony	0.20843	1.459
Iroko	0.01967	0.059

* Quantity in tonnes

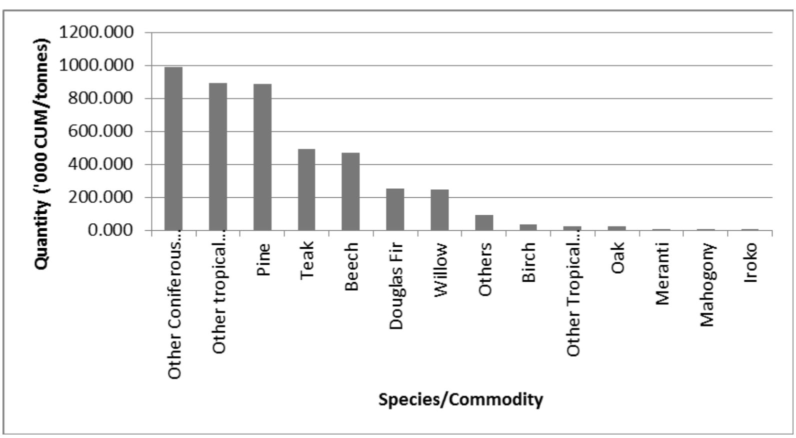

Fig. 5: Total imports of sawn wood, species wise from 2001 to 2015

Amongst the imports of sawn wood, coniferous articles are preferred, possibly because India's forests are largely tropical. Amongst the species, pine is the most preferred followed by teak and Beech. Teak, Oak and Meranti are mostly imported in rough than in sawn wood form.

Indications from the data

The sudden decline in imports of wood in rough (Fig. 1) and a surge in imports of sawn wood (Fig. 3) indicate that sawn wood has replaced wood in rough as far as imports are concerned. Imports of substitutes (Plywood and Fibre Board) have not contributed to the decline of imports of Wood in Rough.

Acknowledgement

The cooperation of Directorate General of Commercial Intelligence and Statistics is gratefully acknowledged in providing ICFRE access to its database for obtaining statistics on international trade.

Wood and Wood Products in India 2014

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Forest Situation & Outlook

1n 1952, the Government of India established a goal to raise the forested area to one third of India's land mass. Subsequently, a number of efforts were made to limit human and animal pressure on forests and reforest key areas. However, the pressure from humans to harvest wood for fuel and other uses along with the clearing of land for agriculture, coupled with persistent use of forests as a source of fodder for animals, have prevented the government from reaching its goal. In addition to 1.2 billion inhabitants living in an area that is one-third the size of the United States, India has large cattle and goat populations that graze widely and consume forest resources.

According to the 2011 Forest Survey of India, forests covered just 22 percent of India of which 2.5 percent is dense forest defined as a tree canopy density of 70 percent; 10 percent is moderately dense defined as a tree canopy density of 40-70 percent; and 9 percent is open forest defined as a density of 10-40 percent. These figures do not differentiate tree cover by type; hence parks, orchards, mangrove areas, and plantations are counted as part of the forest cover, suggesting that actual forest cover is well below 22 percent. Additionally, a significant portion of India's tree cover lies in mountainous areas above an altitude of 4,000 meters, making it difficult to access. Conservation efforts appear to be helping to stem the loss of forested area; between 2009 and 2011, forested area was virtually unchanged, dropping by just 367 square kilometers. India's eight northeastern states, located primarily between Bangladesh and Myanmar, are the most densely forested area of India, accounting for just eight percent of India's area, but a quarter of its forests.

Two policies have had a significant effect on the industry over the past 30 years. In 1988, the National Forest Policy called for greater substitution of wood wherever possible and the development of agroforestry. It also determined that forests should be used primarily to meet the needs of India's tribal people, scheduled castes, and small scale industries. Any large commercial operations required government approval of the management plan, but states could designate areas for commercial harvesting. This policy slowed timber production and removed much of the financial incentive for large scale harvesting of wood, it also ushered in the beginning of India's sustained importation of logs. Timber production dropped again in 1997 when the Supreme Court ruled that only the central government could approve the use of forestry land for any non-forestry purposes. This effectively stopped the states from "de-reserving" certain forests for commercial harvesting and closed saw mills that did not have explicit approval from the central government to harvest in forests. The action drove domestic production even lower, especially in India's northeastern states where much of India's forests are located. The Court's action coupled with stronger economic growth over the past decade has led to a sustained increase in India's wood imports.

In 2011, only 3.2 million cubic meters (mcm) of wood were produced from Indian forests, while the vast majority of domestically harvested wood was harvested from "trees outside of forests" such as tree plantations, farms, and private lands. There is no official estimate of the amount of annual production from trees outside of forests, but the estimate of the potential wood that could be harvested was 44 mcm in 2011, significantly more than the amount harvested from forests. Land ceiling laws limit the amount of land that private firms can own for tree plantations and complex transport and cutting permits in forests and local tax laws also complicate the production and movement of forest products, limiting the domestic industry's ability to expand.

Trade

India's wood market has long defied the expectations of foreign wood exporters who sensed that a growing economy and a large population in a country with limited forest resources should result in new opportunities for wood suppliers. Instead, Indian industries that would normally consume wood were heavy users of substitutes like concrete and steel. However, starting about ten years ago, Indian imports of wood began to rise, increasing from $630 million in 2003 to $2.7 billion in 2013 (See Figure 1).

India has long sought to augment its domestic wood supply through the importation of logs. Going back 20 years when imports of value added wood products were effectively banned, logs were one of the only wood-sector products that could be imported. Logs enjoy a lower tariff and satisfy the general policy of shifting value addition to India whenever possible. While logs comprised a significant (75 percent) portion of the value of India's wood product imports in 2013, that share is declining as imports diversify to other higher value processed wood products as wood-based projects and applications increase in sophistication and quality.

More than two thirds of log imports come from Malaysia, Myanmar (formerly Burma), and New Zealand due to a freight advantage and relatively lower prices. Major log imports from these countries include hardwood species of teak and meranti and softwood species of pine. Other major suppliers of logs to India are Cote D'Ivoire, Papua New Guinea, Gabon, Ecuador, Costa Rica, Panama and Cameroon. In 2013, imports from United States were valued at $54 million which included log imports valued at $20 million.

Marketing

Wood processing is largely in the small-scale or "unorganized" sector, where the majority of wooden furniture, joinery, and other household products are made to order by small workshops or individual craftsmen. Larger design firms are increasing in number to serve both the export and growing domestic market for wood furniture and wood interior items. Familiarity with woods other than those found in India and certain tropical hardwoods is low, but that too is starting change. Nevertheless, the Indian wood industry, craftsmen, and other wood users are accustomed to teak and other hardwoods that are perceived to be more resistant to termites and decay. Consumers also have a strong preference for dark tropical woods. Teak is typically seen as a benchmark with respect to grade and prices of other wood species. Major imported wood species are teak, meranti, and mahogany. Domestic farmed and plantation timber includes teak, eucalyptus, and poplar, spruce, pine, and fir. India imports small quantities of temperate hardwoods such as ash, maple, cherry, oak, walnut, and beech for commercial and home interiors and furniture, some of which is made for export. Wood imports are expected to continue rising, but the move away from logs and tropical woods will likely be slow. Even as Indians become aware of foreign woods, the perceived benefits of importing logs and the cost of foreign woods are often cited as reasons for maintaining the status quo. Nevertheless, India is a potential market for imported wood products, including American species, but exporters should be prepared to start small and be patient.

Rising incomes and real estate development are boosting demand for imported hardwood and softwood lumber varieties for use in building projects as interior decorating materials and furniture. India's smaller "tier- two" and "tier-three" cities are emerging markets, with a growing housing supply and need for interior materials and furnishings. India's first home stores have opened over the past few years, introducing customers to new concepts in home decoration. New stores include Homecentre, Durian, Evok, Homestores, and Hometown. E-business is also emerging as an increasingly important marketing and distribution channel for both raw wood materials and finished wood products. India has an estimated 120 million active internet users and online retailing is the fastest growing retail segment.

Distribution

For wood logs and lumber, wholesale markets remain the most important distribution channel for medium or small-sized processors and interior design companies. However, large construction projects and manufacturers prefer to purchase directly from wood manufacturers and importers. Finished consumer wood products (floorings and furniture) targeted at domestic markets are mainly further distributed through professional building material markets and specialized showrooms to urban consumers. India is increasingly becoming a market where imported woods are converted to higher value products such as furniture for export.

U.S. Wood and Wood Products in India

In 2013, exports of U.S. wood and wood products from the United States to India were valued at a record $54 million with processed wood constituting 64 percent of the imports. Imports from the United States have increased significantly over the past six years (See Figure 3). Logs make up a relatively small share of U.S. exports accounting for just 36 percent of total wood exports. Demand for high quality furniture products for both the domestic and export markets has increased over the past few years prompting imports of high grade lumber. See Table 2 for more background on India's wood imports from the United States.

Tariffs

India has reduced tariffs on wood and wood products to facilitate imports. India's bound tariff rate (the highest tariff India can apply and still comply with its World Trade Organization commitments) for wood products is set at 40 percent, while the applied rates of most wood products range from 5 to 15 percent. India has traditionally kept tariffs low on log imports (5 percent) relative to processed wood products in an effort to shift value addition (domestically produced lumber from imported logs) to India and reduce harvesting in India. Despite the preferential tariff structure, logs' share of India's forest product imports has been declining over the past decade. With the increase in real costs for almost all the components of production, i.e. energy, resins, chemicals, and transportation, saw mills are looking to more processed woods or rough sawn lumber as options to save on costs.

Market Access

Wood and wood products can be imported into India without quantitative restrictions. Imports of logs, sawn/sized wood, and saw dust from pine species from the United States are prohibited due to phytosanitary concerns. Imports of other wood species in log form require an import permit from the Ministry of Agriculture, which has specified the import requirements in the "Plant

Quarantine (Regulation of Imports) Order 2003" and its amendments. (http://www.agricoop.nic.in/gazette.htm).

Imports of wood logs with bark are allowed based on a phytosanitary certificate issued by the exporting countries certifying agency (USDA's Animal and Plant Health Inspection Service, for example), with inspection of the consignment by a duly authorized plant protection officer at the port, and fumigation, if required. For example, imports of sawn or sized wood without bark, fumigated by methyl bromide (48 gm/cubic meter for 24 hours) or kiln dried (56 degrees centigrade for 30 minutes) prior to export and accompanied by a treatment certificate, are allowed entry without a phytosanitary certificate. These shipments are cleared only after inspection by an Indian plant protection official and fumigation upon arrival, if required. Imports of processed wood products such as plywood, particleboard, and veneers are exempted from these requirements.

For exporting any species of American hardwood or softwood species that are not specifically listed in the Plant Quarantine (PQ) Order 2003 of India, specific market access requests have to be submitted to the Indian government. Officials will review the request and make a determination as to the necessary requirements for importation. Ministry of Agriculture (MOA) officials only accept new market access requests from the national plant protection organization (NPPO) of the interested exporting country.

Trade Shows

1. Indiawood, Bengaluru - Indiawood is Asia's biggest sourcing platform for furniture manufacturers, wood based handicraft manufacturers, saw millers, craftsmen, woodworking professionals, architects and interior designers in the region. The eighth edition of the trade fair Indiawood 2016 is scheduled to be held on February 21-25, 2016 in Bengaluru.
   http://www.indiawood.com/iw14/#

2. Delhiwood, Noida - Launched in 2009, Delhiwood is the regional edition of Indiawood show targeting the wood industry in North India. Organized biennially, the fourth edition of the show is scheduled to be held February 6-9, 2015.
   http://www.delhi-wood.com/

3. Mumbaiwood, Mumbai Mumbaiwood is the regional edition of Indiawood show targeting the wood industry in Western India. The second edition of this regional trade fair is scheduled to be held in Mumbai. Dates have not been finalized yet.
   http://www.mumbai-wood.com/mw13/

4. The Inside Outside Mega Show - Inside Outside Mega Show is the leading event focused on interior decoration, furniture, furnishing as well as building & construction industries.
   http://iomegashow.com/cms/?page_id=27

5. United Business Media (UBM) Index International Interiors Event, Mumbai UBM Index trade fairs showcase designs and trends in the furniture and hardware industries. The show is organized annually and the next edition is scheduled to be held on October 9-12, 2014 in Mumbai.
   http://ubmindexfairs.com/

Post Contact Information

The following reports may be of interest to U.S. exporters interested in India. These and related reports can be accessed via the FAS Home Page: www.usda.fas.gov by clicking on "Attaché Reports" and searching by the report number. Reports given below will provide additional information to exporters interested in the Indian market.

Report Number	Subject
IN3152	Exporter Guide Annual 2013
IN3161	FAIRS Export Certificate Report 2013
IN3164	FAIRS Country Report 2013

For Additional Information please contact:

Agricultural Attaché

Office of Agricultural Affairs

American Consulate General

C-49, G Block, Bandra Kurla Complex, Mumbai 400051

Ph: (91-22) 2672-4000

E-Mail: agmumbai@fas.usda.gov

Table 1: India's Total Imports of Logs and Wood Products by Category (US$ Million)

Category	2007	2008	2009	2010	2011	2012	2013
Logs	1,100	1,293	1,194	1,336	1,831	2,008	2,035
Other Products	82	105	79	126	150	161	238
Sawn Lumber	23	33	42	58	131	160	185
MDF/HDF	54	55	41	77	84	92	96
Plywood	24	38	37	52	113	90	81
Veneer	16	23	20	27	46	56	66
Particle Board	45	45	33	54	83	63	44
Total	**1,345**	**1,591**	**1,446**	**1,730**	**2,438**	**2,629**	**2,745**

Source: Directorate General of Foreign Trade, Ministry of Commerce

Table 2: India's Imports of Logs and Wood Products by Category from United States (US$ Million)

Category	2007	2008	2009	2010	2011	2012	2013
Logs	1	2	1	2	6	8	20
Sawn Lumber	0	3	2	2	14	21	15
Other Products	1	2	2	3	3	3	3
Veneer	0	0	0	0	1	0	0
MDF/HDF	0	0	0	1	1	1	2
Particle Board	0	0	0	1	1	1	1
Plywood	5	6	5	13	9	10	13
Total	7	13	11	23	35	45	54

Source: Directorate General of Foreign Trade, Ministry of Commerce

Table 3: India's Total Imports of Logs and Wood Products by Country (US$ Million)

Partner Country	2007	2008	2009	2010	2011	2012	2013
Myanmar	320	399	339	430	604	691	740
Malaysia	360	432	446	476	600	658	612
New Zealand	81	100	91	127	216	238	236

Partner Country	2007	2008	2009	2010	2011	2012	2013
China	44	53	52	82	178	134	126
Germany	30	43	33	40	50	57	78
Thailand	25	24	22	34	47	48	65
Ecuador	24	27	17	16	32	47	63
Papua New Guinea	32	46	45	62	67	41	59
Vietnam	2	4	5	11	21	41	56
Indonesia	6	10	12	27	34	38	52
United States	7	13	11	23	35	45	54
Rest of the World	294	283	248	268	402	417	439
World	**1,345**	**1,591**	**1,446**	**1,730**	**2,438**	**2,629**	**2,745**

Source: Directorate General of Foreign Trade, Ministry of Commerce

Table 4: India's Imports of Logs (HS Code 4403) by Country (US$ Million)

Partner Country	2007	2008	2009	2010	2011	2012	2013
Myanmar	312	386	327	415	588	678	725
Malaysia	327	382	413	421	535	596	556
New Zealand	77	95	84	123	207	230	229
Ecuador	24	26	17	14	31	45	62
Papua New Guinea	32	44	43	59	63	36	56
Costa Rica	15	17	22	25	48	56	50
Ghana	57	83	50	47	46	56	44
Cote de Ivoire	40	49	48	52	39	36	37
Panama	14	10	8	11	22	30	26
Benin	9	9	12	13	20	23	24
United States	1	2	1	2	6	8	20
Rest of the World	192	188	169	153	226	212	206
World	**1,100**	**1,293**	**1,194**	**1,336**	**1,831**	**2,008**	**2,035**

Source: Directorate General of Foreign Trade, Ministry of Commerce

Table 5: India's Imports of Wood Products (Excluding Logs) by Country (US$ Million)

Partner Country	2007	2008	2009	2010	2011	2012	2013
Partner Country	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
China	44	53	52	80	162	132	126
Germany	17	21	15	30	43	49	66
Thailand	25	22	19	33	43	44	61
Vietnam	2	2	2	5	18	40	56
Malaysia	33	50	33	55	65	62	56
Indonesia	6	10	11	26	31	37	52
Tanzania	0	3	11	11	11	9	20
Brazil	1	3	3	7	10	19	19
Australia	1	2	2	2	1	1	19
Italy	10	14	13	12	13	10	17
United States	6	11	10	20	29	36	34
Rest of the World	99	107	80	113	180	181	183
World	245	298	252	394	607	622	710

Source: Directorate General of Foreign Trade, Ministry of Commerce

Table 6: India's Import Tariff on Wood and Wood Products

ITC HS Code	Unit	Basic Duty (BD)	Effect	PRE	ACD	CVD	Cess	Total	Policy
44.01	mt	5	5	-	4	0	0.15	9.356	Free
44.02	mt	5	5	-	4	0	0.15	5.150	Free
44.03	m3	5	5	-	0	0	0.15	5.150	Free
44.04	kg	10	10	-	4	0	0.30	14.712	Free
44.05	kg	10	10	-	4	0	0.30	14.712	Free
44.06	m3	10	10	-	4	12	0.70	28.852	Free
44.07	m3	10	10	-	4	0	0.30	14.712	Free
44.08	kg	10	10	-	4	12	0.70	28.852	Free
44.09	kg	10	10	-	4	12	0.70	28.852	Free

ITC HS Code	Unit	Basic Duty (BD)	Effect	PRE	ACD	CVD	Cess	Total	Policy
44.10	kg	10	10	-	4	12	0.70	28.852	Free
44.11	kg	10	10	-	4	12	0.70	28.852	Free
44.12	m3	10	10	-	4	12	0.70	28.852	Free
44.13	kg	10	10	-	4	12	0.70	28.852	Free
44.14	kg	10	10	-	4	12	0.70	28.852	Free
44.15	u	10	10	-	4	12	0.70	28.852	Free
44.16	kg	10	10	-	4	12	0.70	28.852	Free
44.17	kg	10	10	-	4	12	0.70	28.852	Free
44.18	kg	10	10	-	4	12	0.70	28.852	Free
44.19	kg	10	10	-	4	12	0.70	28.852	Free
44.20	kg	10	10	-	4	12	0.70	28.852	Free
44.21	kg	10	10	-	4	12	0.70	28.852	Free
64.06	kg	10	10	-	4	6	0.50	21.782	Free
94.03	kg	10	10	-	4	12	0.70	28.852	Free

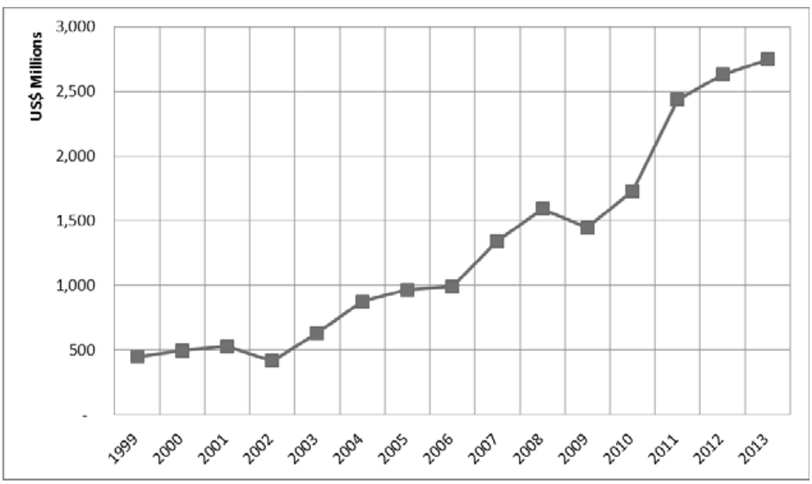

Fig. 1: India's total imports of Wood and Wood Products by value

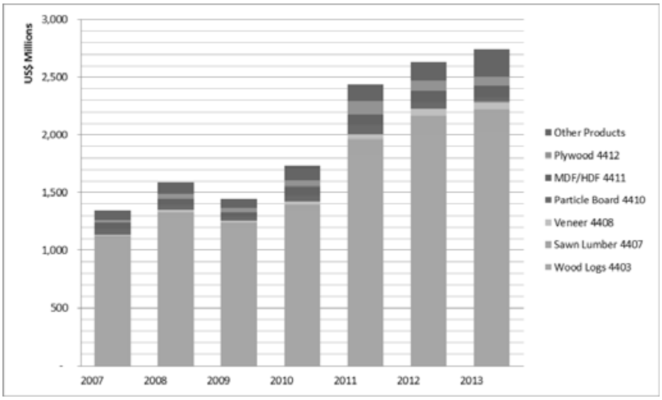

Fig. 2: India's total imports of Logs and Wood Products by category

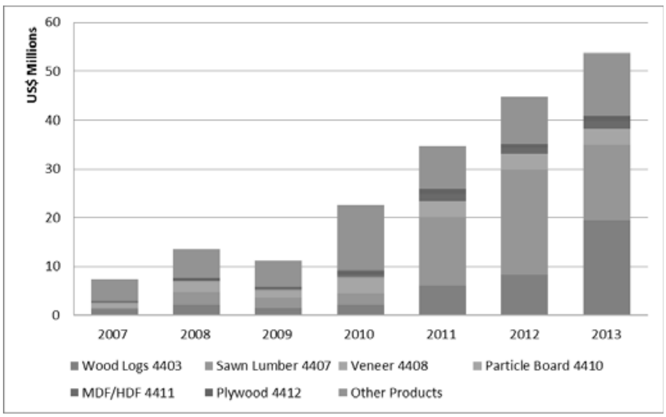

Fig. 3: India's total imports of Logs and Wood Products by category from U.S.

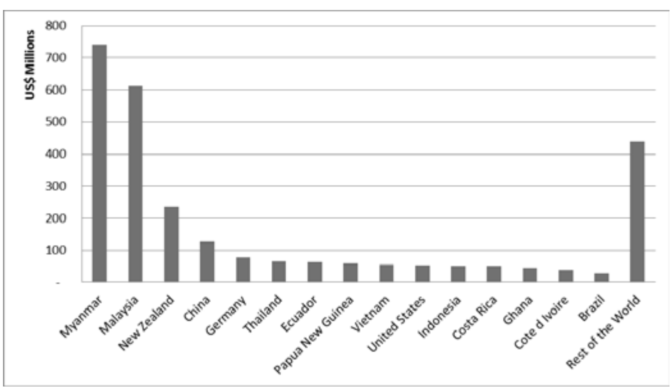

Fig. 4: India's total imports of Logs and Wood Products in 2013 by country

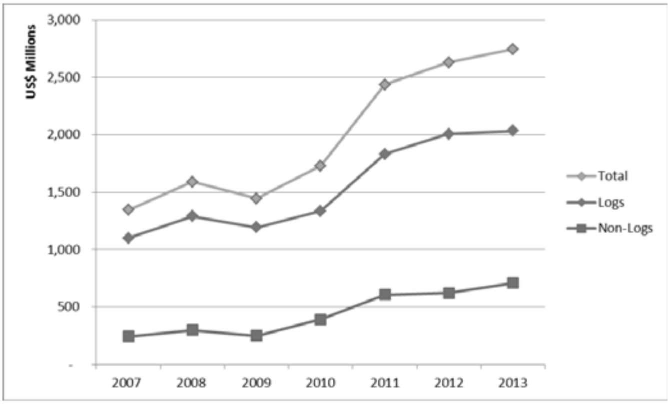

Fig. 5: Growth of Logs vs. Non-Logs Imports

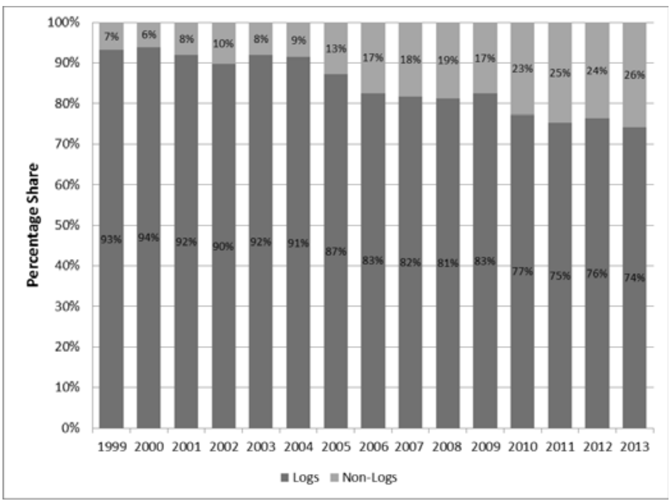

Fig. 6: Share of Logs vs. Non-Logs Imports

Acknowledgement

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Quality Seed Production for timber trees of India - Current status and future strategies

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India is a key producer and consumer of tropical timber. It has increased its timber import in order to strike a balance between domestic demand and supply. The India's state of forest report 2015 recorded 21.34% (70.17 million ha) forests and 2.82% (9.26 million ha) tree cover of the geographical area of the country. It also assessed that there has been an increase of 0.11% forest (21.23% forest in 2013) and 0.045% tree cover (2.78% tree cover in 2013) as compared to 2013. There are many factors contributing to the rapid increase in tree cover over the years. Today's forestry in India mainly being conservation forestry instead of the erstwhile production forestry, has led to increased dependence on timber produced from trees outside forests. Also factors such as failing monsoons, soil infertility, labour costs etc. have resulted in shifting to tree cultivation. As a result the need for quality seeds for quality planting stock production has become all the more important in recent days.

India's requirement for timber was estimated at 54.94 MT for 2006 (MoEF, 2000). According to studies by Wiles (2005) an estimate of 28.81 MT is contributed by farm forestry, 9.38 MT is harvested from forests and 2 MT imported indicating a shortage of 14.74 MT and this deficit is further expected to increase to 60.3 MT by 2020 (Khanduri and Mandal 2005). On the other hand, the quantity of quality seeds produced for supply within the country is very minimal restricting to few species like Teak, Sal, Shisham, Padauk, Poplar, Acacias, Mahagony, etc. while considering the diverse range of timber species exploited in the country. This paper therefore discusses the present status and future strategies of the country's quality seed production, with special reference to timber trees.

Quality seed source

The seeds for plantation programmes are generally collected from any of the following available sources: 1) Plantations, 2). Seed Production Areas, 3) Plus trees, 4) Clonal Seed Orchards (untested), 5) Clonal Seed Orchards (tested) 6) Seedling Seed Orchards (untested) and 7) Seedling Seed Orchards (tested). In India invariably the seeds are collected from plantations and Seed Stands/ Seed Production Areas. Under various programmes establishment of Clonal Seed Orchards and Seedling Seed Orchards have been taken up by the State Forest Departments. These CSOs and SSOs are mostly established for important commercial species while Seed Stands/SPAs serve as interim sources of quality seeds for plantation activities until seeds from CSO and SSO are available in sufficient quantities.

Under the Planting Stock Improvement Program (PSIP) aided by World Bank, production of quality seeds was aimed through improving the genetic quality of seeds and by appropriate seed handling and storage practices. The improvement of genetic quality of seeds entailed establishment of authenticated seed sources namely Seed Production Areas (SPA), Seedling Seed Orchards (SSO) and Clonal Seed Orchards (CSO). In this the Indian Council of Forestry

Species (scientific name)	Seed orchards		
	Number	Generation	Area
Abies pindrow	-	-	37.00
Acacia auriculiformis	1	-	1.00
Acacia catechu	6	-	62.00
Acacia nilotica	2	-	13.00
Acacia occidentalis	-	-	12.00
Acacia spp.	7	-	39.40
Acrocarpus fraxinifolius	1	-	10.20
Adina cordifolia	1	-	3.00
Ailanthus spp.	2	-	3.50
Albizia procera	2	-	10.20
Artocarpus chaplasha	1		10.00
Artocarpus spp.	1	-	2.00

Species (scientific name)	Seed orchards		
	Number	Generation	Area
Altingia excelsa	1	-	3.00
Azadirachta indica	6	-	12.85
Bombax ceiba	2	-	24.24
Chukrasia tabularis	-	-	1.00
Dalbergia sissoo	27	*	411.60
Dipterocarpus spp.	476	*	1.25
Gmelina arborea	30	1	418.40
Juglans regia	-	-	38.00
Melia azedarach	-	-	5.00
Michelia champaca	1	-	6.00
Ougeinia oojenensis	1	-	3.00
Phoeba goalparensis	-	-	1.00
Pinus carribaea	1	-	5.00
Pinus kesiya	-	-	1.50
Pinus roxburghii	-	-	44.00
Pinus wallichiana	-	-	36.00
Populus deltoides	-	-	4.00
Pterocarpus marsupium	-	-	4.00
Pterocarpus santalinus	5	-	7.00
Pterocarpus dalbergiodes	1386	*	2.77
Terminalia procera	353	*	0.60
Terminalia bialata	209	*	0.20
Santalum album	2	-	23.60
Shorea robusta	-	-	-
Tamarindus indica	20	-	432.00
Tecomella undulata	-	-	-
Tectona grandis	160	-	4555.11
Terminalia chebula	1	-	3.00
Terminalia myriocarpa	-	-	5.00
Terminalia sp.	-	-	6.00

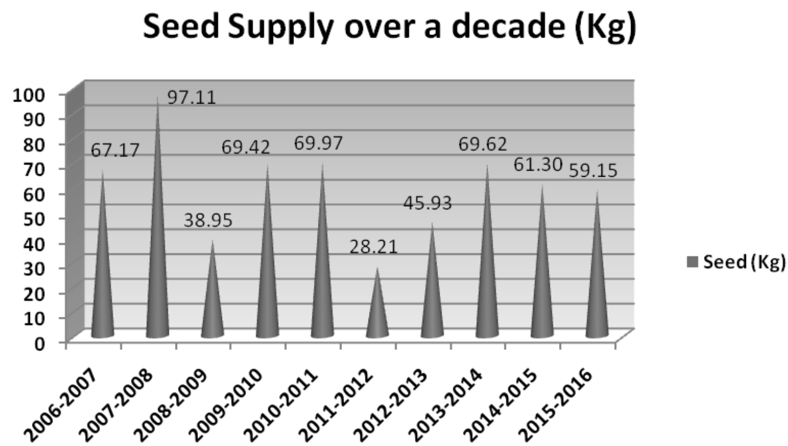
Research and Education (ICFRE) played a major role to supplement the seed production efforts by the State Forest Departments (SFDs) and Forest Development Corporations. In the long way, Forestry colleges under State Agricultural Universities and wood based industries have also contributed for improved seed production. Systematic tree improvement of only few species for improving timber production have paved way to establishment of seed orchards as listed by India-Country Report on State of Forest Genetic Resources 2012.

Quality Tree Seed Production- Demand and supply by IFGTB

The interest in tree cultivation has increased the requirement for quality seeds. In addition to seed demand for quality planting stock production for afforestation, reforestation and restoration programs of the State Forest Departments, seed requirement for tree cultivation outside forests has increased manifold. Quality seeds are those which are physically, physiologically and genetically superior and result in quality seedlings. As seeds form the basis for successful planting stock production, full-fledged research inputs have gone into quality seed production at the Institute of Forest Genetics and Tree Breeding Institute, Coimbatore, since two decades. Presently the clients of IFGTB are farmers, industries, foresters and NGOs who look forward for quality seed supply throughout the calendar year. The Institute also encourages its clients to use quality tree seeds for the benefit of attaining maximum economic and ecological gains.

The time interval between planting and realization of benefits being usually long in most tree species, it is necessary to ensure the seed quality before supply. Authenticated good seed source, time and method of collection, processing, packing and storage methods result in quality seeds. Presently the Institute is supplying improved seeds of *Acacia auriculiformis* and *A. mangium* collected from the seed orchards established by the Institute while quality seeds of indigenous tree species such as *Melia dubia, Gmelina arborea, Neolamarckia cadamba* and *Tectona grandis* are being collected from Candidate Plus Trees or SPAs and made available to the user groups. Albeit the cost of the tree seeds that has gone up during the recent past, the demand for seeds keep rising. Therefore, efforts to bring more areas under seed orchards are being undertaken by the Institute.

Technology transfer for establishing seed orchards by industries and establishment of community seed orchards for decentralized quality seed production are also being augmented by the Institute in order to meet the seed demand. The overall seed supply over the past 10 years by the institute has been presented in the Figure below.



Quality seeds from SPA

There is a perpetual demand for teak timber in the country for construction purposes, in both urban and rural areas. Seed Production Areas (SPAs) have been the major source of quality teak seeds in our country. Seed Production Area is referred to a phenotypically superior stand made up of vigorously growing healthy trees, upgraded by thinning to remove poorer phenotypes and treated and managed to cause abundant seed production. Since the culling of inferior trees is recommended, it is also called as negative selection, because inferior phenotypes are selected for removal from the seed stand. The Seed Production areas are mainly established for species for which there are constraint of implementing elaborate tree improvement programme.

The IFGTB in collaboration with State Forest Department of Tamil Nadu and Kerala has identified potential plantations of Teak and converted them into SPA. The State Forest Department use these sources for collection of seeds for raising plantations.

SPA – established by SFD with IFGTB support

Species	State	Area selected	SPA
Tectona grandis	Kerala	95.3 Ha	50 Ha
	Tamil Nadu	39.0 Ha	20 Ha
Acacias	Kerala	12.3 Ha	2.3 Ha
	Tamil Nadu	37.5 Ha	5 Ha

Annual seed production from seed production areas

State	Species	Extent of spa	Quantity of seeds which can be collected	Extent of plantation can be raised annually
KERALA	*Teak*	85 Ha	38,250 Kg	6955 Ha
	A. auriculiformis	4.5 Ha	1,170 Kg	3600 Ha
TAMIL NADU	*Teak*	50 Ha	22,500 Kg	4090 Ha
	A. nilotica	12 Ha	7,500 Kg	4412 Ha
	A. leucophloea	4.5 Ha	1,125 Kg	3571 Ha
	A. feruginea	6 Ha	3,120 Kg	2400 Ha
	A. planifrons	10 Ha	3,750 Kg	2679 Ha

It is estimated that there will be 15% gain in productivity of progenies raised from SPA over progenies of normal plantations. While planning for establishing plantations, extent of seed orchards/ SPA for priority species of interest, seed requirement and related details need to be derived and an example for the same is shown below.

Seed production in SPA (*Tectona grandis)*

1.	a) Extent of SPA in Tamil Nadu	: 52.77 Ha
	b) Total Seed Production	: 15,810 Kg
	c) Extent of plantation which can be raised annually with existing SPA	: 4163 Ha
2.	a) Average number of trees per Ha in SPA	: 150
	b) Seed yield per tree	: 3 - 4 kg
	c) Nett seed collection per tree	: 2 kg
	d) Seed yield per ha of SPA	: 300 kg

	e) Extent of plantation which can be raised annually from 1 ha of SPA	: 79 Ha
3.	a) Estimated number of germinated seeds per kg of seed	: 723
	b) Number of seeds per kg	: 2065
	c) Germination percent	: 35
4.	Raising of plantation	
	a) Number planted	: 1111 (3 x 3 m)
	b) Addition for replacing field casualties	: 389 (35%) [35x1111/100]
	c) Total requirement of plantable plants	: 1500
	d) Additional requirement for nursery losses	: 1250
	e) Total requirement of germination seedlings	: 2750
	f) Number of kg needed per ha. of plantation	: 3.8 [2750/723]
5.	Extent of plantation that can be raised with 1 kg of seed	: 0.263 Ha [1/3.8]

Future needs

Various assemblages and plantation information about timber trees raised across the country need to be collated through networking of SFDs, research institutes and State Agricultural Universities and kept updated at periodic intervals so that national programmes to convert them to SPAs/orchards can be launched based on an All-India coordinated mode.

Lesser known timbers trees with multipurpose utility need to be given more attention for improvement, popularisation and marketing so that pressure on few selected timber species can be reduced.

SPAs for fast growing native timber species need to be established on priority basis inorder to ensure supply of quality seeds until seed orchards are in place and to match the pace of tree cultivation interest of farmers.

Augmentation at regular intervals through infusions from other countries for selected species under tree breeding is required to help increase the productivity and regulate genetic degradation. However the present status in our country is cumbersome for such overseas seed exchange programs and this needs to be relaxed.

Similar to tailor made clones, combined efforts of biotechnology, tree improvement and silviculture is required to develop trait based seeds- like drought tolerant, saline tolerant, pest resistant, climate resilient and site specific seeds, though its highly challenging in tree species which are primarily of out crossing nature.

Developing mobile apps for tree seed availability would enable dissemination of the seed information far and wide. Hosting details about quality seed availability by various authorised seed suppliers like forest departments/ research institutes /SAUs would facilitate increased use of quality seeds.

SFDs need to come forward to extend funding support so that many undocumented and abandoned plantations of the SFDs can be revisited and evaluated with the scientific support so as to convert them to seed orchards.

Community seed orchards need to be established for decentralised supply of quality seeds so that new income generation opportunities open up with peoples'participation.

Seed certification of tree species need to be made mandatory in the country and appropriate certification authority need to be vested with forestry research institutes and state forest research wings so that only quality seeds are made available for all planting activities and certified seeds alone can be legally marketed.

The Forest Genetic Resource Management Network in the country need to be strengthened so that all information related to timber trees can be obtained through a single window system.

Annual requirement of quality seeds at state level- by agro forestry departments, extension wings of SAUs and SFDs need to be estimated so that preparations for seed collection at appropriate time from reliable sources can be implemented successfully.

Waste and underutilized vacant lands can be encouraged for raising orchards of suitable species.

Government authorised certified nurseries for tree species which uses certified seeds need to be popularised as a commercial source of quality planting stock in the country.

More awareness, suitable market for uptake of end products and timely supply of quality seeds with proper guidance for timber tree cultivation would definitely encourage more stakeholders to venture in this endeavour.

Further Reading

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Quality Seed and Seedling Production in Important Timber Tree Species

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Introduction

Seeds are unique in natural regeneration and propagation because seeds constitute a unique genetic composition resulting from the mixing up of parental genetic material. They produce offspring of genetic variation, which in turn enhances ecological adaptability. Seeds are produced in large numbers and are readily available in each year or at longer intervals. They are much more resistant to damage and environmental stress than vegetative propagules. In essence, seed is a miniature tree because it is responsible for its regeneration and ultimately for its reproductive success (Schmidt, 2000). Following fertilization, growth sets in various parts of the ovule resulting into a seed; the zygote develops into the embryo, the primary endosperm nucleus gives rise to endosperm and the integuments form the protective seed coat, which is the seed's primary defence against adverse environmental conditions. Seed quality is the first and foremost factor, which decides the success and viability of a tree plantation as an afforestation programme or for that matter, even a genetic improvement programme. Management of seed quality starts from the selection of plus trees continues through seed collection, extraction, processing, seed enhancement and storage. Each and every step has its own significance; this will guide the seeds men, to obtain seeds of high quality. In this chapter deliberations are made on issues and challenges of quality seed and seedling production in important timber tree species.

Seed supply

Seed supply is one of the most critical factors limiting the any planting programmes. This is especially, in countries where trees grown as an exotic species and seed used totally from old trials or pilot plantations. Problems of seed supply, including the amount and quality of the annual seed requirement, are considered.

Seed requirement

It is well known that most of the timber tree species seeds posses seed dormancy. Where as in teak seed is concern the germination is poor and sporadic as a result of its dormancy behaviour. Under nursery conditions the germination of untreated seed is about 30-50% over a germination period of 50 days (Kaosa-ard, 1986;; Masilamani and Buvaneswaran, 2011). This germination behaviour causes a very low plant percentage in nursery production. Wellendorf and Kaosa-ard (1988) estimated that the plant percentage in a teak nursery is only 5%, or five plantable seedlings produced from 100 seeds sown in one crop year. The amount of seed required for a hectare of plantation with 4 (4 metre spacing is about 8 kg, including 25% for beating up (Wellendorf and Kaosa-ard, 1988).

Seed quality

The success of planting programmes depends not only on the site quality but also on the genetic quality of the planting materials. The use of improved seed (i.e., from seed production areas, seed orchards and plus trees) is most essential in the improvement of growth, stem quality and other characters of the plantation. It has been estimated that by using such improved seed, the growth and/or volume production gain of the plantation is increased (from base populations) by 5-25%, depending on types of seed source and planting site (Wellendorf and Kaosa-ard, 1988) in teak.

Seed production

The use of improved seed or plant materials is shown to be essential to increase the growth and quality of plantations. To obtain such improvements, Seed production areas and/or seed orchards are required.

A Seed Production Area (SPA) is a converted plantation or a natural stand for seed production, treated by removing all inferior trees, and SPAs seem the most practical short term option for improved seed production programmes. An abundance of improved seed can be obtained within one year of establishment. Through the SPA option, the gain in volume production of plantations is 5-15% over routine seed sources (Kaosa-ard, 1993).

The Clonal Seed Orchard (CSO) is another option of seed source establishment. It is a plantation of mixed clones derived from plus trees, designed, established and managed for seed production purposes. It is established as a propagation part of the improvement programme. Generally, the CSO starts producing seed at 10-15 years and its initial gain is about 25% over the base population (Kaosa-ard, 1993).

Seed production capacity of both SPAs and CSOs is relatively poor, at least in the case of Thailand. The production capacity in the SPA and CSO is about 10 and 70 kg/ha of teak seed respectively (Meekaew, 1992). Low production capacity of teak seed in the CSO is also reported from India, 0.5-1 kg per tree or approximately 50-100 kg/ha. However, a contrasting result is reported from Nigeria, where the productivity of the CSO is as high as 734 kg/ha (Egenti, 1981). The needed areas of SPAs and CSOs to support a 1,000 ha annual planting programme has been estimated and given in Table 1. This estimation is based on available information from Thailand where the seed production capacity in SPAs and CSOs is 10 and 70 kg/respectively.

Table 1. Estimated areas of SPA and CSO for various options of a 1,000 ha planting programme

Spacing (m)	Seed Requirement (tons)	SPA Requirement (ha)	CSO Requirement (ha)
2 × 2	33.78	3,378	483
3 × 3	15.00	1,500	214
4 × 4	8.43	843	120
4 × 2	16.88	1,688	241

Seed enhancement

Seed enhancement is a range of treatments of seeds that improves their performance after harvesting and conditioned, but before they are sown. They include priming, steeping, hardening, pre-germination, pelleting, encrusting, film-coating, tagging and others (Black *et al*., 2006). They are used to improve seed sowing, germination and seedling growth by altering seed vigor and/or the physiological state of the seed. The alteration may improve vigor or the physiological state of the seed by enhancing uniformity of germination. Other treatments include the use of chemicals that trigger systemic acquired resistance or improve stress tolerance. The use of antioxidants, enhancements like pelleting, coating and encrusting improve seed handling and planting. Some treatments enhance nutrient availability or provide inoculates by delivering materials needed during sowing, germination and seedling establishment.

Clonal propagation

Apart from SPA and CSO, tissue culture is another option for mass supplying of genetically improved materials for the planting programme of this species. This technique of propagation has been developed successfully for commercial propagation of selected plus trees (Kaosa-ard and Apavatjarut, 1989). In this technique, shootlets are produced under laboratory condition and are then transferred to glasshouse conditions for rooting. The rooted shootlets or plantlets are transplanted for stock production. Through this process, the cost of shootlet production (as estimated in 1989) was US$5.12 per 100 shoots at 1 million scale of production. This production cost seems to be the same level as the cost of seed production (viable seed) in the CSO (Kaosa-ard, 1990). This CSO production cost includes establishment and maintenance of CSO for at least 10 years prior to full seed production, plus the cost of seed collection and processing.

Seed Testing

Tree Seed Testing is the art of science of evaluating seed quality for plantation purpose. Although initially developed for evaluating the planting quality of field and vegetable seeds, it is also valuable for determining the quality of lawn, flower and tree seeds (Copeland and Mc Donald, 2001). The expression seed quality is used loosely to reflect the overall value of seed for its intended purpose. Seed quality is usually a composite of several factors, all of which contribute to the desirability, or planting value of the seed. The key question is "why do we test seeds? There are several reasons. First, and most obvious, is that the dry seed's potential to establish a seedling cannot be determined until the seed has been germinated. However, we also test seeds to determine the genetic (varietal) and mechanical (weed/other crop) components of the seed lot. Seed testing results provide important information to both the seed producer and purchaser. The seed producer wants to ensure that only a quality product is marketed so that consumer will return for their future seed needs.

Strength of Indian Seed Testing System

- India we are having 136 notified state seed testing laboratory include one Central Seed Testing Laboratory and one referral laboratory in Central Institute of Cotton Research for Bt. cotton testing.
- The NSRTC Seed Laboratory has been notified as Central Seed Testing Laboratory (CSTL) w.e.f. 1st April, 2007 by Gazette of India. The NSRTC Central Seed testing Laboratory has become member laboratory of International Seed Testing Association (ISTA), Zurich, Switzerland during 2007 onwards. The primary objective of establishing NSRTC is to have a separate National Seed Quality Control Laboratory, to serve as Central Seed Testing Laboratory (CSTL), under Seeds Act, and Referral laboratory for courts in India.
- In addition to public sector seed testing laboratory, 12 private ISTA member laboratories and 5 ISTA accredited laboratories and one public sector ISTA accredited laboratory also involved seed testing research (Table 2).

Cultural Practices for Effective Seedling Production in Important Timber Tree Species

Shading / crown cover in nursery

Seed-beds and polythene tubes are shaded during germination and early seedling stage. Shades or shelters protect seeds and young plants from direct

Table 2. List of ISTA Accredited Seed Testing Laboratories in India

Sl.NO	ISTA Accredited Laboratories
1	Bejo Sheetal Seeds Pvt. Ltd., Jalna, Maharashtra
2	Indo-American Hybrid Seeds (India) Pvt Ltd., Bangalore
3	Maharashtra Hybrid Seeds Company Ltd.Jalna (M.S.)
4	Namdhari Seeds Pvt. Ltd.,Bangalore
5	Nuziveedu Seeds Limited, Secunderabad
6	STL, Department of Seed Certification, Lawley road, Coimbatore, Tamilnadu

sunlight, large temperature fluctuations, desiccation, heavy rain, and, in some areas, from frost and hail (Napier and Robbins 1989).

Irrigation

Water requirements will differ according to species and weather conditions. Too little moisture causes reduced growth or, in the worst case, wilting; too much water causes problems in root respiration and often promotes fungal diseases. Young germinants are especially sensitive and must be watered frequently. As the seedlings grow, their water demand increases, and watering should be increased accordingly. Different types of irrigation methods viz.,

a. Flow irrigation
b. Overhead irrigation
i. Automizer
ii. Water can or rose can
iii. Sprinkling

Fertilization

The need and type of fertilizer application depends on the nutrient content of the soil, size of seedlings and length of time spend in the nursery. Where forest top soil is used in germination beds or as potting soil, fertilizer application may be unnecessary. Where planting soil is relatively poor in nutrients, application of a granular NPK or other fertilizer will be beneficial. A fertilizer relatively rich in phosphorus is usually recommended, both because phosphorus is the limiting factor in many soil types, and because it encourages root development and stimulates the development of N-fixing bacteria in Leguminosae. Conversely, nitrogen encourages leaf and shoot development and discourages N-fixing bacteria, neither is desirable in the nursery.

Pruning

Potted plants are pruned for a number of purposes:

1. To reduce overgrowth in the nursery
2. To facilitate the physical planting process
3. To promote side root development for potted seedlings

The idea of potted seedlings is that their root system fills up most of the pot volume, but roots must not grow outside the pot and anchor the seedlings into the soil below. Bare-root seedlings may be root-pruned in order to facilitate planting since, a large spreading root makes practical planting difficult. Another reason is that deep roots are easily damaged when removing them from the nursery. Bare-root seedlings may be root-pruned mechanically by undercutting the whole seed-bed.

Weed Management

Controlling the weeds in the nursery has different methods viz.,

a. Physical control

i. Mechanical weeding

ii. Hand weeding

b. Biological control

c. Chemical control

For quality seedling production in the nursery, the weed problem needs to be taken care at early establishment stages. Weeds must not be allowed to grow in nursery beds, because they compete with seedlings for water, nutrients, light and space (Muzik, 1970). Weeds can also have an allelopathic effect on nursery seedlings. i.e., they can harm seedlings through the production of chemical compounds that escape into the environment. Other negative impacts of weeds are their potential for harboring insects or disease organisms (Owston and Abraham, 1984). Furthermore, weedy nurseries may have an adverse psychological impact on workers and customers, thus potentially reducing productivity and profits. Nurserymen generally prepare nursery media using red earth, sand and farmyard manure in different ratios. These mixtures have chances for mixing up of weed seeds and other reproductive structures like rhizomes, tubers, roots, corms, bulbs and bulb lets. The weed growth cause large interference in the nursery on germination and seedling growth. Weed control is a global problem in bare root nurseries. Without the use of chemicals, some seed beds have required over 10,000 hand weeding hour's ha^{-1}. As a result, weed control is potentially, one of the most expensive steps in the production of tree seedlings. In some cases, the cost of hand weeding has constituted 25 to 90% of the total production costs (Boyer and South, 1984). Weed problems in the forest nurseries can result from the common practice of leaving gap of bare ground and growing single species crops that do not utilize all of the site recourses. Application of herbicides is considered to be the effective way of reducing the weed infestation in forest nurseries and thereby lowering the cost of hand weeding (Bargali, 2003).

Masilamani et al., 2017 Studied three different pre-emergence herbicides on weed control efficiency, seedling survival and seedling growth of teak nursery. Three days after planting the stumps in poly bags, pre emergence herbicides viz. atrazine (50% WP), pendimethalin (30% EC) and oxyfluorfen (23.5% EC) were applied as herbicide spray with water at different concentrations on the nursery bags using knapsack sprayer. Thirty and sixty days after application of herbicides, observations were made on number of leaves/stump, number of secondary roots/stump, dry matter production (g $seedling^{-1}$) and survival parentage of teak seedling in each treatment. Weed control efficiency was worked out on the basis of weed dry weight (g) recorded in each treatment at 30 days after application of herbicides. To evaluate the efficiency and compatibility of pre-emergence herbicides on seedling growth of teak were observed through phytotoxic scoring on 3 days interval up to 30 days and 15 days interval up to 60 days after application of herbicides. The results revealed that the compatibility of application of pre-emergence herbicide of atrazine at 0.50% - 1.0% can be effectively control weeds without impairing the seedling growth of *Tectona grandis* (Table 3&4).

Table 3 .Influence of pre-emergence herbicide on number of leaves, number of secondary roots, dry matter production and survival (%) of teak (60 DAHA)

Treatments	No. of leaves/stump	No. of secondary roots/stump	DMP (g/seedling)	Survival (%)
T_1 - Control (water spray)	9.0	8.0	8.14	100.0(89.09)
T_2 - Atrazine - 0.50%	7.0	5.0	7.28	98.0(81.87)
T_3 - Atrazine - 1.0%	8.0	8.7	6.11	94.1(75.94)
T_4 - Atrazine - 1.50%	6.0	6.0	5.25	93.0(74.66)
T_5 - Pendimethalin - 0.8%	7.0	5.0	5.64	93.0(74.66)
T_6 - Pendimethalin - 1.2%	8.0	7.0	5.00	93.1(74.77)
T_7 - Pendimethalin - 1.6%	7.0	7.7	5.58	96.0(78.46)
T_8 - Oxyfluorfen – 0.4%	8.0	5.7	5.81	98.0(81.87)
T_9 - Oxyfluorfen – 0.6%	6.0	6.0	5.92	93.1(74.72)
T_{10} - Oxyfluorfen – 0.8%	6.0	7.3	4.21	96.9(79.96)
SEd	0.52	1.09	0.12	0.24
CD (P=0.05)	1.08	2.30	0.25	0.51

Note: DAHA – Days After Herbicide Application

Table 4 .Effect of herbicide spray on phytotoxicity scoring of teak seedling

Treatments	Days After Herbicide Application											
	3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**45**	**60**
T_1 - Control (water spray)	0	0	0	0	0	0	0	0	0	0	0	0
T_2 - Atrazine - 0.50%	0	0	0	0	0	0	0	0	0	0	0	0
T_3 - Atrazine - 1.0%	0	0	0	0	0	0	1	1	1	1	0	0
T_4 - Atrazine - 1.50%	0	0	0	0	0	0	2	2	2	2	0	0
T_5 - Pendimethalin - 0.8%	4	4	4	5	5	5	5	5	5	4	0	0
T_6 - Pendimethalin - 1.2%	4	5	5	6	6	6	6	6	6	6	0	0

Treatments	Days After Herbicide Application											
	3	6	9	12	15	18	21	24	27	30	45	60
T_7 - Pendimethalin - 1.6%	4	5	5	6	6	6	8	7	7	7	0	0
T_8 - Oxyfluorfen – 0.4%	3	3	3	4	4	6	7	7	7	7	3	1
T_9 - Oxyfluorfen – 0.6%	3	3	3	4	4	6	7	7	7	7	4	2
T_{10} - Oxyfluorfen – 0.8%	3	3	3	4	4	6	7	7	1	7	4	2

Note: Pooled mean of three replications Data not statistically analyzed

Hardening off

A few weeks before the seedlings are transplanted into the field they must be hardened to adapt them to the harsher field conditions. Watering is reduced and fertilization stopped. Shelters are usually removed to expose the seedlings to full sunlight, although some shelter may be maintained for species that are to be planted under shelter trees, e.g. some rain forest trees. Hardening should normally be initiated some days after root pruning so that the seedlings will have some days to recover from the pruning shock (Hoskins 1983).

Control of insect pest and diseases and animal management

Sometimes, several insect pest cause extensive damage in the nurseries. Generally, soil characters, climate, water quality/irrigation and general locality are the main site factors determining the occurrence of disease, insect and to some extent animal problem will plague a nursery. Any one or a combine of these factors will influence the kind and amount of damage caused by pest and the types, timing and effectiveness of controls. A constant vigilance is needed for the protection of nursery beds from insect pests and diseases. Proper knowledge of insect pests, fungus and disease are essential in order to control them.

Scope for Mechanization in the Nursery

Mechanized sowing and lifting of the seedling is possible for large scale commercial tree nursery. For example the annual planting target of teak in our country is more than 50,000 ha, which are raised through different seed sources. The common practice is to raise teak plantation using root-shoot cuttings (stump). Transportation and the planting cost are minimum for stump planting when compared to seedling planting. The food material stored in the stump is utilized directly by the sprouting shoots and boosts their initial growth until the establishment of root system (Chandrasekhara Pillai *et al*., 2014). Lifting and stumping of teak seedlings from nursery beds is generally conducted during the planting time. Lifting of nursery seedlings can be done by hand using crowbar (digging/pulling). Hand lifting is commonly practiced in both government and private planters. Teak Improvement Centre Ngao, Lampang, Thailand they were practiced machine lifting in large scale, where millions of seedlings are to be lifted within a few weeks. This is especially the case when the seedlings are lifted for storage in the dry period (Kaosa-ard, 1986). Although a large volume of scientific results in this field has been recorded in various journals. Work on lifting of seedlings for preparing stump through machinery on a commercial scale is not available in India. Against the backdrop Masilamani et al.,2017, Studied the effect of different methods of lifting and stumping of teak seedling on stump quality. Teak seedling were lifted manually done by hand using crow bar (digging / pulling) and by using back hoe loader in 10 month old teak mother bed (each 10 beds- size 1m length and 5m width) nursery. Variable costs such as machinery and labour were of interest in this study. Other inputs were assumed to be equal across treatments. Hiring charge of back hoe loader, machine hour, labour type, working hour and wage rate were measured. From this experiment it could be concluded that lifting the teak seedling by back hoe loader resulted in reduce the human drudgery, lifting of more seedling with lesser time and cost without impairing the seedling growth (Table 5&6).

Table: 5. Effect of different methods of lifting of teak seedling on stump quality*

Treatments	30 days after planting					
	Damage percentage (At the time of lifting)	Survival percentage	Days taken for initial sprouting	Number of leaves /stump	Number of secondary roots/ stump	Dry matter production (g/ seedling)
T1-Seedling lifted by manual method	1.0	100	4	6.0	12.5	7.52
T2- Seedling lifted by back hoe loader	6.2	99.0	4	6.2	12.3	7.48

*pooled mean of four replications

Table 6. Results of Partial Budget Analysis

Situation

Economic analysis of lifting the teak seedling by manually Vs using back hoe loader from ten month old teak mother bed nursery- 10 beds each

Additional Costs	Cost (Rs.)	Additional Returns	Cost (Rs.)
Machinery hiring charges (41min *@ Rs12.50 per min)	512.50		
For collecting cost (hired female labour@ 30 min)	29.25		
Total	541.75		
Reduced Returns		**Reduced Costs**	
		labour cost(Manual lifting requires three hours of male and two female labour force)	702.00
		Total	702.00
Total annual additional costs and reduced returns	541.75	Total annual additional returns and reduced costs	702.00
		Net change in income	160.25
		Benefit cost ratio (702/541.75)	1.30

*Other benefits of back hoe loader method over manual method
Time saving, Less cost involved, Vey less human drudgery

Future Prospective

- All Tree seed laboratories should develop the Standard Operation Procedure (SOP) and Quality Management handbook to maintain the documentation on staff, training, reports, equipment, and proficiency tests.
- Calibration of equipment / instrument, internal / external audit, corrective action, check sampling and testing should be part of the seed testing laboratory.
- Adequate support needed for Quality training in seed testing viz.; Basic training in different tests. Tree seed testing laboratories in India minimum

in number and the number of seed samples analysed in various seed testing laboratories has considerably low. However, desired level of perfection in tree seed testing has yet to be achieved.

- Additional laboratories in private/public sector are in the process of establishment to cater the need of tree seed testing for increased the Plantation targets.
- Most of the laboratories in India are either ill equipped or without adequate infrastructural facilities and trained manpower resources.
- The Seed Legislation in our country were formulated in the Seeds Division, Department of Agriculture, Cooperation and Farmers Welfare, Government of India, New Delhi and enacted at different points of time, viz., The Seeds Act in 1966, The Seed rules in 1968, The Essential Commodities Act in 1955, The Seeds (Control) Order in 1983, The New Seed Policy on Seeds in 1988 and The New Seed Bill, 2004 (Draft in Parliament).
- Through these legislations, the Government has strived to ensure that right quality seeds are sold to farmers so that targeted production of food grains can be achieved and farmers get due return for their hard work. Since enactment of these legislations, many notifications have been issued from to meet the changing requirements of the seed sector and needs to the farmers (Trivedi and Gunasekaran, 2014). This type of legislations were not formulated and enacted in Forest tree seed sector. It needs to be strengthened.
- Hence, in order to train the Human resources and equipe all the laboratories, Govt. of India, Ministry of Environment and Forests establish Tree Seed Quality Control Wing for tree seed certification and giving more emphasis by providing required funds for the Tree Seed Testing Laboratories and train the personnel who are involved in the Tree Seed Quality Control Laboratories.
- As per the Seed Bill 2004: Chapter III registration of kinds and varieties of seeds, etc. *The Horticulture nursery to be registered.*

(1) No person shall conduct or carry on the business of horticulture nursery for any of the purposes of this Act unless such nursery is registered with the State Government.

(2) Every application for registration under sub-section (*1*) shall be made in such form and contain such particulars and shall be accompanied by such fees as may be prescribed.

Duties of registration holders of horticulture nursery

Every person who is a holder of a registration of a horticulture nursery under section 23 shall

(*a*) keep a complete record of the origin or source of every planting material and performance record of mother trees in the nursery;

(*b*) keep a layout plan showing the position of the root-stocks and scions used in raising the horticulture plants;

(*c*) keep a performance record of the mother trees in the nursery;

(*d*) keep the nursery plants as well as the parent trees used for the production or propagation of horticulture plants free from infectious or contagious insects, pests or diseases affecting plants; and

(*e*) furnish such information to the State Government on the production, stocks, sales and prices of planting material in the nursery as may be prescribed.

- Such type of rules and regulations must be formulated in forest nurseries, this will help to improve the quality planting stock production in impotent timber species.

The following countries viz., Austria, Belgium, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Netherlands, Norway, Poland, Russia, Slovakia, Spain, Sweden, United Kingdom and United States are suppling coniferous and broad-leaved tree seeds to various counties (worldseed.org.2013), in this list India is not there. The reason is India having minimum number of ISTA Accredited Seed Testing Laboratories, which are the only eligible laboratories to provide orange certificate for exporting the seeds. It needs to be strengthened.

In view of the globalization of tree seed trade, it would be desirable to update the tree seed testing rules and regulations in conformity to the international level. It is so far newly private Seed Testing Laboratories in India is accredited with ISTA. The importers from various countries insist for this certificate. ISTA Accreditation Procedure is given below for getting accreditation from ISTA Secretariat, Zurich, Switzerland.

I. ISTA Accreditation Procedure

1. ISTA Membership
2. Participation in the ISTA Inter-laboratory Proficiency Test Programme
3. Establishment of a Quality Management System
4. Application for Accreditation
5. Document Review
6. ISTA Audit
7. Authorization to issue ISTA Certificates

Conclusion

Commercial timber plantations have been widely established throughout the tropics with the main objectives to produce high quality timber within a minimum period year. Three main factors affect growth and quality of the plantation: site quality, seed supply and silvicultural management. Site quality has direct effect on the growth and development of the plantation. The rotation age can be greatly reduced through site selection. A large quantity of improved seed can be obtained through establishment and management of Seed Production Areas and Seed Orchards. Clonal propagation by tissue culture is an option for mass production of planting stock. This technique is technically and economically feasible for most of the timber species. Establishment of notified Tree Seed Testing Laboratories (TSTL) and strengthening of micro propagation structures of important timber yielding species are need of the hour across the country.

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Quality Planting Stock Production Towards Enhanced Timber Production

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Introduction

Good plant quality is the basis for tree planting success. It is not worth a farmer's effort to transport plants to the field, prepare an area, plant and maintain trees unless they are of good quality. A poor quality tree will always be a poor quality tree even if planted on a well-prepared, good site. In the field, each poor quality tree wastes space and resources leading to low site productivity. High quality trees have a higher survival rate and faster growth in the field than poor quality trees. Fast growth allows a tree to outcompete weeds and reduces the initial labour costs of establishment. Fast growth also enables a farmer to harvest wood or tree products sooner, increasing the return on the farmer's investment. Production of trees is for people's livelihood; they depend on having high quality trees.

Quality Planting Stock Production

Seedling quality is a concept, widely used in forestry, which has received considerable attention in recent past. It is important because afforestation seedlings cannot receive the same care that may be given to individual ornamental or fruit trees. After they are planted, the seedlings have to survive without irrigation or fertilizer, and this is often the case in agroforestry as well as farm forestry sites too. Many studies have shown that field survival and productivity are related to the quality of the seedlings used.

Seedling quality has two main aspects. The first is the genetic quality or the source of the seed. The second component of seedling quality is its physical condition when it leaves the nursery. Improving genetic quality of seedlings requires a long term strategy of seed selection, while improving the physical quality can be accomplished in just one or two seasons.

Seedling quality depends on

- The ability to produce new roots quickly
- The speed with which seedlings get anchored in the ground, and start assimilating and growing after planting out
- A well-developed root system
- Sun-adapted foliage
- A large root collar diameter
- A balanced shoot:root ratio
- Good carbohydrate reserves
- An optimum mineral nutrition content
- The establishment of adequate mycorrhizal or Rhizobium infection

Quality seedlings targeted for different sites may look different from each other but they all have one thing in common: a well-developed root system with many root tips from which new roots can quickly develop. In areas with adverse environments, such as dry, flooded, saline or nutrient-deficient sites, only well-developed plants have a good chance of survival. For dry areas produce seedlings with a deeper root system. For weedy sites larger plants are better they can outgrow weeds quickly.

Many seedling quality characteristics, such as the shoot:root ratio, are difficult to observe and/or require destructive sampling. The shoot:root ratio is an important measure for seedling survival. It relates the transpiring area (shoot) to the water absorbing area (roots). It is usually measured by determining root and shoot dry weights. A good ratio one which indicates a healthy plant is 1:1 to 1:2 shoot:root mass.

A less rigorous, but non-destructive, index is the ‘sturdiness quotient’, which compares height (in cm) over root collar diameter (in mm). A small quotient indicates a sturdy plant with a higher expected chance of survival, especially on windy or dry sites. A sturdiness quotient higher than 6 is undesirable.

Although plant quality indices have been developed for many gymnosperms but it has not been tested on tropical species.Nursery bed density, shading, pricking out techniques, seedling size atplanting, watering and fertilizing before and after planting out all thesehave significant and long-lasting effects on seedling quality and subsequenttree development, insect and pest resistance, and tolerance to environmentalstresses such as drought.

Quality Seed

Seedling quality also depends on the seed used. The quality of seed planted in the nursery is of crucial importance, since seeds are the most basic input into any planting programme. It is therefore necessary to pay proper attention to quality issues when procuring and subsequently storing tree seed until planting.

Seed for a planting programme may be obtained in different ways. It can be collected directly from local stands of a species (such sources include native or naturalized stands and stands established specifically for seed production). Alternatively, seeds also can be obtained from a commercial or noncommercial seed supplier. Most nursery managers get their seed from seed suppliers. When ordering seed from a supplier, always attention to be paid on the genetic quality of seed. Genetic quality relates to the origin (provenance) ofseed and its genetic diversity.

If seed is collected directly from a local stand, the same issues of quality should be considered. To ensure a wide genetic base, never collect seed from a single tree, always collect your seed from a number of trees (normally at least 30). Note the species, origin, collector and date of collection (as a minimum), for future reference. It is important to collect mature seed, because immature seed has low viability and storage life.

After Collection

For most species, extract seed from fruit as soon as possible. The method used will depend on the species. For many legumes, pods can be dried in the sun for two days and then rubbed across a coarse wire mesh through which seed falls. The extraction method used should not damage seed so that a significant loss in viability occurs. During extraction, remove impurities (for example, diseased or partly eaten seed, contaminating seed, soil, chaff and insects) by winnowing or hand-sorting.

After extraction, most seed should be dried further before storage. Generally, the lower the moisture of seed, the longer it can be stored. Normally, seed with a moisture content of 10% or less will maintain high viability for several years, if stored correctly. Sun drying seed for two to three days generally reduces moisture to an acceptable level, although more time is needed for large seed. Spread seed on raised beds to help air circulate, and shade the beds from strong sunlight (move seed into the shade for around two hours at midday).

During processing, the viability and purity of seed is normally tested. Viability is the percentage of germinating seed in a seedlot and is measured by germinating seed under conditions (including any pre-treatments such as nicking or soaking in hot-water) that would normally be applied during germination. This provides a reference level of germination for users. Purity is the percentage by weight of pure seed in a sample and is estimated by weighing a sample of seed before and after the removal of impurities. Record particular impurities, such as contaminating seed. The International Seed Testing Association (ISTA) has published guidelines for seed testing that qualified seed suppliers should adhere to.

Label seed properly during processing and storage. An unidentified seedlot is almost worthless. As a minimum, seed should be labelled with the species name, original collection source, production location, collection date, producer and viability.

Seedling Development

There are three phases in seedling development

- Establishment
- Production
- Hardening

The establishment phase includes seed germination and first root growth. The production phase is manifested by rapid shoot growth. During the hardening phase, seedlings are gradually accustomed to field conditions.

Establishment

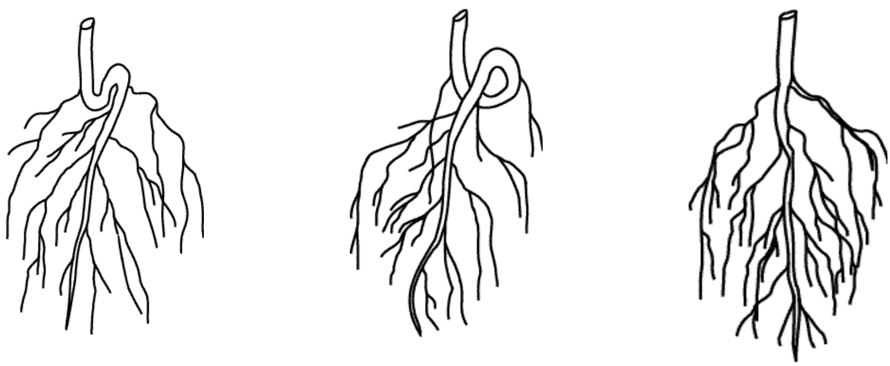
Various pre-treatments can be used to accelerate the start of germination and/or to shorten the germination period for all seeds so that germination is uniform rather than scattered over a long period of time. Most common seed pre-treatment methods are soaking in cold water for 12, 24 or 48 hours, immersion in hot (70°C) water, letting cool and soaking for 12, 24 or 48 hours and nicking/partial or complete removal of seed coat.

Whenever possible, sow seeds directly into containers or a bare-root nursery bed. Germinating seeds in germination trays or beds and pricking them out later can lead to severe root deformities unless it is done carefully. If the use of germination trays is absolutely necessary, for example because seeds are extremely small or sensitive, always sow in several trays. This will minimize the risk of losing all seeds due to unforeseen problems, such as disease, flooding or drying out of the tray. Prick out the seedlings as early as possible after germination. Only very tender seedlings, such as Eucalyptus, need to have the first true leaf pair developedbefore pricking out. Avoid letting the roots grow too long and developing sideroots, or they will be damaged when transplanting. Especially with biggerseeds, transplanting can be done as soon as the root begins to emerge.

Inoculation with mycorrhizal fungi or Rhizobium bacteria is necessary for good plant development of most agroforestry tree species. It can increase plant disease resistance and help alleviate plant stress by enhancing the plant's water and nutrient uptake. Early infection with mycorrhiza can also increase the propagation success of cuttings and seedlings. It is especially important that mycorrhizal and Rhizobium associations are well-established when seedlings are produced for acid or degraded soils.

Production

As soon as a seedling is established, either a few days after germinationor after pricking out, both roots and shoots begin growing rapidly. This phaseis as important as the establishment phase. Root development is important forgood inoculation with symbionts, for efficient nutrient uptake and for outplantingsuccess. The number of fine roots with growing points largely determines theability of the seedling to recover and start growing after planting out. If theroot system is small and/or distorted, the tree cannot anchor itself sufficientlyin the ground and is prone to wind-throw or lodging when waterlogged.The appearance of a healthy root system is of course different for specieswith a strong tap root, than it is for those with a mass of shallow roots. However,most tree seedlings have a straight, slightly tapering main root and a large mass of fibrous roots. Healthy roots are not bent, crossing or injured. Knotted and bent roots are common in plants that have been left in the nursery too long or have been pricked out without the necessary care. These plants cannot survive in the field because the crossing roots may eventually strangle the tree or they may die back and become vulnerable to disease and termite attacks.



Bent Root Looped Root Healthy Root

Hardening and Planting out

Seedlings need to get accustomed to the conditions at a planting site. Therefore, about 4–6 weeks before planting out, start hardening them by reducing watering gradually to once a week and by gradually removing the shading. Plant seedlings out as soon as they have reached their optimum size. This varies with the species and the site, but it will usually be a height of 15–30 cm. It can be much larger for some slow-growing species, or when there is strong weed competition at the planting site. Do not leave seedlings in the nursery into the next season. Often, late rains, high workloads and other obstacles delay plantings. If this is anticipated try to slow down plant development. For example, when producing plants in containers, delay potting on into bigger containers, or stop fertilizing. These are only temporary solutions, because the quality of the planting stock will deteriorate considerably if it is left too long in the nursery.

A very important point which is unfortunately often overlooked is that feedback from scientists carrying out long-term research and from farmers should be sought and used for further improvement of plant quality. Client feedback is important for the fine-tuning of nursery operations. Try to visit field sites and experiments in the years after planting out, in order to see the effects of particular nursery practices. In addition, collect data on a regular basis to allow evaluations and possibly amendments of current nursery practices.

Handling Seedling Variability

Every plant population has some degree of variation. This can be greatest for populations which have not undergone any domestication. Since few agroforestry tree species have undergone any significant domestication there will be wide variation in the size and quality of seedlings. This variation is still visible in the field many years after planting. Although much agroforestry research focuses on determining and utilizing the variation within populations, an important prerequisite for some research is uniformity of planting stock. For example, an experiment with the aim of comparing management practices will give more precise results if variation in the seedlings used is minimized.

Uniformity of seedlings from non-domesticated seed sources can be improved by rigorously culling the population before the plants leave the nursery. Culling is the removal of weak, diseased, or overgrown plants. It is essential to set culling targets to reduce the variation in experimental plots in a reproducible way without depending on nursery staff to choose plants to discard and without significantly increasing costs. Remove unwanted seedlings early on to achieve a relatively homogeneous nursery population. If necessary, cull the plants again before seedlings are planted out. One way of describing the variability is by using the coefficient of variation (CV). The CV is more useful than the standard deviation, because CV is independent of the measured units (cm, mm, etc.)

This allows a better comparison of variability than standard deviation allows. CV is calculated as follows: standard deviation (SD) divided by sample mean = CV. This figure is multiplied by 100 and expressed as a percentage. The smaller the CV, the more uniform the population.

Good Nursery Practices

- Consult farmers as well as forestry technicians when selecting the seed sources for the nursery
- Select the parent trees well in advance and design a strategy to ensure sufficient seed is collected
- Collect seed from at least 30 parent trees
- Judge seedling quality by several traits
- Conduct regular surveys of plant quality
- Sacrifice a few plants to improve total nursery production quality
- Use plant quality surveys to correct problems through appropriate nursery practices
- Discard poor quality trees as soon as it was detected

Poor, but Unfortunately Common Nursery Practices

- Collecting seed from only a few trees close to the nursery
- Selecting the best seedlings for planting out, and delivering the bad plants to the next customer rather than throwing them away
- Leaving plants in the nursery from one production year to another

Important Timber Trees Grown in Tamil Nadu

- *Acacia auriculiformis*
- *Acacia mangium*
- *Ailanthus excelsa*
- *Albizia lebbeck*
- *Albizia odoratissima*

- *Albizia procera*
- *Neolamarckia cadamba*
- *Azadirachta indica*
- *Dalbergia latifolia*
- *Dalbergia sissoo*
- *Gmelina arborea*
- *Hardwickia binata*
- *Holoptelia intergrifolia*
- *Khaya seneglensis*
- *Ptrerocarpus marsupium*
- *Swietenia macrophylla*
- *Swietenia mahagoni*
- *Syzygium cumini*
- *Terminalia catappa*
- *Terminalia paniculata*
- *Terminalia tomentosa*
- *Terminalia arjuna*
- *Pterocarpus santalinus*
- *Tectona grandis*

Important Timber Trees Grown in Tamil Nadu and their Propagation

S. No.	Species	Propa gation	Method	Success rate(%)
1	***Acacia auriculiformis***	Seeds	Soaked in cool water for 24 to 30 hours	96
2	***Acacia mangium***	Seeds/ Vegetative	H_2SO_4 (96%) for 90 min or boiling water 60 sec	85
3	***Ailanthus excelsa***	Seeds	Not essential	98

S. No.	Species	Propa gation	Method	Success rate(%)
4	***Albizia lebbeck***	Seeds	Immerse in H_2SO_4 for 5 minutes	80.3
5	***Albizia odoratissima***	Seeds	soaking of nicked seeds	76
6	***Albizia procera***	Seeds	Soaking in cold water for 48 hours	71
7	***Neolamarckia cadamba***	Vegetative	Cuttings treated with 3000 ppm IBA	85
8	***Azadiracha indica***	Seeds	Not required	92
9	***Dalbergia latifolia***	Seeds	Not required.	90
10	***Dalbergi sissoo***	Seeds/ Vegetative	Not required	90
11	***Gmelina arborea***	Seeds	Pretreatment of seeds not necessary. Pre-germination in damp sand is sometimes practiced	97
12	***Hardwickia binata***	Seeds	Not required	75
13	***Holoptelia intergrifolia***	Seeds	Not required	84
14	***Khaya senegalensis***	Seeds	Not required	92
15	***Ptrerocarpus marsupium***	Seeds	Soaking in cow dung solution for two days	88
16	***Pterocarpus santalinus***	Seeds	Soaking in cold water for 72 hours or soaking in cow dung slurry for 72 hours	98
17	***Swietenia macrophylla***	Seeds	Soaking the seeds for 72 hours in cold water or in cow dung slurry for 48 hours	92
18	***Swietenia mahagoni***	Seeds	Not required	84
19	***Syzygium cumini***	Seeds	Not required	90
20	***Tectona grandis***	Seeds	Either boiling water treatment; or immersion in cold water for several days;	80

S. No.	Species	Propa gation	Method	Success rate(%)
21	***Terminalia catappa***	Seeds	Seeds should be placed in little heaps for successful sprouting	74
22	***Terminalia paniculata***	Seeds	Not required	80
23	***Terminalia tomentosa***	Seeds	Seeds should be placed in little heaps for successful sprouting	82
24	***Terminalia arjuna***	Seeds	Soak the seeds in cool water for 48 hours	85

Seedling Certification Standards for some Important Timber Species

Acacia auriculiformis

- Should be 20-30 cm in height, to the base of the newest leaf or buds
- Should have straight, undamaged and un-forked stems
- Low concentration of effective microorganism upto 2% can be recommended for seedling development
- Well lignified stem at least for half of their seedling height
- Should have root collar diameter of over 4 mm
- Should be quite free of insect and fungal disease
- Should have root collar diameter between 7 and 20 mm, and a root diameter of at least 7 cm

Acacia mangium

- A leaf phosphorus asssy for seedling of acacia mangium
- Should be 20-30 cm in height, to the base of the newest leaf or buds Have straight, undamaged and un-forked stems
- Well lignified stem at least for half of their seedling height
- Have root collar diameter of over 4 mm

- Should be quite free of insect and fungal disease
- Should have root collar diameter between 7 and 20 mm, and a root diameter of at least 7 cm

Ailanthus excelsa

- Should be 20-30 cm in height, to the base of the newest leaf or buds
- Should have straight, undamaged and un-forked stems
- Well lignified stem at least for half of their seedling height
- Have root collar diameter of over 4 mm
- Should be quite free of insect and fungal disease
- Should have root collar diameter between 7 and 20 mm, and a root diameter of at least 7 cm

Albizia lebbeck

- Should be 20-30 cm in height, to the base of the newest leaf or buds
- Should have straight, undamaged and un-forked stems
- Well lignified stem at least for half of their seedling height
- Have root collar diameter of over 4 mm
- Should be quite free of insect and fungal disease
- Should have root collar diameter between 7 and 20 mm, and a root diameter of at least 7 cm

Neolamarckia cadamba

- Pricking out can be done when the seedlings are about 5 cm high after about one month in polythene bags with fungicide.
- The *seedlings* are also very sensitive to frost
- Seeds are small sized
- The seedbed should be protected from heavy rain and not watered too much as damping of can be a problem to prevent damping of disease seedling should be placed in well ventilated conditions.

Azadirachta indica

- Seeds/stones are to be collected during November – March.
- Seed/stones are dried and stored in gunny bags or in sealed tins for about one year.
- Soak the stones in warm water for 5-6 hours or in cold water for 12 hours before sowing.
- Poly pot seedlings can be grown in nursery.
- Direct sowing in plantation site is also done.
- Propagation can also be done through stumps planting.
- Seedlings should be kept free from overhead shade.
- The preferable planting size of seedling is 20-30 cm

Dalbergia sissoo

- Seeds are to be collected during March-May.
- Clean dried seed can be stored in sealed tin or gunny bays for about 6-12 months.
- Pre-treatment with soaking in water for 6-12 hours before sowing.
- This species is propagated by direct sowing method; seedlings can also be raised in nursery, stumps and by root suckers are also used for planting.
- Sisoo seedlings to be protected from weeds, cattle and fungal infection.
- This species prefer alluvial soil adjoining rivers and can grow up to 1000 meters (MSL) elevation.

Dalbergia latifolia

- Direct seeding is possible under moist conditions with good weed control.
- Seeds are to be collected during February - March.
- Clean dried seed can be stored in sealed tin or gunny bays for about 6-12 months.
- Pre-treatment with soaking in water for 6-12 hours before sowing.

- Grows best on deep, well-drained, moist soils
- This species is propagated by direct sowing method; seedlings can also be raised in nursery, stumps and by root suckers are also used for planting.
- Sisoo seedlings to be protected from weeds, cattle and fungal infection.

Gmelina arborea

- Seeds are to be collected April-June.
- Seeds are collected by de-pulping and dried in sun for 2-3 days.
- Seeds can be stored in dry ventilated room for about 6-12 months.
- Seeds collected from animal droppings are better.
- Seeds should be soaked in water for 2-3 days before sowing.
- Seedlings are raised in mother bed and transplant in secondary beds.
- Stumps are prepared for planting out when seedlings attain thump size girth.
- Directly sowing also gives good result.
- It is species of moist sub-tropical zone, prefers moist, fertile and well-drained soil up to 1200 MSL elevation.

Tectona grandis

- Seeds are to be collected during December-February.
- Seeds (bony drupe) can retain viability for long period and can be stored in well-aerated sack.
- One-year-old drupe gives better result than fresh one.
- Alternative soaking and drying under concrete sun for 2-3 weeks before sowing.
- Seeds can be treated by light burning of drupe.
- Seeds are sown in mother beds and pricked out in secondary beds when leaves appear.

- Stumps are prepared for planting out when seedlings attain thump size girth.
- Direct sowing can also be practiced.
- Seedlings of *Tectonagrandis*should be grown about 600m (asl) altitude & below and should not be planted in steep slopes as it deteriorate soil because of large foliage system.

Some of the Certified Tree Nurseries

1. Green Field Agroforestry Products for Acacia auriculiformis
   Sanjivani Nagar
   Jabalpur
   Madhya Pradesh

2. Shreeji Sandal Wood Firm for Redsanders
   Khada – Ahamadabad Highway
   Bharath Gas Complex
   Hriyala PO, Kheda, Gujarath

Agroforestry as a solution for India's timber deficit

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Introduction

"Trees for life" is becoming a very popular slogan worldwide in the recent years. The different extreme catastrophic scenarios such as flood, drought, heat & cold wave and global warming forcing us to adopt woody perennial systems to sustain the farm production and livelihood. Trees play a crucial role in almost all ter-restrial ecosystems. They provide a wide range of products and services to rural and urban people. As natural vegetation is cleared for agriculture, trees are integrated into productive landscapes - the practice known as agroforestry (Garrity *et al.* 2006). The immense potential of agroforestry has helped to improve the livelihoods of the rural farmers. The trees on farmland are an age-old traditional farming system and particularly plays pivotal role wherever people depend on fragile ecosystems for survival and sustenance. Agroforestry has the immense capacity to provide sustainable agricultural benefits. Approximately 1.2 billion people of the world is practicing agroforestry one or other way (World Bank, 2004). Remote sensing data show that in 2010, 43% of all agricultural land globally had at least 10% tree cover and that this has increased by 2% over the previous ten years (Zomer *et al.* 2016). In India, so many estimates has reported varying figures on agroforestry area by Zomer et al. (2007), Dhyani et al (2014) Dhyani (2015); FSI (2013, 2015) and Rizvi et al. (2014). Chavan *et al.* (2015) documented the agroforestry area based on data from CAFRI, Jhansi and Bhuvan LISS III, was 13.75 m ha (Fig 1). However, Forest Survey of India estimated the same as 11.54 m ha, which is 3.39% of the geographical area of the country.

Fig 1 State-wise Agroforestry and Forest area in India (Chavan *et al.* 2015)

The role of traditional agroforestry system is well accepted and documented by scientific community of the world. These systems are on the edge of vanishing due to modern cultivation practices, decreasing natural resources, changing cropping pattern and marketing channel. The traditional agroforestry systems were true bio-mimic of natural forest and designed to fulfil own family requirement such as 6Fs i.e. food, fibre, fuel, fruits, floss, fertilizers and fodder (Chavan et al. 2015). These systems are not enough to provide extra-income to farmers and the adoption rate is decreasing too fast due to yield reduction, small land holding, market rate and economic returns from the system. As per the Planning commission of India, the benefit:cost ratio of indigenous tree based systems was 1.09-1.80, which is lower than conventional agriculture. Therefore, negligence of traditional agroforestry system is more and famers are adopting lucrative economic systems.

The commercial agroforestry systems in India are developed through farm forestry to fulfil the timber deficit. Timber from natural forests is in-creasingly less available because of conservation, environmental and social concerns. Industrial plantations make up only about 5 percent of the total forest area but provide 35 percent of the world's wood supply (FAO, 2001). Expansion of industrial plantations, however, is limited because of competition from alternative land uses. Yet the demand for timber and other forest and tree products is increasing at the local, regional and international levels. In response, many small-scale agroforestry systems have evolved market orientations. As per the Arvind Bijalwan (2015) the production potential of trees for wood generation is restricted to about 0.7 cubic metre/hectare/year in the country as compared to the world average of 2.1 cubic metre/hectare/year. This results in a huge gap between demand and supply. Also the National Forestry Action Programme says, India's timber requirement in 2006 stood at 82 million cubic metre whereas the domestic availability was just 27 million cubic metre. Moreover, in the past 10 years, the money spent on import of wood has jumped from US $1 billion in 2001 to more than US $ 5 billion in 2011. Owing to the scarcity of domestic timber resources and a burgeoning demand, wood imports in the country have doubled since 2006. The increased demand for forest products, fast population growth, urbansiation, higher rate of economic growth and trade liberalization are putting pressure on all resources including forests.

The demand for food to feed increasing population causing extension in agriculture and shifting cultivation resulted into decline in area under forests. During last two decades, India witnessed annual depletion of forest cover at rate of 253 square kilometres (Anon., 1999). By keeping this in view, India has introduced new National Agroforestry Policy 2014 of its kind to minimize the timber deficit through adopting farm forestry and increseing tree cover p to the one third of area. Also agroforestry is only viable solution to provide employment to rural and urban population through production, industrial application and value addition ventures. Current estimates show that about 65 % of the country's timber requirement is met from the trees grown on farms.

Timber production in India

India's annual imports of logs and wood products have increased from $500 million to $2.7 billion over the past decade. Restrictions on domestic harvesting from forests coupled with limited forest resources have limited supply, while expanding consumer and commercial interest in wood interior products and wooden furniture have increased demand. India is also becoming a furniture exporter, turning imported wood into finished products for export. Low tariffs and liberal import policies have made logs the dominant import category for years, as India sought to maximize value addition while minimizing pressure on its forests. However, lower tariffs on other wood products coupled with increasing sophistication among wood users has increased market share for processed wood products. Logs' share of imports has dropped from 90 percent to 74 percent over the past decade. India's imports of U.S. wood products were valued at a record $54 million in 2013 (GAIN report, 2014). In 2011, only 3.2 million cubic meters (mcm) of wood were produced from Indian forests, while the vast majority of domestically harvested wood was harvested from "trees outside of forests" such as tree plantations, farms, and private lands. There is no official estimate of the amount of annual production from trees outside of forests, but the estimate of the potential wood that could be harvested was 44 mcm in 2011, significantly more than the amount harvested from forests. The countries timber import value is growing at 12% per annum and is likely to increase in years ahead. This liberalization of imports has benefited the domestic timber market has benefited, particularly wooden handicrafts and furniture sector, which otherwise faced paucity of the desired wood in the required quantity and quality. As per the current Export & Import Policy, the principal raw material, viz., wood logs are freely importable under OGL. The total production of Plywood during 2006-07 was 54,45,857 Sq. Mtrs. and production during 2007- 08 (up to December) was 43,38,998 Sq. Mtrs. The production of Particle Board during 2006-07 was 44,76,704 Sq. Mtrs. and production during 2006- 07(up to December) was 47,60,457 Sq. Mtrs. The export and import of plywood during 2006-07 was Rs.126.25 crore and Rs.57.62 crore respectively. The export and import of Particle Board during 2006-07 was Rs.18.86 crore and Rs.148.64 crore respectively.

According to FSI Report 2015, the total forest cover in India is 70.17 million hectare, which is 21.34% of the total geographical area. Out of this, 8.59 million hectare (2.61%) is very dense forest, 31.54 million hectare (9.59%) is moderately dense and the rest 30.04 million hectare (9.14%) is open forest. The trees outside forest (TOF) are estimated to cover 9.26 million hectare area, which constitutes about 2.82% of the India's total geographical area, thus, the total forest and tree cover of the country is 79.42 million hectare (24.16%). The country's forests have very low growing stock, *i.e.*, 5,768 million m^3, comprising 4,195 million m^3 inside forest areas and 1,573 million m^3 outside the recorded forest areas, which imply an average growing stock of 72.63 $m^3 ha^{-1}$ in 79.42 million hectare of forest and tree cover (FSI, 2015). The top three states in growing stock were: Arunachal Pradesh, Uttarakhand and Chhattisgarh, which accounted for 9.3%, 8.7% and 7.5% of the total growing stock respectively. With 2.5% of the total world's land area, India supports nearly 17% of the world's human population besides a large livestock population. Therefore, the forests are under intense biotic pressure, leading to degradation of forest resources. Forests have much lower growing stock (72.63 m^3ha^{-1}) as compared to the world average of 110 $m^3 ha^{-1}$. Likewise, the mean annual increment of forests in India is low (< 1 $m^3 ha^{-1} yr^{-1}$) as compared to the world's average of 2.1 $m^3 ha^{-1} yr^{-1}$. The condition of forest based industries is very poor in India, thus, the promotion of large-scale farm or agroforestry plantation, which is essential in India, can be made possible through social forestry.

Regulation and restrictions on tree felling

The restrictions imposed on harvesting, transportation and marketing of agroforestry produce plays a significant role in the minds of the farmer looking forward to adopt agroforestry. There are many common species which grow naturally in the forest areas and are well adapted to local regions and also grown by the farmers under agroforestry systems. There is urgent need to remove these regulatory restrictions at least for those species which are widely adopted under agroforestry systems and providing raw material to the wood based industries. Bansal committee (Committee constituted by the Ministry of Environment & Forests in July, 2011 to study the regulatory regime, felling and transit regulations for tree species grown on non-forest/private lands) recommended relaxation in transit and felling permission for the species preferred by the farmers and agroforesters. Implementing this action plan in agroforestry policy will encourage active participation of farmers and help in achieving 33% forest cover ensuring raw material to wood based industries as well as environmental security (Chavan *et al.* 2015). An overview of regulated and restricted tree species, existing in different states is mentioned in table 1.

Table 1. List of exempted and restricted tree species from different states of India

State	Exempted (No Permission)	Restricted species (Permission required)
Tamil Nadu	*Grevellia robusta, Eucalyptus* spp., *Casuarina equsetifolia, Leucaena leucocephala*	*Santalum album, Diospyros melanoxylon, Pterocarpus santalinus, Dalbergia latifolia* and *Tectona grandis*
Kerala	61 species permitted. Some of the important are *Pongamia pinnata, Hevea brazilensis, Ailanthus excelsa, Mangifera indica, Garcinia cambogia*, and *Terminala* spp.	*Santalum album, Tectona grandis, Dalbergia latifolia, Xylia xylocarpa, Hopea parviflora, Michelia champaca, Grewia tiliaefolia, Cedrus toona*
Punjab & Haryana	Eucalyptus, Poplar and *Melia composita*	*Acacia catechu, Emblica officinalis* and bamboo

State	**Exempted (No Permission)**	**Restricted species (Permission required)**
Uttar Pradesh	Poplars, Eucalyptus, Subabul., Casuarina, *Ailanthus* spp.; *Gmelina arborea; Grevillea robusta, Morus alba, Anthocephalus cadamba, Melia composita, Acacia* spp., *Albizzia* spp., *Borassus flabeliformis, Butea monosperma, Tamarindus indica, Grewia oppositifolia*	*Mangifera indica, Madhuca indica, Ficus bengalensis*, *Azadirachta indica* and *Carpinus viminae*
Gujarat	Eucalyptus, *Casuarina equisetifolia* and *Prosopis juliflora*	*Tectona grandis*, *Mangifera indica* , *Madhuca latifolia, Acacia catechu, Dalbergia latifolia, Santalum album, Madhuca indica, Gmelina arborea* and *Anogeissus pendula*
Maharashtra	*Acacia nilotica, Leucaena leucocephala*, *Prosopis, Eucalyptus, Moringa, Phoenix*, Sapota, *Acacia auriculiformis* and Poplar	*Terminalia chebula, Tectona grandis, Madhuca latifolia, Tamarindus indica, Mangifera indica, Artocarpus integrifolia Acacia catechu, Santalum album, Pterocarpus marsupium, Adina cordifolia, Terminalia tomentosa, Hardwckia binata Syzigium cumini,* Mangrove
Bihar	Poplar, Eucalyptus, *Anthocephalus cadamba, Mangifera indica, Bombax ceiba, Gmelina arborea*, Litchi, Phoenix and Bamboo except *Dendrocalamus strictus*.	*Tectona grandis*
Madhya Pradesh	Eucalyptus, Casuarina, Subabul, Poplar, *Pithocellobium dulce*, Prosopis	*Acacia nilotica, Albizia lebbeck, Azadirachta indica, Zizyphus mauritiana, Butea monosperma, Syzygium cumini, Acacia leucophloea*, Bamboo

State	**Exempted (No Permission)**	**Restricted species (Permission required)**
West Bengal	No tree exempted	*Acacia catechu*, *Bombax ceiba*, *Dalbergia sissoo*, *Diospyrus melanoxylon*, *Gmelina arborea, Madhuca indica, Michelia champaca, Shorea robusta, Swietenia mahogany*, Teak and Mangroves
Orissa	*Bambusa nutan, B. vulgaris, B. tulda, Samania saman, Eucalyptus* Hybrid, *Acacia auriculiformis, Cassia siamea, Casuarina equisetifolia*, Silver oak	*Mangifera indica, Artocarpus heterophyllus, Schleichera oleosa, Madhuca indica, Tamarindus indica, Santalum album*
Karnataka	Eucalyptus Casuarina, Subabul, Rubber, Coconut, Arecanut, orange, *Erythrina, Gliricidia, Sesbania*, Silver oak.	*Dalbergia latifolia, Santalum album, Acacia catechu*
Jharkhand	*Acacia nilotica,* subabul, Bamboo, Cane*, Shorea robusta, Tectona grandis, Pterocarpus marsupium, Boswellia serrata, Terminalia elliptica*	*Mangifera indica, Madhuca indica, Gmelina arborea, Dalbergia sissoo, Artocarpus heterophyllus, Syzygium cumini*
Andhra Pradesh	*Mangifera indica, Casuarina equisetifolia, Acacia nilotica, Syzygium cuminii, Psidium guajava, Azadirachta indica, Anacardium occidentale, Cocus nucifera, Ficus religiosa*, Eucalyptus and Subabul	*Pterocarpus santalinus, Tectona grandis* and *Santalum album*

Agroforestry and timber production

Agroforestry can improve the lives of resource-poor rural population by providing increased income, diversification and sustainability of agriculture and food security. It can also reduce pressure on natural forests and has a potential to bridge the gap in demand and supply of forest products, including pulp and paper. The supply of industrial wood from forest areas has been dwindling. Trees outside forest (TOF) are the major source of wood for the Indian industry. Most of the wood based industries like plywood and paper pulp are largely dependent on farm grown wood rather than wood from natural forests and forest plantation. Huge volumes of logs, sawn timber, pulp and newsprint are being imported for meeting the growing domestic demand. Eventually, there is a great need to increase the area under tree cover and to improve the productivity.

As of 2003, it is estimated that approximately 50% of India's wood fiber supply comes from non-forest resources (ITTO, 2005). The other half of supply is provided by imports and local public forests and forest plantations. The Indian agroforestry system consists of plantations within the TOF, and represents only a small fraction of the country's geographical area and growing stock, but its study may reveal some of the trends of the wood market. It accounts for 3.4% of the country's geographical area (27.6 million ac), and most of the tree cover is located in the West Coast (3.3 million ac), East Deccan (3.1 million ac) and Eastern Plain (2.4 million ac). The estimated total volume of wood available in the agroforestry system of the country is 1,022.85 million m^3. The top three states in growing stock within the agroforestry system are Maharashtra, Andhra Pradesh and Gujarat. *Mangifera indica* (common name Aam) is the species with highest growing stock within India's agroforestry system (13.3%), and it is followed by *Azadirachta indica* (6.76%) and *Borassus flabelliformis*, two of which belong to the mahogany family (FSI, 2003).

Table 1 India's Consumption of Forest Products in 2014

Item Category	Unit	Production	Import Quantity	Export Quantity	Consumption
Round Wood	m^3	49,517,000	595,336	476	50,111,860
Other Fibre	tonnes	1,995,300	21,029	491	2,015,838
Paper and Paperboard	tonnes	10,247,000	2,400,537	631,966	12,015,571

Item Category	Unit	Production	Import Quantity	Export Quantity	Consumption
Sawnwood	m^3	6,889,000	551,570	79,183	7,361,387
Wood Fuel	m^3	307,172,633	113	198	307,172,548
Wood Panels	m^3	3,125,700	762,330	82,942	3,805,088
Wood Pulp	tonnes	2,307,600	1,1593,00	5178	346,172

(Source: FAO, 2015)

Though agroforestry is being practiced in large parts of the country in one or the other way and has been adopted by the farmers in different agro-climatic zones, the periodic estimation and monitoring of the area under it is still a challenging task due to lack of uniform methodology adopted by the different agencies (Kumar et al., 2014). The current approximate area under agroforestry is estimated to be 25.32 m ha, or 8.2% of the total geographical area of the country as per Dhyani et al. (2013). Based on data of CAFRI and Bhuvan LISS III, the area under agroforestry is 13.75 m ha. However, Forest Survey of India (2013) estimated as 11.54 m ha which is 3.39 per cent of country's geographical area. Maharashtra, Gujarat and Rajasthan ranks high in state wise area under agroforestry. The area estimation as per CAFRI and FSI is represented in figure 1. The estimation by FSI does not include many agroforestry practices such as block plantations thus reflecting lower estimates than CAFRI.

The commercial agroforestry is gaining momentum due to large scale demand from pulp and paper industries. In order to meet the requirement of paper mills, industry requires around 2.5 million ha of land for pulpwood plantation. Currently, the commercial agroforestry is estimated to be practiced over 5 million ha with tree species belonging *to Eucalyptus, Populus, Casuarina, Leucaena, Ailanthus, Melia, Anthocephalus, Acacia, Leucasena, Bombax e*tc. genera. The area under commercial agroforestry is represented in Table 3. The practice is estimated to produce 100 million m^3 timber/pulpwood for industrial and domestic use and 150 million tonne firewood, add approximately 15 million tonne organic matter through leaf fall, sequester 60 million tonne carbon annually in tree components (excluding in soil and that locked in the wood products), generate employment of 4000 million person days/annum in nursery and plantation activities. The value of wood/pulpwood produced is estimated to be around Rs. 10,000 billion and that of firewood as Rs. 30,000 million annually (Dhiman, 2014). It is evident that private enterprises like pulpwood, match wood and other plywood industries are in huge demand for raw material supply which can be tied up through PPP model or any new approaches that will be beneficial to farmer also and indirectly will help in achieving forest cover. Table 4 provides the overview of important agroforestry trees of India with their production capacity.

Table 3. Area expansion of traditional and commercial agroforestry systems in India

Type of AFS	State	Area (000' ha)	Species
Traditional Agroforestry			
Alder-Cardamom	North-east India	34	*Alnus nepalensis*
Kangayam agroforestry	Tamil Nadu	384	*Acacia leucophloea*
Homegarderns	Kerala	1330	Mix tree species
Khejri based agroforestry	Rajasthan	1586	*Prosopis cineraria*
Commercial Agroforestry			
Pulpwood agroforestry(Paper)	Punjab, Haryana, Uttar Pradesh, Andhra Pradesh, Gujarat, Tamil Nadu	657	Eucalyptus, Poplar, Casuarina and Subabul
Timber Based Agroforestry (Furniture)	Kerala, Maharashtra, Tamil Nadu, Madhya Pradesh	1700	*Tectona grandis*
Willow based Agroforestry (Bat industry)	J& K, Himachal Pradesh, Uttarakhand and Punjab		137 Salix species

(Source: Chavan *et al.* 2015)

Table 4. Description of the 20 important MPTS suitable for agroforestry at the national level

Sl.No.	Scientific, English & Common name	Distribution	Clones/ varieties	Uses & Remarks	Rotation age	Wood production (m3/ha)
1	*Tectona grandis* [Teak, Sagwan]	Throughout India, except the dry western zone and Temperate climate	Clone PDKV/ AF/1, seed/clonal orchards at ICFRE	Construction, Railway sleepers, Plywood, MAI 21-30 m^3 ha/yr, Estimated 44% of teak plantation of the world in India	40-60	10-12 $m^3 \cdot ha^{-1} \cdot yr^{-1}$
2	*Populus deltoids* [Eastern Cottonwood Necklace Poplar]	UP, Punjab, Haryana, Uttarakhand, Bihar and HP	G -48, G-3, Uday, WSL-22, PL-2 (L71/84)	Poles, plywood, Veeners, charcoal making, 20-25 MAI m^3 ha/yr	6-8	50 m3$\cdot ha^{-1} \cdot yr^{-1}$
3	*Salix alba* [Indian Willow, Bed]	W. Himalayas, Kashmir, Kullu Vally, Uttarakhand	J-799, SE-63-007, NZ-1140, J-194, seed/clonal orchard -YSPHUF, Solan	Basket and rope work, Cricket bats, MAI 8-23 m^3 ha/yr	12-15	2-3 m3$\cdot ha^{-1} \cdot yr^{-1}$

Sl.No.	Scientific, English & Common name	Distribution	Clones/ varieties	Uses & Remarks	Rotation age	Wood production (m3/ha)
4	*Ailanthus excelsa* [Tree of Heaven, Ardu]	Indian peninsula, Western and Central India	Seed/clonal orchard	Catamarans for fishing, packing cases, sword sheaths, matchbox, fodder, biomass yield 41.8 t/ha	8-12	5-6 m3·ha^{-1}·yr^{-1}
5	*Acacia nilotica* [Indian Gum Arabic, Babul, Kikar]	Most parts of India particularly in MP, Bihar Chhatisgarh, Punjab, Haryana, UP, TN, AP, Karnataka, Maharashtra, Rajasthan	Seed/clonal orchard	Carts, Ag. Implements.Gum, kutch, Katha, Fodder, 3-5 MAI m^3 ha/yr	15-20	2-3 m3·ha^{-1}·yr^{-1}
6	Dalbergia sissoo [Rosewood, Sitsal Beete]	Indian peninsula. Central India, Indo-gangetic region, Tarai, sub-Himalayan Sikkim, Bihar, Orissa	C10, C42, C41, C66, seed/clonal orchard	Premium furniture making and cabinetry, as veneer	18-22	8-10 m3·ha^{-1}·yr^{-1}

Sl.No.	Scientific, English & Common name	Distribution	Clones/ varieties	Uses & Remarks	Rotation age	Wood production (m3/ha)
7	Grewia optiva [Bhimal]	Western Himalaya, Punjab to Bengal	Seed orchard	Food, Fodder, Fuel, Fibre	10-12	2 $m3 \cdot ha^{-1} \cdot yr^{-1}$
8	Azadirachta indica [Indian Lilac, Neem]	Throughout India	Seed/clonal orchard	Oil, Fodder, Timber, Medicine	20-25	4-5 $m3 \cdot ha^{-1} \cdot yr^{-1}$
9	Leucaena leucocephala [Ipil-Ipil, Subabul]	AP, Kar, TN, HP, UP, MH, Gujarat, Punjab, Haryana, WB, Bihar	K8, K28, K 29, K 67. K636, seed/clonal orchard	Pulp, poles, fodder,	4-5	150-200 t/ha
10	Hardwickia binata [Indian Black	Deccan peninsula and Central India.	Seed orchard	Wood timber, bark -fibre	15-20	5-6 m3
	wood, Anjan]			Leaves fodder		
11	Melia dubia [Persian Lilac, White Cedar, Malabar neem, Ghora neem]	East Himalayas, N.Bengal, Khasi and Cachar hills, Tirunelvelli Konkan region, Nallamallai hills and W. Ghats,	Seed/clonal orchard	Fruit stones are used in making necklaces and rosaries. Wood is good for agric. implements,	8-12	10-15 m3
				furniture, plywood, boxes, poles, tool handles		

Sl.No.	Scientific, English & Common name	Distribution	Clones/ varieties	Uses & Remarks	Rotation age	Wood production (m3/ha)
12	*Eucalyptus tereticornis* [Mysore Hybrid, Mysore Gum, Safeda, Nilgiri]	Throughout India	FRI- 4, FRI 5-15, ITC - AP 3, AP147, AP 10, AP 5: TERI clones 348, 107, seed/clonal orchard	Rafters, beams, window and door frames, shutters, agric. implements, Pulp-, fuel-wood and charcoal, 3.85 to 18.94 m^3 ha/yr, > 4 million ha under cultivation in India	6-8	60-70 t
13	*Prosopis cineraria* Mesquite, Khejri]	Punjab, Gujarat, Haryana, West Rajastan, Central and South India	Tree BK-1 and BK- 2, seed/clonal orchard	Fodder, Firewood, Timber, Charcoal, Pods consumed by human beings, 1 - 2 m^3 ha/yr	25-30	2.0 m^3/ha 19.96 tones ha^{-1}
14	*Anthocephalus kadamba* [Miracle tree, Kadamb]	Sub Himalayan WB and Assam. MP, AP, Kar, Kerala, ArP	Selections, seed/ clonal orchard	Ceiling boards, packing cases, Veeners and plywood. Writing and printing paper. Fruits edible. Bark	6-7	70-100 t/ha

Sl.No.	Scientific, English & Common name	Distribution	Clones/ varieties	Uses & Remarks	Rotation age	Wood production (m3/ha)
				and leaves used in medicine, pencil making, 19 m^3 ha/yr		
15	*Casuarina equisitifolia* [Casuarina, Beefwood Sura, Chowku]	AP, Orissa, Tamil Nadu, West Bengal, MH, Gujarat, Orissa, & Karnataka	(MTP CA1 –*C. equisetifolia*; TNAU Casuarina MTP, seed/clonal orchard	Poles, pulp for paper making, Charcoal, 10–20 MT/ha/yr	4-5	100-150 t
16	*Jatropha curcas* [Physic nut, Ratan Jyot]	Most parts of the country	SDAUJ1 (Chatrapathi)	Seeds- oilBiodiesel	15-20	2-3 tonne/ha /yr seed yield
17	*Albizia species*	Throughout India	seed/clonal orchard	Poles, fuelwood, fodder	12-15	7-8
18	*Bambusa vulgaris* [Golden bamboo, Peela bans]	Throughout India	seed/clonal orchard	Paper and pulp, poles, post, rayon	4	100-150 t/ha
19	*Terminalia arjuna* [Arjun]	Peninsular India, Indo Gangetic plain, Bihar, Orissa, MP, Karnataka	seed/clonal orchard	Carts, boat building, Tussar silk, fire wood, charcoal making, medicine and tannins	20-25	10-12

Sl.No.	Scientific, English & Common name	Distribution	Clones/ varieties	Uses & Remarks	Rotation age	Wood production (m3/ha)
20	*Gmelina arborea* [Malay Beechwood, Gamhar] W. Himalyas, WB.	Tropical semievergreen, sub-montane, very moist & dry teak-forests,	Selections, seed/ clonal orchard	Food, Fodder, Fuel, Apiculture, Fibre, pulp, timber, plywood, matches and Medicine, silkworm culture.	8-15	15-21

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Timber Resources of Tropical Dry Evergreen Forest

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Timber has been a major natural resource in all civilizations across the world. The demand for timber has been traditionally met only from the forests. Large scale utilization of timber, especially after the industrialization, has reduced the natural timber stock acutely in several tropical and temperate countries.

India stands as an example for how unregulated large scale harvest of timber can reduce the natural stock greatly and can turn it from a timber exporting to a timber importing country. Currently India imports wood to the tune of about 2.7 billion dollars, mostly from tropical American countries and Pacific Islands. We are primarily dependent on a few selected major timber species such as teak, sal, rose wood and a few Gymnosperm species. However, we have a vast diversity of timber species, particularly in dry forests of India, which are paid far inadequate attention in developing as alternate sources of timber. This paper deals with selected species of timber importance from Tropical Dry Evergreen Forest (TDEF) that occurs along the East coast.

A survey of tree species indicates there are over 160 species that are highly adapted for dry climatic zones. Of this rich diversity of tree species at least 60 species can be listed as commercially important and locally useful timber resources. Some of the valuable timber species include *Cassine glauca* (Rottb.) Kuntze, *Callophyllum inophyllum* L., *Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr., *Terminalia arjuna* (DC.) Wight et Arn., *Terminalia paniculata* Roth., *Diospyros chloroxylon* Roxb., *Butea monosperma* (Lam.) Taubert, *Dalbergia lanceolaria* L.f., *Pterocarpus marsupium* Roxb., *Chloroxylon swietenia* DC., *Thespecia* *populnea* (L.) Sol. Ex Corr. Serr., *Azadirachta indica* A. Juss., *Walsura trifoliolata* (A.Juss.) Harms, *Albezia lebbeck* (L.) Benth., *Syzygium cumini* (L.) Skeels, *Mitragyna parvifolia* (Roxb.) Korth., *Morinda pubescens* J.E. Smith, *Psydrax dicoccos* Gaert.and *Manilkara hexandra* (Roxb.) Dubard.

At present we do not have the population status of these species and none of them have been entered in to the cultivation. Hence it is important to develop programs to study, propagate and genetically improve these tree species for fulfilling the future demands of timber in a sustainable manner.

Production and supply of important timber trees in Andaman and Nicobar Islands - A review

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Introduction

Forests are one of the most important natural resources essential for the well being of human being in the modern day civilization. India is endowed with rich forest resources spread across the country but has undergone tremendous changes in the past century. The annual productivity of India's forests is 3.175 m^3 ha^{-1} yr^{-1}, which is too low compared to other developed countries (8.20 m^3 ha^{-1} yr^{-1}) (FSI, 2011). Besides this, the human dependency on forests is enormous in India which has led to excessive use of forests resulting in degradation, which quite often becomes irreversible if not checked in time (Tewari, 1994). The human demand extends not only to various goods and services produced by forests but is intertwined with the forest ecosystem as a whole.

In India, the consumption by wood based industries takes place in many sectors *viz.,* housing construction, furniture, paper, sports and goods manufacture, pencil industry etc. The estimate of total annual consumption of wood was calculated at 48 million m^3 (FSI, 2011). Owing to the growing demand for wood and wood products which is very often reflected in a total mismatch between demand and supply, there has been a shift in the emphasis from utilization of the often complex natural forests to plantation species which are relatively easy to manage and capable of producing large quantities of wood per unit area (Wilan, 1973). The ever-widening gap in demand and supply could be narrowed down only by development of large-scale plantations. The National Forest Policy of 1988 guided the wood based industries to raise their own raw material without depending on forest department supplies. This is more pertinent to Andaman and Nicobar Islands particularly due to stringent government regulations and ban. Accordingly, almost all wood based industries in the country are in the process of establishing captive industrial wood plantations (Lal, 2000).

On the other hand, the increasing demand coupled with low productivity of plantations is one of the major concerns faced by wood based industries. The major reason for low productivity of plantations is non-availability of genetically improved planting stock and proper management practices. Improved planting material coupled with location specific silvicultural practices hold the possibility of improving the productivity of the plantations.

The annual rate of growth of plantations is around 1.7 m.ha. and with increasing thrust on tree planting, the targets are bound to increase every year for which 140 m.ha. of wasteland and about 35 m. ha. of degraded forests will have to be used. Among the indigenous species, the potential of Multi Purpose Tree species (MPTs) in enhancing the diversity, sustainability and productivity of marginal ecosystem has received increasing attention in recent years. This appears to a viable options but the success varies with the local socio-political and climatic conditions. In Andaman and Nicobar Islands timber was extracted by the imperial government followed by the local administration since independence. However, in recent times there are lots of restrictions on timber extraction and in some cases there is complete ban which affected the booming timber industry of the islands. Environmental concerns and well being of the tribals have forced the government to bring stringent laws and its enforcement. On the other hand the demand for timber is growing, and the supply system is at its rudimentary stage of development and not able to meet the demand. In spite of this, there are certain possibilities and the climate is favourable. Therefore, in this review we present the diversity of species used for timber extraction, its current status, and we aim to address the vital issue of bridging the gap between demand and supply of timber trees in Island condition through agroforestry systems.

Study area

The Andaman and Nicobar group of Islands comprises 572 Islands and Islets which stretch from Burma in North to Sumatra in the South between 6^0

and 14^0 N Latitudes and 92^0 and 14^0 N (E) longitude. As these islands are situated close to equator and exposed to the oceanic impacts having the tropical warm humid climate with the temperature ranging between 18°C to 35°C. These islands receive the heavy rainfall (>3000m) for 8 months starting May to October and the relative humidity is usually 65% to 85% depending on the prevailing weather conditions. About 81.36% of the total geographic area of Andaman & Nicobar Islands is under forest cover (FSI, 2013). Of the total forest cover, 42.1% is under very dense forest, 34.1% under moderately dense forest, 8.2% is open forest and mangrove constitutes 9.6%. Situated between two major biodiversity hot spots, namely the Indian sub continent and the Malaysia-Indonesia region (Balakrishnan and Ellis 1996), it is hardly surprising that the islands manifest biodiversity of extraordinary range with in a limited geographical area.

Vegetation diversity of Andaman and Nicobar islands

Parkinson (1923) provided the first detailed taxonomic account of the trees, shrubs and principal climbers of the Islands in the "Forest flora of the Andaman Islands". Champion & Seth (1963) broadly classified the vegetation of the union territory into (i) Beach forests, (ii) Mangrove forests, (iii) Wet evergreen forests, (iv) Semi-evergreen forests, (v) Moist deciduous forests and (vi) Grasslands. Some of the predominant components of these forests are *Baccaurea* spp., *Brueguirea* spp., *Calamus* spp., *Canarium* spp., *Ceriopsis* spp., *Clerodendron* spp., *Dipterocarpus* spp., *Leea* spp., *Mallotus* spp., *Mangifera* spp., *Rhizophora* spp. and *Thuarea involuta*. So far 2428 species belonging to 980 genera under 178 angiosperm families have been recorded from these islands and the dominant families of angiosperm in Andaman and Nicobar Islands having economic values are presented in Table 1. Besides, the lower plant kingdom including 8 Species of Gymnosperm, 142 species of Pteridophytes, 76 species of Byrophytes, 383 species of Lichens and 182 of Algae have also been recorded (Murugan and Kamble, 2012).

The degree of endemism is estimated to be 10 % of the total flora. About 315 species belonging to 187 genera under 74 families are reported to be endemic of which 229 species under 141 genera are from dicot and monocot consists of 72 species under 38 genera belonging to 12 families. This shows the rich diversity of vegetation of Andaman and Nicobar Islands. These have been used for extracting timber only in the last century yet majority of the forest remains very intact.

Table 1. Dominant families in flora of Andaman and Nicobar Islands

S.No	Family	No. of Species recorded	No.of Genera recorded
1	Poaceae	197	80
2	Leguminaceae	172	69
3	Orchidaceae	152	63
4	Rubiaceae	147	48
5	Euphorbiaceae	139	41
6	Cyperaceae	115	19
7	Moraceae	66	8
8	Annonaceae	60	20
9	Araceae	49	17
10	Meliaceae	36	11

Diversity of Endemic and Threatened plant species

There are several endemic species which are threatened which requires conservation (table 2). At the same time most of them produce highly priced woods which were exploited in the past. The review resulted in finding of only 3 genera, viz., *Nicobariodendron*, *Pseudodiplospora* and *Sphyranthera* and about 315 species belonging to 187 genera and 74 families are endemic to the union territory, constituting about 10% of the flora (Singh *et al.*, 2014). The flora of Andaman and Nicobar Islands also consists of considerable number of threatened taxa. About 112 threatened vascular plant species under 74 genera and 38 families have been recorded from the islands (Singh *et al.*, 2014). The islands also harbour a number of economically important plant species which are used by the tribals, locals and in some cases for commercial use. In addition the island also harbours about 300 non-indigenous or cultivated species which are believed to be introduced at various point of time by the European traders or settlers from mainland (Dagar & Singh, 1999; Lakshminarasimhan & Rao, 1996).

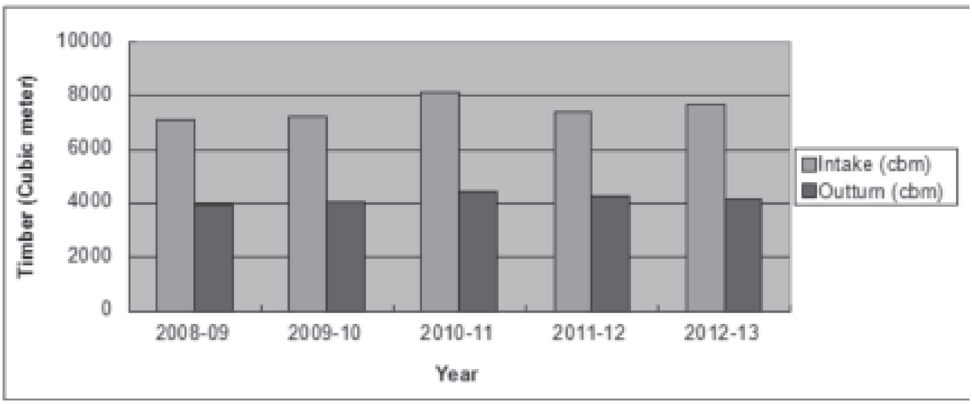
Table 2. Summary of endemic, threatened and economically important forest vegetation

Endemic	Threatened	Economically Important
Anoectochilus narasimhanii,	*Dendrobium tenuicaule,*	*Abrus precatorius,*
Ceropegia andamanica,	*Eulophia nicobarica,*	*Aristolochia tagala,*
Codiocarpus andamanicus,	*Ginalloa andamanica,*	*Barringtonia asiatica,*
Cyrtandromoea nicobarica,	*Malleola andamanica,*	*Barringtonia racemosa,*
Grewia indandamanica,	*Taeniophyllum*	*Bruguiera gymnorrhiza,*
Hippocratea grahamii,	*ndamanicum* and	*Colubrina asiatica,*
Leea grandifolia,	*Wendlandia andamanica*	*Cordia grandis,*
Mangifera nicobarica,	*Sphaeropteris albo-setacea*	*Duabanga grandiflora,*
Memecylon andamanicum,	and	*Flagellaria indica,*
Mesua manii,	*Sphaeropteris nicobarica*	*Garuga pinnata,*
Miliusa andamanica,	(Appendix II List of	*Horsfieldia glabra,*
Ophiorrhiza infundibularis,	CITES)	*Leea grandifolia,*
Pterocarpus dalbergioides,		*Manilkara littoralis,*
Salacia nicobarica,		*Morinda citrifolia,*
Sonerila andamanensis,		*Myristica andamanica,*
Sphaeropteris albo-setacea		*Orophea katschallica,*
and *Vernonia andamanica*		*Psychotria andamanica,*
		Scaevola taccada,
		Xanthophyllum
		andamanicum,
		Ximenia americana

Extraction of timber

A summary of important trees extracted for timber by the Department of Environment and Forest, Andaman and Nicobar Administration is given in table 3. This include ornamental wood, superior hardwood, standard hardwood, soft wood and non-commercial timber extracted from different species found in these islands. In contrast to the mainland, in these islands the timber supply is done only by Forest Department through saw mill. In the year 2012-13 the intake of timber was 7677 m^3 and out turn was 4168 m^3 (FSI, 2013). According to rules determined by the Ministry of Environment and Forests (MoEF) and implemented by the Island Development Authority (IDA), which falls under the Union home ministry, not more than 1 lakh cubic metres (cum) of timber can be extracted annually from the islands. There has been a huge demand of 16,000 m³ of sawn timber every years but the department could only meet a portion of the demand due to ban on the felling activities (Fig. 1). Due to various policy and regulation measures the intake and outturn of timber over the years are stable and the supply could not meet the ever increasing demand for quality timber. This resulted in shipment of timber from mainland to meet the demand, which also insufficient requires some strategic measures to meet the demand.

Fig. 1. Year wise intake and outturn of timber (m³) at Government sawmills



Source: FSI, 2013

Constraints for timber production from Trees in the Island

There are several constrains for the timber production though the climatic condition is very condusive. They are listed below:

- In these islands forest covers nearly 86% of the total geographical area and the revenue land is limited. Therefore, only very limited scope for the extend of forest area for commercial exploitation of timber. Further, it is not possible to exploit timber from the reserve forest area nor the forest area can be denotified for commercial exploitation.
- Silvicultural aspects covering seedling to timber production of many of the useful endemic trees have not been studied which are very essential for its commercial cultivation outside the forest area.

Table 3. Important economic species used in Andaman and Nicobar Islands

Ornamental Wood	Superior Hardwood	Standard Hardwood	Soft Wood	Non Commercial Timber
Diospyros marmorata, Murraya exotica, Pterocarpus dalbergioides, Sagaeria elliptica, Tectona grandis, Terminalia bialata and *Podocarpus nerifolia*	*Albizzia lebbek, Lagerstroemia hypoleuca, Prunus martabanica, Terminalia manii, Artocarpus chaplasha* and *Dipterocarpus sps.*	*Artocarpus lakucha, Adenanthera pavonina, Amoora wallichii, Chakrasia tabularis, Calophyllum inophyllum, Duabanga sonneratiodes, Hopea odorata, Lannea grandis, Madhuca butyracea, Mesua ferrea, Mangifera andamanica, Mimusops littoralis, Nauclea gageana, Pajanelia longifolia, Planchonia andamanica, Parishia insignis, Terminalia procera, Terminalia bialata, Miliusa tectona,Crataxylon formosum* and *Ganophyllum falcatum*	*Anthocephalus chinensis, Albizia stipulate, Ailanthus kurzii, Canarium euphyllum, Endorspermum chinense, Evodia glabra, Pterocymbium tinctorium, Salmalia insignis, Sideroxylon longipetiolatum, Sterculia alata, Tetrameles nudiflora* and *Zanthoxylum budrunga*	*Dillenia species, Enterolobium saman, Ficus species, Myristica species, Pometia pinnata, Xanthophyllum andamanicum, Spondias mangifera, Bracantomalum mangifera, Syzigium species, Antiaris toxicaria,Ganophyllum falcatum, Baccaurea sapida, Pongamia pinnata, Sterculia villosa* and *Aglaia andamanica.*

Source: FSI, 2013

- The rainforest soils are not suitable for long-term agricultural practices. Rainforests have a poor soil formation and store very few nutrients at a given time due to intense leaching by the rainwater. Once exposed, rainforest soils soon dry up and nutrients are liable to be washed away by the force of the rain. The land then becomes barren without forest cover in the rain forest region (Rao, 1999).
- The large influx of human population and other developmental works in the islands has led to the disturbance of several natural processes occurring in the forest areas which hinders the propagation of some of the commercially viable tree species.
- Coastal areas are mostly saline and waterlogged due to periodical inundation with tidal water. In case of lowlands having proximity to the sea, due to the high water table with high concentration of salts in it. Such a condition is unsuitable or hinders the establishment of commercially viable timber species in these islands.
- Non availability of seedlings of endemic, threatened and commercially important tree species did not favour its production in the revenue land. Further, the seedling production technology and seed materials are not available for its large scale production and use.

Agroforestry systems for timber production in the island

As a result of significant increases in demand for wood, wood market in the island and throughout the globe is undergoing rapid changes, putting considerable and increasing pressure on the natural forests. Without significant investment in promoting management of sustainable forest and plantations and innovative method of producing timber from identified suitable species, it must be expected that, increasing demand for wood will lead to further degradation and fragmentation of forests. In this context, agroforestry systems integrating woody perennials (including forest and fruit trees, bamboos, palms, and plantations) with agricultural crops, fishery, and livestock have a significant role to play in improving the agricultural and environmental scenario of the coastal and island regions through enhanced availability of food, fodder, timber, and fuel wood and also through effective conservation and amelioration of the natural resource bases. Some of the agro-forestry methods with suitable timber yielding species are given in table 4.

Plantation-based multi-storeyed farming systems, home gardens, alley cropping, cultivation of fodders under coconut plantations (plantation-based silvo-pastoral systems), aqua-culture in association with mangroves, and multi-enterprise farming systems are some unique agroforestry systems of coastal and island regions which can yield timber.

Inundation of coastal areas and denudation of mangroves leads to saline marshes and consequently formation of acid sulfate soils. Under this scenario, plantation-based agroforestry is most important part of coastal and island agriculture. Range of agroforestry systems for these areas have been studied and identified (Nair and Sreedharan 1986; Dagar 1991; Pandey et al. 2007). Some of these such as home gardens, plantation-based cropping systems, live fences and hedges, shelterbelts and shore protection, grazing under plantations (silvopastoral systems) and aqua-silviculture are already being practiced at large while others such as alley cropping, and fish/shrimp culture with mangroves, can be adopted by farmers after they receive suitable trainings. Some site specific practices such as rehabilitation of saline areas are used by different stake holders in these islands.

In a multistorey cropping model involving tree species, the tall forest trees, including commercial timber trees (e.g., *Dipterocarpus* spp. *Pterocarpus dalbergioides, Terminalia* spp., *Bombax insigne, Legerstroemia hypoleuca, Artocarpus chaplasha, Albizia lebbeck, Canarium euphyllum*, and others) can be maintained as canopy crops, vines and spices as middle storey crops, and pineapple or fodder tree crops as a ground storey crops (Jaisankar *et al.*, 2014 ; Jaisankar *et al.*, 2016).

During last one decade, Noni (*Morinda citrifolia*) has been widely collected and cultivated as sole tree and in combination with several plantations such as coconut, cashew nut, and fruit trees in Andamans (Singh et al. 2009). Similarly varieties/ecotypes of nutmeg (*Myristica fragrans*), Rudraksha (*Elaeocarpus sphaericus*), betel vine (Piper betle), banana, mango, and many others are found distributed wild in natural forests can be collected and grown for improving their germplasm.

Table 4. Production of timber from suitable species in different agro-forestry system

Sl. No.	Agroforestry system	Recommended tree species	Approximate wood yield ha^{-1} (m^3)	Remarks
1.	Home gardens	*Pterocarpus dalbergiodes*, *Lagerstoemia hypoleuca*, *Terminalia bialata, Dipterocapus grandiflora, D. alatus*, *D. gracilis, Artocarpus chaplasha, Hopea odorata*, *Amoora wallichii, Calophyllum* sp.	70 - 80	Wider spacing Pandey et al, (2006)
2.	Plantation-based multiple cropping Systems (Other than home garden)	*Mussaenda macrophylla, Ficus hispida, Trema tomentosa, Bauhinia variegate*, *Sapium baccatum, Crypteronia paniculata*	40 - 45	Wider spacing Jaisankar et al., (2015)
3.	Silvo-pastoral systems	*Ficus hispida,Trema tomentosa, Bauhinia variegate, Sapium baccatum, Techtona grandis, Pterocymbium tinctorium, Aegle marmelos, Artocarpus spp., Erythrina variegata, Grewia glabra, Hibiscus tiliaceous, Moringa oleifera, Pongamia pinnata, Samanaea saman, Sesbania grandiflora*	25 - 30	Close spacing Pandey et al, (2006) Jaisankar et al., (2014)
4.	Integrated farming system	*Morinda citrifolia, Bauhinia variegate, Sapium baccatum, Techtona grandis, Pterocymbium tinctorium, Aegle marmelos,*	45- 53	Wider spacing Jaisankar et al., (2015)

Sl. No.	Agroforestry system	Recommended tree species	Approximate wood yield ha^{-1} (m^3)	Remarks
		Artocarpus spp., Erythrina variegata, Grewia glabra, Hibiscus tiliaceous,		
5.	Alley cropping system	*Cassia siamea, Morus alba, Artocarpus chaplasha, Hopea odorata*, *D. alatus* Roxb., *Amoora wallichii, Glyricidia sepium*	40 - 50	Close spacing Dagar and Kumar, (1992)
6.	Aqua-silviculture systems	*Anthocephalus chinensis, Albizia stipulate, Ailanthus kurzii, Evodia glabra, Tetrameles nudiflora*	15- 20	Wider spacing Dagar and Kumar, (1992)
7.	Brackish water aquaculture	*Rhizophora, Ceriops, Aegialitis, Bruguiera, Kandelia, Aegiceras, Cynomitra, Morinda citrifolia*	45 – 50	Wider spacing Dagar and Singh (2007)
8.	Block plantation in waterlogged salinesoils	*Pandanus spp., Thespesia populnea,Scaevalia taccada, Tournefortia ovata, Hibiscus tiliaceus, Pongamia pinnata, Terminalia catappa, Calophyllum innophyllum*	15 – 20	Close spacing Dagar and Kumar, (1992)
9.	Boundary Planting (bio fence)	*Casuarina equsetifolia, Trema tomentosa, Albizia stipulate, Pterocymbium tinctorium, Syzigium species*	15 - 25	Close spacing Jaisankar et al., (2015)
10.	Bio shield	*Pongamia pinnata, Sterculia spp. Thespesia populnoides, Manilkara littoralis,*	60-70	Close spacing Jaisankar et

Sl. No.	Agroforestry system	Recommended tree species	Approximate wood yield ha^{-1} (m^3)	Remarks
		Vitex negundo, Cassia ostula, Pandanus spp. Terminalia catappa, Clerodendron serratum, Gyrocarpus americanus, Guettarda speciosa, Hibiscus tiliaceus, Bombax insigne		al., (2015)

*1- 3 m for closer spacing; 3 - 7 m for wider spacing, however the spacing will slightly vary based on the land form and soil type.

Strategies for enhancing timber production in the island

- If demand for wood cannot be met through sustainable supplies, forest degradation and deforestation will continue or even accelerate. The consequential events will be a major concern for the forest and resource managers and policy makers. Therefore, to successfully change this situation, wood demand must be met through sustainable wood production from plantation management, agroforestry and other innovative methods. To facilitate such a process, the production system must increasingly adopt mechanisms that not only ensure sustainable timber production and conservation, but also provide satisfactory livelihood opportunities for forest- dependent communities, and promote sustainable economic development. Consequently the sustainable production of wood to meet increasing demand will continue to play a predominant role in national and island specific developmental plan involving sustainable development.
- It is urgently required to document the timber yielding endemic species, their distribution and conservation status in the islands. Following this, silvicultural practices should be developed for their judicious utilization for timer extraction.
- The existing revenue and other waste land should be used for such identified endemic species with timber value following suitable agroforestry models.

In this process the locals and tribal and even owners of private land can be integrated to share the benefits which bring together all the stakeholder together.

- There should be a policy and financial support as that of agricultural development for the forest plantation or silvicultural system establishment and management. This will lead to quick establishment of timber yielding trees in the islands for future use. This will also encourage formers to take up the silvicultural system as one of the primary activities.
- Revisit the total ban on the timber extraction for the forests of Andaman and Nicobar islands and replace it with judicious or limited use with strict supervision and conservation plan. This not only reduces the demand and supply gap but also provides the locals with livelihood options and ease out the pressure on the reserved forest and other tree species grown outside.

Conclusion

There is significant gap in the supply and demand for timber in the island which keep widening. The increasing demand and high price of wood for fuel, timber and pulp unlike the agricultural crops will be the foremost reason for farmers to plant more trees in association with agricultural crops. Production and supply of commercially important timber trees in Island ecosystem can be done through incorporation of more fast growing timber species in the existing agroforestry system or the tree seedlings can be planted in the salt affected land and existing plantations prevailed in the Islands. As the demand is more for domestic as well as export of timber the suitable strategy would be site specific and location specific agroforestry system development. It is also very important that the extent of the genetic diversity within and between populations of the commercial timber species in the plantations, and much less, in the natural forests, remains largely unknown needs to be documented for its judicious use.

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An overview of trees outside forests in Kerala with focus on the timber sector

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Introduction

Trees are among the most versatile renewable assets due to their contribution to the social and economic well-being of the society and to environmental and ecological stability. Tree based food sources such as fruits, leaves, spices, medicinal products offer livelihood and nutritional security especially to the small and marginal farmers of the state. Timber from wood is an excellent source of revenue. Diverse kinds of non timber tree products such as gums, resins, latex, fibers, essential oils, biofuels, fodder and medicinal products provide excellent economic leverage to tree farming. Quite often their ecological role outweighs the direct economic benefits. This is particularly true when the larger role of trees in the mitigation and adaptation of climate change is considered. In the wake of India becoming a signatory to the Paris Agrement-2015 of the UNFCCC it becomes binding for the country to formulate strategies for CO_2 emission reduction through viable means. In this context, bringing more area under trees cover assumes greater importance as a cheap, but effective strategy to combat global climate change. Furthermore, renewed awareness on the ecological and economic benefits from trees and their potential role in the provision of quality water and soil productivity calls for their large scale expansion.

There exists little scope for expansion of tree cover in the recorded forests areas owing to severe space limitations and the demographic pressure on the available forests. In this context, Trees outside the Forests (TOF) form an excellent option for the expansion of tree cover in the country. Trees outside the forests are defined as all trees excluded from the definition of recorded forest and other wooded lands. TOF primarily include trees in cities, on farms, along roads and in many other locations which are by definition not part of recorded forest area. Growing populations, shrinking forests and degraded ecosystems all suggests that trees outside the forests are destined to play a larger local and global role in meeting the challenges of resource sustainability, poverty eradication and food security. More importantly, trees outside forests reduce the pressure on ecologically important natural forest by meeting tree based services of the society.

The Kerala scenario

By virtue of its congenial agroclimatic conditions, Kerala is endowed with rich tree wealth. High rainfall, humidity, and concomitant edaphic conditions confer the state with rich natural biodiversity and high diversity of trees. The profound association of state's populace with trees from time immemorial is unique and needless to say, trees play a significant part in their day to day life. Consequentially, compared to majority of other states, the status of TOF in Kerala is as good as any other in the country. The recent FSI reports (2015) suggests that 11,073 sq. km area is under TOF in Kerala which is about 28.49 % of the state's geographical area (Table 1). Interestingly this figure is more than the tree cover under the recorded forest area in the state (8,166 sq. km; 21%). However there exists good scope for further expansion of tree cover in this sector. This can only be achieved by promoting the potential of tree cultivation as a profitable land use option. However, this assumes a challenging proposition considering the high real estate value of the land and the diverse land use options available, including non-agricultural practices such as expansion of built up area, conversion of land for developmental activities etc.

Hence the promotion of tree stocking in the state calls for a paradigm shift in the present land use practices for making this sector more economically attractive than other land use options. Planting of valuable timber trees, promotion of commercial farm forestry for meeting the domestic and industrial requirements, self sufficiency in tree based food, fruits, fodder, fuel etc are some of the potential strategies for making leads in this sector.

Table 1. Forest cover outside the recorded forest area (TOF)

Forest cover type	Area (km^2)
Very dense forest	249
Moderately dense forest	4,744
Open forest	6,080
Total forest cover	11,073
Percentage to total area	(28.49%)
Tree cover	2,950
Forest cover + tree cover	14,023

Source: FSI State of the Forests reports 2015

TOF sector in the state of Kerala cover broad areas of agricultural plantation crops, homegardens, agricultural fields, forest plantations/wood lots, farm forestry, sacred groves and urban green spaces. In the public sector, trees in public parks, avenue plantations, coastal plantations, social forestry wood lots, community wood lots, wind breaks and shelter belts assumes importance. Major portion of the TOF area in the state is occupied by coconut and rubber plantations. Other prominent tree growing sectors are arecanut, jack, coffee, mango, tea, nutmeg and teak (Table 2). Despite the vast diversity of tree species of forestry importance, plantations involving forest trees species are very much limited in the TOF sector in the State.

Table 2. Area under tree crops in the state of Kerala-2014-15

Sl No	Tree crops	Area under tree cover (ha)
1.	Coconut	7,93,856
2.	Rubber	5,49,955
3.	Arecanut	96,686
4.	Jack	92,203
5.	Coffee	85,359
6.	Mango	77,301
7.	Tea	30,205
8.	Teak	23,461
9.	Nutmeg	20,627

Source: Department of economics and statistics, Kerala, 2015

Timber sector

The favorable edaphic and climatic conditions, makes Kerala the home to diverse trees including an array of timber tree species. Table 3 shows the tree species available for various commercial end uses. Prominent traditional structural timber trees for industrial and furniture use include Tectona grandis (teak), *Dalbergia latifolia* (rosewood), *Sweitenia macrophylla* (mahogany), *Artocarpus heterophyllus (Jack) Artocarpus hirsutus* (wild jack), *Xylia xylocarpa*, *Lagerstroemia lanceolata*, *Albizia lebbeck, Albizia odoratissima, Terminalia tomentosa, Gmelina arborea, Pterocarpus marsupium, Bridelia retusa, Grewia taelifolia etc.* However, most of these species barring teak mahogany, jack and rubber are not cultivated on commercial basis in Kerala. Treated rubber wood has attracted considerable attention in the recent decades as a timber species substituting most of the above tree species.

Fast growing trees such as *Ailanthus triphysa, Gmelina arborea, mahogany,* eucalypts, casuarinas, acacias etc. show wonderful growth performance in the humid conditions of Kerala. These are mainly preferred for packing case, matchwood, plywood and pulpwood industries. However, the non availability of these species in large quantity poses serious limitation in catering the needs of the above industries. Probably, the availability of rubber in large quantities permit the sustenance of these industries. For instance, the rubber based sawmills in Kerala supply sawn rubber wood for wooden packing case industries located in Tamil Nadu and Andhra Pradesh. In the recent instance of the significant slump in the prize of natural rubber there is renewed interest among the farmers to replace it with structural timber species such as mahogany and teak.

Rubber constitutes the major share of timber tree species in Kerala sprawling over an area of 5,49,955 ha (Table 4). Among the districts Kottayam represents the largest tract of rubber cultivation (1,14,340 ha) followed by Ernakulam and Pathanamthitta. Yet another tree species of fast increase in area is jack with an estimated extent of 92,203 ha across the state. Estimated volume of standing stock of jack in the country is 38, 885 m. m^3 while the corresponding value for wild jack (*Artocarpus hirsutus*) was 10,527 m. m^3 (FSI, 2015). Idukki and Kozhikode are the two flourishing districts in jack cultivation. Teak though the most demanding and costly timber species, its distribution in the TOF sector is relatively limited to around 23,461 ha. On account of the large area under rubber, the supply of rubber from the existing plantations will be on the increase for the coming years. The good structural properties and the appeal of well treated rubber wood made it a lucrative timber species and has substituted traditional timber species such as teak and jack. Recent interest on cultivating fast growing Acacias has lead to their steady expansion in Kerala. For example, the area under *Acacia mangium* has increased for 3,583 ha during 2010 to 4,255 ha in 2014 (Gupta, 2016). This species has been extensively studied for wood properties, provenance evaluation, intercropping potential and its vast potential as a structural timber species in Kerala condition has been tested (Kunhamu, et al., 2009; 2010; Anoop et al, 2012).

Table 3. Trees used for various wood-based sectors in Kerala

Sector	Species being used	Sources
Construction timbers	*Artocarpus heterophyllus* (jack), *A. hirsutus* (wild jack), *Tectona grandis* (teak), *Sweitenia macrophylla* (mahogany), Eucalyptus spp, *Acacia auriculiformis, Acacia mangium*	Home gardens and forests
	pyinkado (*Xylia dolabriformis*), padauk (*Pterocarpus indicus*), keruing (*Dipterocarpus* spp.), kusia (*Nauclea diderrichii*), purpleheart or violet wood (*Peltogyne* spp.), mora (*Mora excelsa*), beech wood (*Fagus sylvatica*), taukkyan wood (*Terminalia alata*), Kwila or merbau (*Instia bijuga*), green heart (*Ocotea rodiei*)	Import from abroad

Sector	Species being used	Sources
Furniture	Teak, rosewood, mahogany, *Xylia xylocarpa, Lagerstroemia lanceolata, Albizia lebbeck, Albizia odoratissima, Terminalia tomentosa, Terminalia paniculata, Gmelina arborea, Pterocarpus marsupium, Bridelia retusa*. purpleheart, rubberwood, acacia sp.	Forests, home gardens, estates, imports from other States and abroad.
Packing case	Rubberwood, *Macaranga peltata*, *Mangifera indica*, Eucalyptus spp. *Grevillea robusta* (silver oak), *Albizia* spp, *Alstonia scholaris*, *Olea dioica* (edana), cashew wood, cocoa wood, *A. heterophyllus*, *A. hirsutus*, Erythrina indica, Bombax ceiba, Michaelia chempaka	Estates, home gardens, import from other States.
Matchwood	*Ailanthus triphysa (matty)*, *Macaranga peltata (vatta), Alstonia scholaris (pala), Bombax ceiba (*elavu) *and albizia app.*	Home gardens, forests
Plywood	Rubberwood, *Macaranga peltata (vatta)*, *eucalypts,* silveroak, *Terminalia chebula* (*kadukka)*, *Vateria indica* (white dammar), *kalpine*, *Sweitenia macrophylla* (mahogany), *plavu*, *anjily*, imported sp.	Estates, home gardens, imports from other States and abroad.
Pulpwood	Eucalypts, acacia, bamboos sp.	Forests, import from neighbouring States.

Table 4. District wise area under major timber species in TOF sector, Kerala during 2014-15

Sl No	District	Jack(ha)	Teak(ha)	Rubber(ha)
1	Idukki	14727	1263	40520
2	Kozhikode	10351	503	21880
3	Malappuram	9175	2758	42670
4	Waynad	8727	317	10790
5	Kannur	8300	2389	47970
6	Thiruvananthapuram	7052	642	32000
7	Palakkad	6753	5173	37800
8	Kollam	6663	1354	37170
9	Thrisuur	4748	1246	15630
10	Ernakulam	4235	1514	60020
11	Kottayam	3791	2716	114340
12	Pathanamthitta	2813	2162	50810
13	Kasargod	2553	575	33860
14	Alappuzha	2315	849	4495
	Total	**92,203**	**23,461**	**5,49,955**

Source: Department of economics and statistics, Kerala, 2015

Wood demand-supply scenario in Kerala

Timber trees constitute the predominant component of TOF. This sector is the major source of timber supply in the domestic market of timber trade in Kerala. Analysis of wood demand during 1987 to 2011 suggest that total demand progressively increased over time from 1,769, 000 to 2,228, 000 m^3 of round wood (Table 5). The wood demand in the state of Kerala was 22,28,000 m^3 roundwood during 2010-11 (Krishnankutty and Chundamannil, 2012). This includes 24% from the households sector and 45% from industries sector while the remaining 31% from wooden packing cases and other timbers to the neighbouring States. Industrial sector was dominating in wood demand during this period with a moderate increase from 41% (1987-88) to 45% (2010-11) of their respective total demand. This was followed by the export sector (mostly to other states) which showed good growth from 20% of total demand during 1987-88 to 30% demand during 2010-11. These increases are in expected lines consistent with the population growth. However, the demand from the house hold sector was rather stagnant or slightly declined during this period. A plausible reason could be the shift in the preferences and the use of alternative make shift materials in place of wood.

Table 5. Trends in demand for timber in Kerala during 1987 to 2011

Timber-using sectors	Volume ('000 m3 roundwood)		
	1987-88	**2000-01**	**2010-11**
Households sector	543(30.70)	541(27.27)	539(24.19)
Industries sector	742(41.94)	865(43.60)	1,003(45.02)
Institutions sector	121(6.84)	10(0.50)	2(0.09)
Export: To other States* in India	361(20.41)	565(28.48)	683(30.66)
To other countries	2(0.11)	3(0.15)	1(0.04)
Total demand for timber	**1,769**	**1,984**	**2,228**

Values in the parenthesis are the percentage of total demand during respective periods. Excluding coconut wood & poles.*predominantly rubber wood packing cases, including teakwood of 14,000 m^3 in 1987-88 and 8,000 m^3 in 2000-01. (Krishnankutty and Chundamannil, 2012)

As regards the supply wood there has been considerable shift in the contribution from various sectors with time (Table 6). For instance, a steady increase in wood supply has been observed from the rubber sector from 1988 to 2011. Supply from the traditional homestead was the predominant mode till the period of 2000-01 which was surpassed by rubber thereafter. Supply trends showed that major share was from rubber (46.6%) followed by homegardens (35.3%) and imports (16.5%) while forests recorded a dismal proportion of 1.6% during 2010-11. Recent picture may not been too far from this trend but obviously more production from the rubber sector. Import trends in the past decade shows not much increase (15.2% during 2000-01). The present import policy has brought some regulations on the international wood import largely putting restrictions on the import on round wood and limiting to sized wood.

Table 6. Sources of supply of timber and industrial wood in Kerala from 1987-2011

Sources of supply of timber and industrial wood	Volume (‘000 m^3 round)		
	1987-88	2000-01	2010-11
Home gardens	830	790	788
Rubber estates	599	817	1,038
Forests	156	75	35
Import: From other States in the country	78	143	151[#]
From other countries	106	159	216
Total supply of timber and industrial wood	1,769	1,984	2,228

Source: Krishnankutty and Chundamannil, 2012

Import scenario

The recent years has seen dramatic increase in the import of wood to Kerala. Interestingly, despite the land of celebrated teak belt of the country, Kerala has seen the highest import of teak during the past two years. Imported teak coming to Kerala is large dimension logs from the natural forests in Myanmar (Krishnankutty et al., 2010). Reports suggest, import of wood from other States was around 1,53,000 m^3 of which rubber wood alone constituted 83,000 m^3 (Krishnankutty and Chundamannil, 2012). The actual import of timber from abroad was 2,16,000 m^3 during 2010-11. Probably the demand for large sized lumber led to these heavy imports. Import of timber into Kerala has been growing and the trend is expected to continue in the future.

Close analysis of the wood import sector in Kerala shows that there was tremendous increase in the imports from foreign countries during the recent years. The total import increased from 2,84,000 m^3 in 2010-11 to 420,000 m^3 in 2011-12 (Table 7; Krishnankutty and Chundamannil, 2012). However, the interstate imports were fairly less compared to international import. For instance, the actual import from foreign countries increased from 2,16,000 m^3 in 2010-11 to 2,67,000 m^3 in 2011-12, which records a massive growth of about

24% within one year (Krishnankutty and Chundamannil, 2012). It can be seen that out of the total teak wood import, almost 96% is from other countries. Being the land of teak, this large scale import of teak is primarily attributed to the lack of large sized timber in the wood market. Traditional homegardens were the major source of teak in the state. However, large sized teak trees from this sector have declined drastically due to over exploitation of immature or small sized trees.

Table 7. Timber import to Kerala during 2011-12

Origin of import	Volume ('000 m3 roundwood)					
	Teak	Rose wood	Eucalypt	Silver oak	Others	Total
From other States	1	1	3	2	146	153
From abroad	28	0	0	0	239	267
Total import	29	1	3	2	385	420

Source: Krishnankutty and Chundamannil, 2012

Yet another observation is that wood other than teak, rosewood, eucalyptus and silver oak, accounted bulk of the export, implying that exotic timber species dominating the wood import scenario in Kerala. Some of them include pyinkado (*Xylia dolabriformis*), padauk (*Pterocarpus indicus*), keruing (*Dipterocarpus* spp.), kusia (*Nauclea diderrichii*), purpleheart or violet wood (*Peltogyne* spp.), mora (*Mora excelsa*), beech wood (*Fagus sylvatica*), taukkyan wood (*Terminalia crenulata*), Kwila or merbau (*Instia bijuga*), green heart (*Ocotia rodiae*) and several other locally less known timbers from all over the world. The major players in the wood import to Kerala are Myanmar, Malaysia, Brazil and African countries.

The export scenario is primarily limited to interstate export in India while the international export is rather nil. For example, out of the total export of 692, 000 m^3 during 2011-12 almost 691, 000 m^3 was to other neighboring states. Packing case export dominated the interstate export which accounted almost 95% of the export while the contribution from teak, rosewood and other wood were 0.57, 0.29 and 3.61 % respectively. Despite the large scale production potential of teak, the export of teak is very much limited. Among the tree species, rubberwood probably constitute the predominant export species and its contribution over the years is expected to increase. The other exported timbers comprise mostly of low value species such as *Macaranga peltata*, mango, cashew, etc, accompanying rubberwood as packing cases.

Changing trends in wood demand

As such the wood availability in Kerala is surplus with heavy stocking of structural and timber species in the local market. This is attributed to the availability of large quantity of rubberwood and large volume of imported timber in the local market. The present import regulations favour this heavy import of large structural timbers to Kerala. However, there could be control on the wood export from the present source countries in the long run which may inversely affect the wood demand-supply scenario in the state. Furthermore, responsible sourcing from certified forest may become mandatory while importing to India which may put restrictions on the import form many countries. Hence, there should be long term planning to start new wood sources or strengthening the production potential of the available sources. Lack of wood based industries is the major limitation in the progress of timber sector in the state. As such no established markets are available for most of the wood based industries in Kerala. The possibility of developing small scale value addition units and wood processing units has to be attempted.

Trees in the homegardens

The major share of TOF is confined to the traditional homegardens of Kerala. These unique-self reliant systems were rich in diverse tree species along with large number of non woody components. These unique land use systems were formed as result of generation of crop intensification. Trees constituted the dominant component of the homegardens with high functional diversity. Timber trees, fruit trees, fodder trees, medicinal trees, fuelwood trees were common in almost all the homegardens. About 127 taxa of woody species have been reported from the homegardens of Kerala (Kumar and Nair, 2004). Of late, the status of timber stock in the homegardens has substantially reduced. For instance, the average standing stock of timber in the Kerala homegardens two decades back ranged from 6.6 to 50.8 m^3 ha^{-1} and fuel wood volume was 23 to 86 m^3 ha^{-1} (Kumar et al., 1994). Despite this, major share of the local wood demand of the state is primarily met from homegardens. For instance about 35% of the state wood demand in the state is from the homegardens (Krishnankutty and Chundamannil, 2012). These systems are unique in that there is no complete removal of biomass from the homegardens, signifying their relative permanence. However the tree wealth in the traditional homegardens is on the decline at alarming rates. More importantly, large sized timber trees are conspicuously missing in the homegardens of Kerala. There is serious depletion in the species diversity, structural and functional attributes of this land use system. Undesirable socio-economic changes, commercialization and urbanization, demographic motivated land fragmentation, are some of the potential drivers of this shift. Concerted efforts are required for the revival of these unique systems to regain its lost tree legacy. There should be some restrictions on the felling of immature trees from the homegardens that may assure availability of large sized timber in future.

Prioritization of tree species

There has been considerable shift in the priority of tree species in the TOF sector. Studies at Kerala Agricultural University have shown that the species preferences are in the order rubber, Jack, teak, anjili, mahogany, nutmeg and matti. Suitability of fast growing tree species such as *Gmelina arborea* (wood carving), *Melia dubia* (pulpwood), *Ailanthus triphysa* and *Melicope lunu-ankenda* (matchwood), *Macaranga peltata* and cashew (hard boards) should be explored for various agro-ecological regions of Kerala. Bamboos are yet another area of importance in Kerala. Apart from the widely distributed *Bamboosa bamboo*, there are many bamboo species of economic importance suitable for Kerala such as *Dendrocalamus stocksii*, *Dendrocalamus asper*, *Bamboosa gigantea* etc. There is dire need to prioritize minimum ten tree species so as to draw focus for their promotion in the TOF sector of Kerala.

Potential pitfalls in the promotion of tree farming in Kerala

The undesirable transformations in the land use in the state have their consequences on the tree cultivation as well. Unlike the neighboring state of Tamilnadu, organized tree cultivation practices are nonexistent in Kerala. Farmers attitude towards tree planting are often not driven by profit motives.

Major deterrent in the promotion of tree cultivation in the state is the lack awareness on the economic and ecological advantages of tree cultivation. Despite the vast production potential, Kerala's dependence on imported wood is on the increase. Yet another snag in the promotion of large scale tree farming is the poor growth of wood based industries in the State. Organized tree farming ventures are lacking in the state to cater the industrial needs. Public deterrence in tree cultivation due to age-old legal and policy restrictions. The major constraints in the promotion of TOF in the state are summarized below.

1. Rapid urbanization and commercialization/gulf remittance
2. Land fragmentation
3. Alternate opportunity cost of the land
4. High cost of labour and labour shortage
5. Lack of awareness on ecological and economic potential of tree farming and agroforestry
6. Poor linkages between farmers and wood based industries
7. Forest policies and public deterrence from tree farming
8. Long gestation period of trees
9. Scattered trees- supply and market issues
10. Lack of expertise on selection of tree species and tree husbandry
11. Lack of institutional mechanism for the promotion of tree farming.

The way forward

Concerted efforts are required for the expansion of tree cover in the TOF sector in the state. The Social Forestry initiative despite its genuine motives of achieving self reliance in the wood and wood products there by alleviating pressure on the existing forests could not make adequate progress. Other initiatives such as "My tree programme", Hariali project, IWMP have made some impacts in the TOF sector. However, there is genuine lack of continuity in the management of the planted trees in the state. Need of the time is to identify potential area of tree planting, prioritization of tree species, planting design, management of planted trees etc. Some of the priority considerations for the promotion of TOF sector in the State are listed below:

1. **Development of policy frameworks and operation guidelines for implementing National Agroforestry Policy, 2014 with particular reference to TOF in Kerala**: The National Agroforestry Policy, 2014 emphasize upon increasing the forest / tree cover outside the natural forests for meeting the ever increasing demand of timber, food, fuel, fodder, fertilizer, fibre, and other agroforestry products thereby assuring income and livelihoods opportunities for rural households and thereby leading to conserving the natural resources and forest, protecting the environment & providing environmental security. Operational modalities for achieving these goals need to be framed for the state.
2. **Institutional mechanism for the development of TOF in the State**: As such the TOF sector in the state is under-managed or poorly managed. Neither the Forest Department nor the Agricultural Department in the state owns the responsibility of establishing and managing the growth and development of trees outside the forests. Hence there should be a separate Farm Forestry Department for the promotion of TOF.
3. **Establishment of tree grower's consortium for establishing proper linkage with wood based industries**. There is scope for promoting tree cultivation for catering the row material needs of tree based industries. Interestingly the wood raw materials for large number of paper, pulp, matchwood industries in the neighboring Tamilnadu are collected from Kerala. However this sector is highly disorganized in the state. Such organized tree promotion ventures need to be strengthened in the state especially in barren and cultivable wastelands in Districts such as Kasargode and Kannur.
4. **Simplifying timber felling/transit rules**: The existing forest laws on tree planting and harvest continue to keep people away from tree planting. The present felling and transit rules need to be subjected to modifications for the promotion of TOF. There should be separate farmer friendly legal provisions for TOF.

5. **Development of facilities for the value addition of tree/tree products at regional level**: Establishment of local processing centers for timber production, tree based fruits, spices and medicinal products, bamboo based products etc which could assure premium price to the tree growers.

6. **Need for trained agroforestry experts**: The complex biophysical and competitive conditions prevailing in the agroforestry/farm forestry scenario calls for scientific expertise to deal with the TOF. Qualified personnel are required for the selection of compatible trees in combination with other crops, planting and layout of the trees and their management in temporal and spatial sequence. Local/regional level (Block or Panchayath) monitoring facility has to be established with sufficient trained agroforestry personnel for the continuous monitoring and strengthening this sector.

7. **Development of farmer transferable agroforestry models:** Tree planting in outside the forests in the state is challenging as there is limited open land available for tree cultivation. Hence, trees need to be grown with other crops and animal components in an integrated mode. Tree dominated multi-tier agroforestry models with timber, fruit trees, fodder, medicinal and non wood tree products, should be developed for different agro-ecological regions of the state: for small and large farmers of Kerala. Research initiatives in this line at KAU need to be strengthening.

8. **Improving farmers' access to quality planting material**: Development of training facilities for starting decentralized tree nursery for the women entrepreneurs at Panchayath level. KAU can be asked to develop block or district level "master trainers" of tree crop nurseries. These master trainers can disseminate the knowledge and also provide leadership.

9. **Strengthening extension facilities**: Training facilities are to be strengthened in KAU, KFRI and KVKs for farmers and other stakeholders on the prospects of tree farming. Dedicated extension facilities and interpretation centers in the state on profitable tree cultivation practices in farm lands and agroforests. Also on farm live models of profitable tree farming should be developed for small and large farmers of the State. Posting , post a forestry Training Associate (AP cadre) or at least have a Training Assistant (Forestry). At all the KVKs of KAU

10. **Market intelligence about the tree produce for deriving maximum benefits to the tree growers:** Establishing local markets for the tree produce. The local TOF facilitation centre should have access to the tree growers on the day to day prices of timber and other wood products. Identified industries and farmers should work together to establish new markets and to strengthen the already established market linkages. Mobile phone linked tree growers social groups may be established at local level for answering issues in tree cultivation.

11. **Providing institutional credit and insurance cover to promote tree cultivation**: The tree species with buy back arrangement coupled with insurance protection should be provided with institutional credit by all the Nationalized and private banks similar to agricultural credit. Agencies like NABARD should facilitate extending credit facilities to identified and prioritized agroforestry tree species for the state of Kerala. For agroforestry projects, banks should consider an interest rate of 7 % similar to agricultural crop loan system. Crop insurance against tree farming failures should be extended to at least the prioritized species.

12. **To arrange minimum support price for the tree crops**: The state Government should ensure fixation of Minimum Support Price (MSP) for major agroforestry species. The model established by Andhra Pradesh may be referred for this purpose. All tree in the TOF sector should be treated equal to the agricultural crops and TOF should be mainstreamed along with agricultural policies and strategies which will ensure availability of subsidies for farm forestry farmers

Research priorities

The research priorities for the expansion of TOF in the state are given below:

1. Assessment of area under various category of TOF in Kerala and develop data base on the existing trees to identify the possible sectors of focus for expansion of TOF.

2. Quantification of the standing stock timber in the various TOF regions in the state.

3. Prioritization of tree species for farm forestry for various agro-ecological regions of the state with preference to fast growing, multipurpose trees.
4. Revitalization of the traditional homegardens with focus on the timber tree components and their management practices.
5. Growth and productivity studies on the TOF with particular reference to industrial agroforestry
6. Development of farmer transferable farm forestry/agroforestry models for small, medium and large holdings in various agro-ecological regions.
7. Undertake studies on screening trees and agroforestry systems with high carbon sequestration potential.
8. Valuation of perceived ecosystem services from TOF through payment for ecosystem services and incentivizing farm tree cultivation.
9. Socio-economic evaluation of tree based systems
10. Studies on the value addition of trees and tree products.
11. Studies on the certification of trees outside forests.

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Important Timber Species of Haryana- Their Status of Cultivation, Production, Supply System, Policy Issues and Constraints

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Introduction

Forests cover about one third of the world's land area. They are essential for sustaining various life forms on earth. They are the green lungs of mother earth and home to various life forms, many of which are still undiscovered. They are home to 80% of the world's terrestrial biodiversity 70% of agriculture and horticulture diversity. Even in 21st century, forests are home to about three hundred million people worldwide and 1.6 billion people constituting more than twenty percent global population depend on them for their livelihoods. In view of the rapid degradation of environment, anthropogenic causes of greenhouse gases leading to global warming and climate change, there has been global shift in the objectives of forest management from timber harvesting and revenue generation to biodiversity conservation and ecosystem management. So, globally the tree centric activities have been changed to overall management of flora and fauna. But at the same time, it is a fact that wood is good and no material has been able to fully replace wood. Hence, the demand for the timber was there, it exists today and it will continue to exist in the times to come. However, in spite of the worldwide awareness about the need to conserve forests and various life forms being harboured by them, the global loss of forests continues unabated.

Haryana Scenario

Haryana is primarily an agricultural state with more than 80% of its land under cultivation. The geographical area of the state is 44212 sq. km which is

1.3% of India's geographical area. It is not bestowed with bounty of natural forests and only 3.0 % of its geographical area is under notified forests. The Forest and Tree Cover of the Haryana state is 6.49% of its geographical area. Forestry activities in the state are dispersed over rugged Shiwalik Hills in north, Aravalli hills in south, sand dunes in west and wastelands, saline-alkaline lands and waterlogged sites in the central part of the state.

Agroforestry in Haryana

Necessity is the mother of invention and so is true for Haryana. Being forest deficient state, agro forestry is an area wherein Haryana State has taken long strides. Agro-forestry has enabled the forest deficient state of Haryana to support a large number of wood-based industries based on farm-grown wood. The town of Yamuna Nagar has virtually become the national centre of plywood and veneer industry. Our policy of not having any restrictions on felling of trees from private areas and on transit of wood, has also helped in expanding the timber trade and wood-based industries. Our endeavour is to create favourable conditions so that wood-based industries and agroforestry activity can further grow simultaneously. The state is also establishing organised timber market (Mandis) at Manakpur, Yamunanagar district of the state to facilitate transparent trade of farm-grown wood. The farmers can grow, fell, sell and transport farm grown wood anywhere in the state. They don't have to seek the permission of forest department under any rule to fell, transport or sell their produce. So, the farmers have taken up agroforestry in the state in a big way. So, much so that the farmers of neighbouring states also sell their wood mainly in Yamunanagar wood market. The agroforestry has brought prosperity to the farmers of the state. They treat agroforestry plantation as fixed deposits which helps them in times of need.

Timber trees/plants being grown

More than fifty plants species are raised in Haryana forest nurseries, but they are raised as per the demand of the people and as per the site conditions. Major timber species of the state are: *Eucalyptus*, Poplar *(Populus deltoids)*, Kikar/ Egyptian Thorn (*Vachellia nilotica=Acacia nilotica),* Sissoo *(Dalbergia sissoo),,* Burma Dek (*Melia composita*), Red Cedar/Toon (*Cedrella toona*), *Ailanthus excelsa*, Jamoa (a variant of *Syzygium cumini*), White Cedar/Frash (*Tamarix articulata*), Teak *(Tectona grandis)*, Jandi *(Proposis cineraria)*, Siras *(Albizia)*, mulberry *(Morus alba),* Marwar Teak *(Tecomella undulata)*, Chir Pine (*Pinus roxburghii*), Baheda/ Beliric Myrobalan (*Terminalia bellirica*) and Seemal *(Bombax ceiba),* Sandan ***(Desmodium oojeinense** =ougeinia oojeinensis)* and Kusum (*Scheleichera oleosa*), Lasora (Cordia myxa) and Jujube *(Zizyphus mauritiana)* etc.

The status of important timber tree species and various issues associated with them is given:

Poplar

Poplar was introduced by WIMCO in 1976 for diversification of species under agro forestry and also as a substitute for *Eucalyptus* as controversy against it was at peak at that time. However, very soon we found that poplar is not a competitor of *Eucalyptus* but rather they are complementary to each other. Number and diversity of poplar ETPs grown in Haryana especially in Yamunanagar is a barometer of poplar culture and trade in the country. In a survey recently conducted through the field staff of Haryana Forest Department, it was estimated that around one crore poplar ETPs are grown in the state every year. In Yamunanagar district maximum poplar nurseries are grown in Chhachhrauli Tehsil followed by that in Bilaspur, Jagadhari and Mustafabad tehsils. Some locations around Yamuna River especially Karnal and Panipat also grow poplar nurseries for their trade in adjoining locations in Uttar Pradesh. Each year during January to March, number of Lorries, tractors and even bullock cards could be seen carrying poplar saplings across the state borders from Haryana. Lakhs of them are stacked each year on road sides at numerous locations during the planting season for attracting buyers. Unfortunately, such saplings do not perform well, yet nursery growers try to sell them at whatever price they could negotiate with buyers- mostly casual planters.

There are around two dozen clones commercially grown in the country and around one dozen in the state of Haryana. Most poplar growers and its wood users know only one clone i.e., G48. WIMCO has introduced 16 clones in the state of Haryana till date, many of which especially WSL 22, WSL 32, WSL 39, Udai and WIMCO 110 have become popular. The farmer's preference for clones has been changing over the time. Poplar culture in the state was started with IC and D121 clones in 1970's, established with G48 and G3 clones and is now further expanding with new clones developed by WIMCO. G48 is now becoming susceptible to many diseases and it is likely to have a short life. New clones appear to be good growing and productive. During the recent years, poplar pests are posing more problem than ever before. The following pests are affecting poplar cultivation in the state: Defoliator *(Clostera fulgurita),* Stem Borer *(Apriona cineri),* Shoot Borer *(Eucosma glaciata),* Bark Borer *(Indarbela quadrinotata)* and Leaf Blight Disease *(Bipolaris maydis).* There is about 50,000 hectare area under popular. The productivity per hectare is 30cum/ha/yr. The farm grown wood is sold in following categories: Over, under, sokhta and fuelwood.

However, there is very bad news for poplar. The wood prices have crashed drastically during the last two years touching a minimum of four hundred rupees per cubic meters. People have now left planting poplar. No poplar plant has been grown in Haryana nurseries during last two years either in forest department nurseries nor in private nurseries.

Haryana forest department just raises poplar plants in the nurseries for planting by the farmers. Not a single plant is planted by the department in its plantation programme. Therefore, the economics of poplar cultivation was studied on farmers' fields in Kurukshetra district.

North Indian Rosewood/Sissoo/Shisham *(Dalbergia sissoo)*

This is the number one timber species of Haryana. People have craze for Shisham and it is the dream of every citizen of Haryana to use Shisham wood for his/her dream house. Forest Department raises annually about 15 lakh plants of Shisham. Half of these are distributed to the farmers and another half are planted by forest department. The farmers are ready to plant any number of Shisham plants in their fields and there is always shortage of Shisham seedlings in the state. However, this number one tree species of Haryana has been virtually pushed to the level of nearly endangered. Annually about twenty thousand Shisham trees are dying in the state. The process of its death started about three decades ago and the misery is still continuing. Plants of all ages starting from year three are being affected by mass mortality problem. Various reasons

Table-1 Economics of poplar cultivation in 2015

Area planted	Spacing	Planting density (Plants/ acre)	Planting Year	Felling Year	Age	Av Weight of Tree (qtl)	No. of Trees at Harvest	Wood Poduction (qtl)	Rate (Rs)	Amount (Rs)	Income earned per year per acre	Total income by intercroping per acre/ year in Rs.	MAI (cum/ha/ yr)
1 Acre	14'x 14'	225	2006	2010	5	2.78	220	612	700	428400	107100	Approx. 44150/- per year	21.85
10 Acre	14'x 14'	225	2005	2012	8	3.25	220	715	750	536250	76607	Approx. 45500/- per year	15.95
5 Acre	35'x (6'x6') Double line	354	2008	2011	4	0.79	315	250	600	150000	42857	Approx. 44150/- per year	11.16
6 Acre	13'x13'	258	2007	2012	5	2.6	225	585	700	409500	81900	Approx. 44150/- per year	20.89

like water logging, over application of nitrogenous fertilizers, damage to root hairs etc. have been cited as the primary reasons. Because of these reasons, the plant becomes prone to fungi like *Fusarium solani* and *Ganoderma lucidum*. These fungi finally end up killing the plants. However, the real cause for the mortality of Shisham still remains as elusive as the solution to the problem. Shisham trees are dying in lower Shiwaliks far away from the fields where the soils are well drained and nitrogenous fertilizers are applied sparingly. Recently, FRI Dehradun has come out with its clone no. FRI-DS-14 which is a blend of higher productivity, resistance to die-back and excellent bole form. This clone has been planted by FRI Dehradun at our research station in Bithmarha in 2009 and is under observation.

Dieback disease in Shisham is not a problem of Haryana alone. States like Punjab, U.P., Uttrakhand, Bihar etc. are facing similar situation. There is no control for this disease at present. For the purpose of management of this disease, as soon as the initial wilting symptoms start appearing on the foliage, the immediate removal of the trees is done. The roots are also extracted and the pits are treated with copper sulphate and lime. In young plantations, as prophylactic control measure, deep harrowing is avoided and after the removal of the weeds, copper sulphate plus lime treatment is done within one meter radius of the plant. The same chemicals mixed with water are painted on the stem. The drying and dying problem in sissoo is a very big issue for the future of this species in the state.

Production of quality planting material

Although we have fairly good shisham germplasm in the state, yet none of the genotypes is tolerant to *Fusarium solani* and *Ganoderma lucidum*. Bareilly and Gonda areas of Uttar Pradesh harbour the best sissoo genotypes. We have introduced them all and are performing very well. However, none of them have shown tolerance to the aforementioned fungi. However, we have the record for the clones that have gone first and some are still standing. May be in the next five years we will be able to find tolerant genetic material.

We have about 15 hectare area under the superior clones of sissoo from where the seed is supplied to the planting divisions. We have also declared 35 hectares of clonal sissoo plantations as seed stands and seed is being regularly collected from them.

Kikar/Egyptian Thorn *(Acacia nilotica)*

It is also important tree species of Haryana and although it is not preferred by the farmers as agro forestry species, yet it is grown in areas like panchayat land, roadside and canal side. It is the life line of rural life of Haryana and is source of fuel wood, timber and agricultural implements for the rural people. It is also dying in large number in Haryana on Sissoo pattern. Web worm is its another enemy which is weakening plants by initially feeding on the leaves and later making huge web virtually covering the whole foliage. Under the changed climatic conditions, web of Tent Web Spider (*Cyrtophora citricola*) and increasing frost conditions, it is becoming increasingly difficult to grow kikar in the state. The seed setting is also poor and a good seed year is there after four to five years. As in the case of sissoo, the dying and drying is also a very big problem in kikar. It will not be a big surprise if kikar becomes endangered after a decade or so.

Introduction and improvement in *Melia composita*

As part of species introduction and finding suitable alternatives to Eucalyptus, Burma Dek *(Melia composita)* was introduced in Haryana in 2003. We found that it comes up very well in area where soil depth is good and soil does not remain dry for a very long period. However, it does not tolerate salts above pH 8.5. We have found that it does not tolerate water logging and just struggles in sandy areas. Though, it is frost tolerant but hot wind (Loo) kills the top portion leading to deformed stem. We also observed that Rhesus Macaque *(Macaca mulatta)* and Blue Bull *(Boselaphus tragocamellus)* badly damage the plant by breaking the branches and splitting the bark. If the plants are protected well, *M. composita* is an excellent species for diversification of species for agroforestry and also as suitable alternative to *Eucalyptus*.

With the aim to increase productivity of *M. composita* in the state, superior genetic material was introduced from all over the country. Forty thousand plants were raised at two locations in the state by direct seed sowing in nurseries beds of 10mx10m for the selection of best plants based on the growth and shape parameters. Ten plants were selected each from the huge population at both the locations. Meanwhile, FRI Dehardun had also initiated All India Coordinated Provenance Trial on the species. We also collected superior seed from the best performing individuals from all these sources. Farmers on their own also brought some material from elsewhere. From all these selections we have established seed orchards which will hopefully start producing seed from 2017 onwards. FRI has also evaluated its trial in 2016 are in the process of releasing two varieties for growing in Haryana.

Red Cedar/Toon (*Cedrella toona)*

It is one of the most important timber species of Haryana. However, it grows in northern Haryana covering Panchkula, Ambala and Yamunanagar districts. It is the main species of Morni hills and is mainly found growing naturally on the bunds of agriculture fields in Morni hills. Toon is increasingly coming under the attack of shoot borer, which kills the leading shoot of the young plants in nurseries and plantations. The attack is so severe that most the plants do not recover. Owing to making its plantation a success, the department raises annually only about ten thousand plants of it. Its wood is rarely sold commercially by the department. The farmers too use its wood for bonafide domestic use as there are restrictions on its felling in areas where it grows. An estimated five hundred cubic wood of red cedar is felled every year by the farmers and about one hundred cubic meter is permitted to be sold.

Ailanthus excelsa

This is a non native species and is planted in the state in the western and southern regions of the state where loose and sandy soils are available. The department raises annually about 6 to 7 lacs plants of it. These plants are planted on sandy soils along the roads and the canals and also on farmers' fields under agroforestry systems. It comes up very well in the state and is ready for harvest after about ten years. But the post-harvest preservation of its wood is a big challenge. It is badly damaged by Pin Hole Borer *(Dinoderus minutus*) and Powder Post Beetles (*Sinoxylon anale*) reducing the wood to flour. As a result of this, there are not many buyers for its wood. And therefore, not many farmers love to grow it. Annually, about one thousand cubic meter wood of *Ailanthus* is sold by forest department and about equal wood is sold by the farmers at the rate of about four thousand per cubic meters.

Jamoa (*Syzygium cumini* var. Jamoa)

Genetically, this is a variant of *Syzygium cumini* and is valued more for wood than the fruits. It grows in northern and central parts of the state where the moisture conditions are very good. Annually about five lac plants of Jamoa are raised in Haryana. An estimated one thousand and five hundred cubic meter wood of jamoa is felled every year by the farmers and about equal quantity is felled and sold by the department at approximate per cubic meter rate of five thousands. There does not exist any problem for the sale of its wood.

White Cedar/Frash (*Tamarix articulata*)

This is indigenous species of western and southern parts of the state where salts accumulates due to very poor drainage. It loves to have its toes in saline and alkaline soils and farmers too love to grow and retain this species on the bunds of their fields. This yields good quality wood and it is comparable with *Casuarina* wood and is at par or even better than *Casuarina* wood. For the reasons unknown, this is not propagated on large scale and only few trees of this species are seen on farmers' fields. An estimated one hundred cubic meters of its wood is sold in the state at about five thousand rupees per cubic meters.

Teak (*Tectona grandis*)

Teak is not found naturally in the state and was introduced in mid-eighties. It survives well but does not produce quality wood. Annually about five to six lacs plants of teak are planted by forest department in the forests. The reason behinds its liking by the field staff is that it is not grazed and browsed by the animals and gives good success. This is not desirable in the natural forest as it flourishes at the cost of local species. The farmers too plant it but that is negligible. Small quantity of its wood is sold in the state at sissoo prices.

Jandi (*Prosopis cineraria*)

This is called the "Kalptaru of Deserts" and grows naturally in the western and the southern semi-arid and rain deficient parts. It is a fodder and timber species of these parts of the state. But it is vanishing due to modern agricultural practices. The department raises annually about fifty thousand plants of it but the successful plantations rarely exist. Farmers sell about one thousand and five hundred cubic meter wood of this species every year.

Siras

Two species of *Albizia* namely *A. Lebbeck* and *A. procera* are grown in Haryana for timber and fodder. Planting and sale of *A. procera* is negligible as it is not very common and is almost endangered. *Albizia lebbeck* is planted along roads and canals and is fairly common species. The tree is harvested after about forty years and is sold as miscellaneous wood at an average rate of about seven thousand rupees per cubic meters. About three thousand cubic meters of siras wood is sold by forest department in Haryana. It is not planted by the farmers on their farm lands owing to its huge crown.

Marwar Teak (*Tecomella undulata*)

It is a famous wood of India and is also known by the name 'Desert Teak'. As the name suggests, it grows in semi-arid sandy soils of desert areas. Many are not familiar with its wood qualities as it required specialized sawing technique. Once sawed properly, its wood looks better than the teak as the alternate rings become prominently visible.

Its wood takes excellent polish and so it is excellent for furniture making. Its wood is sold unfortunately with low quality miscellaneous wood like siras as forest department field functionaries are not familiar with the excellent quality of its wood. However, if sold as pure wood alone, it fetches prices better than that of sissoo which is the best timber species of the state. Unfortunately, this is a very slow growing species and is ready for harvest after about sixty years. Due to this, not more than ten thousand plants are raised annually by the department. Only salvage felling is done in its case as it is endangered species in the state (though not declared). Total wood sold is less than one hundred cubic meters.

Chir Pine (*Pinus roxburghii*)

This species is found only in Morni Hills of Panchkula district. There is complete ban on its green felling but lot of chir trees dry every year due to the severe attack of pin hole borer and damage due to the increasing incidents of fire. On an average, about one thousand cubic meters of Chir wood is harvested and sold every year.

Khair (*Aacia catechu*)

This species grows only in Shiwalik belt of the state covering Panchkula, Ambala and Yamunanagar districts. It is a major species of the state. It is a durable timber but is valued more for katha making rather than as timber species. However, when used as timber for making doors and windows, its wood lasts for more than hundred years.

Baheda/Belliric Myrobalan (*Terminalia bellirica*)

Baehda is a renowned triphala plant. But its wood is great as timber as well. About one lac plants of this species are raised by the department and is planted along the roads and in the forest in northern Haryana. About 700 cubic meter of its wood (including sold by the farmers) is traded every year in Haryana.

Kusum (*Schleichera oleosa)*

This is fairly a tall tree that grows in natural shiwalik forests of the state. However, for its beautiful pink foliage (due to the anthocyanins), the tree is valued more its ornamental value. The tree is at best during mid February to mid April when the old leaves are replaced by new ones though some pink leaves are seen throughout the year. The pinkish-brown heartwood is very hard and durable, excellent to make agricultural implements, pestles, cartwheels, axles, ploughs, tool handles, and rollers of sugar mills and oil presses. However, it is only found in forests and only dead dry trees are felled and used for timber.

Indian Red Silk Cotton/Seemal *(Bombax ceiba)*

This tree grew throughout Haryana in the past. But at present, it is mainly restricted to the Shiwalik belt. A few trees here and there in the state are those planted about forty years ago. Its wood is excellent for match sticks, plywood and plyboard. The tree was felled for this purpose in the past and that is why it has been almost pushed to the endangered state.

It has excellent nail holding capacity. So, used in hills for supporting slates. On the ecological front, vultures love to rest and make nest on it. But somehow, the tree has been ignored. Only about 20000 plants raised annually in the state. The tree seems to be sensitive to climate change too. Flowering and seeding being badly affected in it for the past 4/5 years. N Haryana the seeds are collected from the plus trees. The tree was felled for mainly for making match sticks in the past and that is why it has been almost pushed to the endangered state. Annual availability of its wood about 200 cubic meters only.

Sandan *(Desmodium oojeinense =ougeinia oojeinensis)*

It is a small to medium sized tree that grows in Shiwalik forests. It is a good fodder and gum yielding plant. For a brief period, it produces beautiful violet flowers as well. Its wood is light brown to red-brown which is hard, tough, close-grained, elastic and durable. Though difficult to work, but wood turns well and takes very good polish. In Haryana, it was being used for making agricultural implements, excellent furniture and cots. But trees has almost become endangered and so is not exploited commercially. Only dead and dry trees are removed.

Lasora *(Cordia myxa)*

This ia medium sized to big tree found throughout the state. Its wood is elastic and is therefore, suitable for agricultural implements, bullock carts and yokes etc. About one thousand cubic meters of its wood is harvested every year in Haryana.

Ber/Indian Jujube (*Zizyphus mauriana*)

It is a tree of jujube that is found throughout the state except Shiwaliks. Its wood is elastic and is therefore, suitable for agricultural implements, bullock carts and yokes etc. About five hundred cubic meters of its wood is harvested every year in Haryana.

Felling of main species

The species wise felling done by the department are given below:

Table-4 Species wise Felling (in cum)

Year	Euc	Shisham	Kikar	Chir	Khair	Misc	Total Vol.
2001-02	28889	16702	76617	795	1394	9953	134350
2002-03	46769	19474	58718	812	377	20860	147010
2003-04	31538	11314	46205	965	2281	14679	106982
2004-05	46041	12293	44508	2001	5589	10042	120474
2005-06	46346	9218	25901	2520	220	12786	96991
2006-07	41768	11836	27179	1415	575	11968	94741
2007-08	48236	8709	17714	664	4393	11305	91021
2008-09	48520	8946	16958	665	2244	16737	94070
2009-10	54932	8310	10254	670	288	12754	87208
2010-11	35588	9361	13367	729	990	14827	74862
2011-12	40484	3955	4696	855	699	7272	57961
2012-13	34952	5479	6744	1113	582	10217	59087
2013-14	26810	2988	6165	2162	299	6701	45125
2014-15	40033	2307	6447	589	73	9101	58550
Total	570906	130892	361473	15955	20004	169202	1268432

Source: O/o PCCF, Haryana, Van Bhawan, Sector-6, Panchkula.

It would be pertinent to mention here that about this much timber is felled by Haryana Forest Development Corporation (HFDC). The figures for the felling done by the farmers are almost the double the combined figures of department and HFDC put together.

Timber market at Yamunanagar and Jagadhri

Due to farmers and industry conducive policies, farmers adopted growing trees along the field crops as well as availability of raw material has helped in installation of wood-based industries in the state especially in Yamunanagar region. Establishment of timber market at Yamunanagar has not only helped the farmers of Haryana but also the farmers of Himachal Pradesh, Punjab, Uttrakhand and Uttar Pradesh as well as they are selling their produce in this market.

As per an estimate based on the feedback from plywood industry of Yamunanagar, around 50 lakh quintals of round timber is peeled annually for plywood in the state wherein around 80% is done in Yamunanagar. Likewise, some 20 lakh quintals of Eucalyptus and poplar is sawn in state with 80 to 85% in Yamunanagar alone for board manufacturing. This comes to 5 lakh cu m of round timber of Eucalyptus and poplar and industrialists of Yamunanagar agree to the point that 20 to 25% comes from Haryana and rest is bought from neighbouring states like UP, Uttaranchal, Punjab, J and K and Himachal. The round timber comes from as far as Nepal border and at any point of time, raw material is available for purchase.

As farmers started growing poplar in their fields, lot of timber was produced in the area, which otherwise is deficient in natural forests. This encouraged many enterprising industrialists of Yamunanagar to set up plywood and plyboard manufacturing units in twin cities of Yamunanagar and Jagadhari. Poplar is better suited for plyboard manufacturing because it is soft and light. Thus 70% of the total output consists of plyboard while 30% consists of plywood. There are about 273 plywood manufacturing units, 297 peeling units and 331 saw mills in Yamunanagar district. According to an estimate, about Rs.3 crore worth of timber comes daily to Yamunanagar market and after value addition wood products worth Rs.9 crores are manufactured. One very striking aspect of industrial development in Yamunanagar had been development of associated or ancillary units so that all the by-products were utilized in an efficient manner. Peeling units and saw mills came up at the same place, scrap was sold to local paper mill for pulp formation, saw dust was supplied to kilns and poultry farms and bark was used as fuel; thus every bit of wood was utilized.

Twin cities of Yamunanagar and Jagadhari are the most important timber markets in Haryana state in terms of volume traded of a large number of species. *Eucalyptus* and Poplar, however, constitute the largest chunk of the market. It is the biggest timber markets of northern India. It is well connected both by rail and road with other important towns. The forest-based industries at Yamunanagar are paper mills, saw mills, hard board, plywood factories and straw board factories, sugar mills, packing case units and furniture making. Timber comes from the forests- the Shiwalik ranges and the foothills of Shiwalik. In addition, there is a fair growth of farm forestry. The market also gets supply from adjoining areas of Uttar Pradesh, Punjab, Uttrakhand, as well as from import of wood. Demands for timber come from varied sources. It is used as raw material for the production of furniture, doors, windows, their frames, pulpwood, packaging materials and now many other industrial uses as well. The bulk buyers of timber and fuel wood, pulp wood, be they contractors, builders or industrial users of timber, are generally hard bargainers, knowing the market and the product too well. On the other hand, real consumers are at the goodwill of the traders.

Marketing of Wood

Players in the timber market of Haryana farmers, Panchayats / Communities, forest department, HFDC, Intermediary buyers/ contractors, commission agents, timber merchants, sawmills, veneer / peeling units, ply board industries, manufacturers of wooden boxes and crates, paper industry and furniture shops etc. Due to the local demand, farmers got attractive prices for poplar crop and income from production of timber in the past, outweighed the losses in the agriculture crops. Those farmers who adopted poplar cultivation in the beginning, became very rich and purchased modern agricultural equipments at the end of the first rotation of poplar crop. This further increased the productivity of the land. This trend continued till mid-nineties, but after that there was a downward slide in the prices of the poplar wood. There are four main reasons that can be attributed to downfall of poplar prices. Firstly, worldwide recession in the economy has decreased the demand for plywood and board but production level of industry was same thus market price of these finished products came down. Secondly, Govt. of India has put timber in the OGL list, which facilitated cheap import of timber and pulp. Thirdly, New Zealand Pine, *Pinus radiata* (though native to California but excels in New Zealand) was available at very cheap rate at Kandla Port, which was used in Blockwood production as blocks. Plywood and blockwood of Yamunanagar was being supplied all over India but the main market is in Gujarat and Maharashtra. Thus block wood producers of Gujarat have an edge over producers of Yamunanagar. New Zealand pine is used to make sleepers. Scrap material after conversion is exported to India at very cheap rate. Fourthly, there was imbalance in dynamic demand and supply in the local market in favour of the buyers of the poplar i.e. there is more supply than demand. Cheap poplar wood was also coming from J&K.

This problem becomes even more accentuated because due to fall in prices of block wood (@ Rs. 4 per sq. ft. from @ Rs. 9 per sq. ft.), industries in Yamunanagar shifting from Blockwood production to plywood production. Poplar not being the best choice for veneering, gives way to eucalyptus, which is harder, more durable and heavier than poplar veneer. Even if poplar veneers are used for plywood manufacturing, it should be of best quality, meaning straight clean clear bole of adequate thickness. Since poplar is the species which is not self-pruned as opposed to eucalyptus, it becomes very difficult for a normal farmer who has very little technical knowledge of growing poplar, to prune poplar trees properly.

The corrective action of the market helped in stabilizing the prices of poplar wood. Besides this general downward trend in the prices of the poplar wood, there is small seasonal variations also which becomes significant from the farmers point of view. Prices between December 15 to March 15 are generally low due to cheap availability of labour. There is also subtle variation in the weight of the timber during the dormant period i.e. in winter, weight is 5% more than the weight in summer. Similarly rate in the morning is higher than in the evening within the same day.

It is worth mentioning here that present forest and tree cover of Yamunanagar district is 24.6% whereas the forestland is just 12.1% of the total geographical area. However, there are still problems associated with species suitability, marketing, policy and industrialisation for which there is a great necessity for discussion and deliberation. Recently, the prices of timber in Yamunanagar market have come to one third of price which was 3-4 years back. There was a conception among farmers that the industry people have formed cartelisation and not giving better prices to the tree growers, therefore, the Government has recommended to increase new licences of wood based industries to 10% of total wood based industries in the State considering the wood availability from various sources.

Face Veneer: At present imported but can be produced by increasing the peeling size

Face veneer is nothing but 8ftx4ft veneer. It is used to give an attractive facelift to the plyboard. The wood in Yamunanagar being used for this purpose is Gurjan (*Dipterocarpus turbinatus*), which is at present imported. During the interaction with the members of plyboard and plywood union, Yamunanagar, it was learnt that popular wood by giving it gurjan colour, can be substituted for the gurjan. But there is no unit in the entire country that peels 8ftx4ft veneer. And so, the veneer is imported. Peeling units are essential integral part of plywood unit. The size of peeling units here is 4 ft. width which needs to be raised to 8 ft. by setting up new peeling units. In this way the face veneers which are imported right now can be manufactured locally and that too at half the prices and also saving a lot of foreign exchange. In case larger peeling units are allowed and face veneers are manufactured here around one lakh cu m of round timber of poplar and Eucalyptus can be utilized further which will shorten the supply demand gap thereby pushing the prices of raw material upwards.

Locally manufactured face veneer will save 57 crores of foreign exchange

The thickness of face veneer is 3mm. Lower side figure of consumption of imported face veneer in Yamunanagar is 15000 cum per unit per month. The area of one face veneer is three square meter. So, the number of face veneer material imported by one unit is 5000 per month. Accordingly, the total thickness of face veneer material comes to 1.5 meters. And the total volume of wood comes to 4.5 cum per unit per month. Considering the present cost of sixteen rupees per square meter, one unit has to spend 2.4 lakhs per month and 28.80 lakhs per annum. Again to be on the lower side, 200 units import this much wood. Accordingly, 57.6 crores (28.8x200) rupees are spent in foreign exchange. So, if the 8ftx4ft peeling unit are installed, one hand foreign exchange will be saved, on the other hand the local consumption of the wood will increase. It is reiterated that sale of poplar and Eucalyptus wood is a problem nowadays in Haryana mainly due to the arrival of the wood from other states. This will also help stabilitize the prices of the wood which regularly happens periodically.

Policy

Haryana state has come up with its own forest policy in 2006. As regards the timber production, its sale and movement, the following provisions have been made:

Most of the raw material for wood based industries comes from private land plantations in Haryana and adjoining states. State has no regulation for timber transit but has the provision of licensing of wood-based industry. The main consideration governing the establishment of wood-based industries and supply of raw material to them should be as follows:-

Wood-based industries based on agro-forestry plantations should be encouraged. These industries should procure the raw material needed by them to meet their requirements, by establishing direct linkages with the tree growers and promoting contractual agro-forestry programmes. No permission should be required for felling and utilization of species grown under agro-forestry.

Farmers, particularly small and marginal should be encouraged to grow wood for better economic returns. There should be no restriction and regulation on the felling and removal of trees species like Eucalyptus and Poplars and other species grown under agro-forestry on private holdings to encourage agro-forestry and ensure regular supply of raw material to wood-based industries.

Wood based industries should be encouraged to supply certified quality planting stock to farmers and to enter into buy back arrangements for the raw material produced by them. However, the farmers should be free to sell their produce in the market if they get the higher prices. Wood-based industries must not only provide employment to local people on priority but also involve them in raising trees.

There should be separate regulated timber trading markets for ensuring transparency in transaction and avoiding exploitation of tree growers. Market intelligence and information system shall be strengthened for the benefit of tree growers and wood consumers. 4.8.5 There should be no restriction in the

State on movement of wood from the neighbouring states. Also the import of wood and wood products should be liberalized.

So, the farmer friendly and industry friendly atmosphere has been created in the state. But industries are not playing any role in supplying superior and certified material as the wood is easily available to them at cheaper prices.

Issues

Ever since the shift in the objectives of forest management from timber production and revenue generation to biodiversity conservation and ecosystem management, the very big question that has arisen is- "What is the role of tree improvement in the forests?" It is so because tree improvement essentially means removal of inferior looking genotypes and retaining only superior individuals having clean bole, long trunk and free from pests and diseases. It also requires clean cultivation. Clean cultivation requires removal of vegetation around, which clearly means removal of biodiversity. This is not desirable in present day forest management. Hence, timber forestry cannot be practiced in forests. Present day forest and wildlife management laws and rules are bent towards conserving everything in their natural forms. On the other hands, some scientists and foresters want that some percentage of forests needs to be set aside for timber production to meet wood requirement and also to reduce pressure on the rest of the forest. There does not exist any provision as such at present.

Agroforestry indirectly helps in conservation of forests by meeting the wood requirement from outside the forests. But increasing area under agroforestry is very difficult. It is so because even fastest growing tree species are slower than any agriculture crop.

Agroforestry particularly in the context of Haryana has very narrow base. We have only two commercially successful agroforestry species namely Eucalyptus and poplar in the state. Poplar can be grown in a limited zone. There is opposition from the environmentalists and bureaucrats for Eucalyptus. More species, varieties, clones and genotypes are required to be explored.

Eucalyptus is very popular with foresters and farmers. Within Eucalyptus we are growing now selected clones. For the past five years in Haryana 90% of clonal plantations comprise of only one clone i.e. 413. This is perfect example of monoculture within monoculture. Now we have started facing problems with this clone. The incidence of *Botryosphaeria dothidea* causing bark split and canker disease in it are increasing every year.

We raise and plant Eucalyptus and clones as per our convenience. Sometimes, this is technically not correct. There is need to devise clone wise models for agroforestry.

In view of no control on the market forces, periodically crash in wood prices is observed. This is a big setback for agroforestry in the state.

Constraints

Haryana claims to harbour India's biggest timber market in Yamunanagar. It is so because Yamunanagar town is located at a place very close to Uttar Pradesh, Uttrakhand and Punjab. There are no timber transit rules in the state and owing to the prevalence of farmer and industry friendly atmosphere in the state. There is no check on the wood coming from other states. Infact, Haryana supplies only twenty percent of the total wood coming to Yamaunanagar. The rest of the wood comes from adjoining states. Whenever the area opens for felling in adjoining states after a fixed cycle, all of a sudden there is glut in timber market. Our own farmers suffer because of this glut which is not our creation.

There does not exist any provision for wood and planting material certification in the state. A number of private popular nurseries have mushroomed up in the state. These nurseries owners use genetically inferior side shoots to raise plants. Such plants do not develop long, straight and clean bole. Later on forest department is blamed for problems arising out of inferior stock.

As a follow up action of Hon'ble Supreme Court of India order in famous Gondaverman case, the total number of saw mills, veneer peeling and plywood units have been fixed on the basis of wood produced in Haryana farms. The wood coming from adjoining states creates a sudden glut and the local suffer due to sudden crash in wood prices. Accordingly, the farmers time and again raise demand for increasing the number of farm wood base industries.

Conclusion

The areas outside forests are going to be targeted for meeting the timber requirement of the country in view of the increasing focus of the forest management from timber production to environment considerations. Fortunately, this is already happening in Haryana as govt. owned natural forests are deficient in Haryana. Having only about three percent geographical area under the forests, Haryana is a forest deficient but a timber surplus state today due to our liberal policies. Our annual wood requirement in the state is about one million cubic meters and even if we do not grow trees in the state for the next 25 years, we will have no problem. Interesting thing about Haryana being a wood surplus is that only one percent requirement is met from the forests and rest is met from the agroforestry. Inspite of having got a tag of leader in agroforestry, a number of issues still remain. Periodic fall in wood prices gives periodic setback to agroforestry plantations for which the solution remains evasive till now. Haryana Forest Department is working on certification of wood for better prices. Similarly, steps are being taken to ensure availability of only certified quality planting material. However, there is a need to focus on individual tree species for higher productivity and production of quality timber. There is also a need to maintain the variability in view of emerging new pests and diseases. Monoculture within the monoculture has to be avoided and clone wise models have to be developed for commercially grown important agroforestry timber species of the state like Eucalyptus and poplar.

Production and Supply of Teak Timber in Kerala - Current and Future Scenario

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Introduction

Teakwood is a valuable multipurpose timber preferred for quality and decorative applications and exported for centuries from India. It is excellent for furniture, doors, decorative veneer, plywood and all sorts of constructions. Teakwood has high rating in most of the timber qualities such as strength, durability and workability. It has been described as one of the most durable timbers of the world (Pearson and, Brown 1932). Traditional use of teak poles for electricity transmission and timber for railway sleepers are a time tested testimony of its suitability for outdoor uses. It is the best timber for ship building and even now sea-going dhows (uru) are built with teakwood in the traditional ship yards of Beypore near Calicut. In the earlier days, Indian, Arab and British merchant and naval ships were built with teak from Malabar. Among Indian timbers, only sandalwood and rosewood command a higher price than that of teakwood.

Teak (*Tectona grandis* Linn. f) has a natural distribution range of South and South-East Asia. India has the maximum genetic variability of teak with a natural distribution of over 8.9 million ha (Tewari, 1992). For the first time, teak plantations were raised in India in 1842 in Nilambur (Ribbenthrop, 1900). It is cultivated throughout the tropics in varying extent. Teak covers about 14% of the total tropical plantations (Evans, 1982). Extensive teak plantations exist in India outside the zones of its natural distribution. (Mamman Chundamannil, CUSAT, 1997).

Demand of timber in Kerala

The demand of timber in Kerala during 2010-11 period is as follows (KFRI - 2012)

Sl No	Timber using sector	Volume (000 Cub M)	%
1	House hold sector	539	24.2
2	Industrial sector	1003	45
3	Institutional sector	2	0.1
4	Export to other states and abroad	684	30.7
	Total demand of timber and industrial wood	2228	100

Supply of timber

The supply of timber from various sectors in Kerala during 2010-11 is given below (KFRI 2012)

Sl. No	Sector	Quantity (Cub M)	%
1	Forest	35,000	1.6
2	Import from other states	1,51,000	6.8
3	Import from other countries	2,16,000	9.7
4	Home gardens	7,88,000	35.3
5	Rubber estates	10,38,000	46.6
	Total	22,28,000	100

Teak plantations under Kerala Forest Department

Because of its wide uses and its importance in Kerala, teak is the main timber species grown by the Kerala Forest Department. The total Plantation area under Kerala Forest Department as on 31.03.2014 is 152719.372 ha, which comes to 13.5% of the total forest area in the state. Major species of plantations are teak, teak and soft wood, *Acacia mangium, Acacia auriculiformis*, Eucalyptus, Cane, Bamboo, Cashew etc. Teak is grown as a mono-crop and also in combination with soft woods. The circle wise break-up of the teak plantations under the department is as follows (Forest statistics 2014).

Sl No	Circle	Major Divisions	Teak Plantation (Ha)	Teak and soft wood Plantation (Ha)
1	Southern Circle	Achancoil, Ranni and Konni	17776.272	3582.592
2	High Range Circle	Kothamangalam and Kottayam	7475.026	590.376
3	Central Circle	Malayattor, Vazhachal and Chalakkudy	15609.87	2381.37
4	Eastern Circle	Nenmara, Palakkad, Nilambur North and Nilambur South	12196.15	95.23
5	Northern Circle	Wayanad South and Kasargode	4376.868	3496.185
6	Agasthyavanam	Thiruvananthapuram	42.58	0
7	Palakkad Wildlife	Parambikulam and Wayanad	17360.175	2117.531
		Total area	74836.175	12263.284
		Grant Total	87099.459	

Produ ction of teak by the Kerala Forest Department – present scenario

The teak in the plantations under the Kerala Forest Department is extracted during the thinning and final felling of the teak plantations. Teak plantations are thinned at various stages and the final felling is done at 50 years of age.

The teak timber collected by the department during thinning and final felling operation is transported to the timber depots under the department for its sale. There are six timber sales divisions and 28 depots under the Kerala Forest Department. The details of teak timber collected in the six divisions during the 2015 and 2016 are given below

Details of teak timber collected (CUM?) in the six Timber Sales Divisions of Kerala

Sl No	Timber Sales Division	Teak timber collected (CUM?)		
		2015	2016	Total
1	Thiruvananthapuram	1970.886	2149.898	4120.784
2	Punnalur	413.154	2082.416	2495.570
3	Kottayam	2829.737	1475.094	4304.831
4	Perumbavur	2370.808	2297.635	4668.443
5	Palakkad	7808.971	8917.125	16726.096

Supply of timber by forest department – Current year (2016-17)

The teak timber collected by the department in the depots is sold to the customers in auction sale and retail sale. From 2014 November onwards, Kerala Forest Department is selling the teak timber mainly through E auction of timber. The detail of timber sold by the department during this financial year is as follows.

Sl No	Timber Sales Division	2016 up to December	
		Quantity	Rate/cum
1	Thiruvananthapuram	1569.898	70068.24
2	Punnalur	1515.97	97010.77
3	Kottayam	3878.95	47695.82
4	Perumbavur	2378.248	87257.06
5	Palakkad	5220.322	87007.10
6	Kozhikkode	493.857	75434.13
	Total	**15057.245**	

Future scenario

The thinning and felling operations in plantation under the department is being done as per the working plan prescriptions to ensure steady output of raw materials. The availability of timber from the department plantations will remain more or less the same in the years to come. More than this change in the approach of the department from production forestry to protection forestry is likely to further reduce the timber output from the department plantations. The rate of various class of teak timber has increased over the years. With economic growth of the country, the demand for timber will keep on increasing and the steady output can increase the cost of teak timber from department plantations in the years to come.

Status of timber in Jammu and Kashmir State

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Jammu and Kashmir is the northernmost hilly state of India and forests form one of the most important resources of the state. The total area of the demarcated forest in the Jammu & Kashmir State is 2023000 hectare of which 20% lies in the total geographical area of the state on this side of the Line of Control. About 43% of the forest area is open, 39% comes under moderate dense category and remaining 18% area constitutes very dense category. More than 99% of forest area is confined to the provinces of Jammu and that of Kashmir only, with largest area of 5848 sq. kms. in district of Doda in Jammu province and smallest area of 481 sq. kms. in the district of Budgam in Kashmir province . Over 19,236 sq. kms.of forests are coniferous softwood (Pine) and the rest 946 sq. kms. under non-coniferous trees. Fir accounts for 41 % of conifer, Kail for 23%, Chir for 22% and Deodar for 14%. Deodar are the preferred timber in the Jammu province because of its ability to ward of borers. Fir and Kail timber are cheaper than Deodar but they exudes resin in warm season at Jammu. But they are preferred in Kashmir and Ladakh where the weather is always cool. Also the construction are largely wood based with panelling and truss work.

The valley of Kashmir has deciduous vegetation. The Chinar, Poplar, Deodar, Fir, Pine, Kail, Partal, Mulbery, Walnut and other fruit trees grow throughout the valley. Chinar is not a useful species for timber. Poplar is used in construction at ladakh where no other timber trees grow.

The Jammu province has conifers in the Doad district, Udhampur district and some parts of Poonch. In lower plains Shisham is an important timber tree. Shisham is not commercially exploited in jammu and most of the demand is met from imported timber.

The ladaks province has some areas under Poplar and Willow. They are largely used as beams in construction. Ladakh depends on Kashmir valley and Doda for its timber.

Industries Dependent on Forests

1. **Match Industry.** Poplar wood available in the valley of Kashmir is mainly used by this industry
2. **The wood of poplar and willow trees** is used for making cricket bats and mulberry wood is used for making hockey sticks.
3. **Sentonin Factory** in Baramula manufactures sentonin from artimisia.This drug is useds used as a helminthecide which is exported to foreign countries also.
4. **Rifle Half-Wrought Factory** in Baramula manufactures walnut wood rifle-butts.
5. **Furniture Industry** – Mostly Shisham is the preferred species for furniture.

The Jammu and Kashmir State is bestowed with conifer forests in majority of the area. The following statement presents the data regarding growing stock (about 30 cm dbh) available in the forest (compiled from Working Plans).

S.No.	Species	Growing stock estimated (Volume in Cubic meter)
1.	Deodar	2.61 crore
2.	Kail	2.89 crore
3.	Fir/Spruce	6.31 crore
4.	Chir	1.26 crore
	TOTAL	**13.08 Cr. Cum**

Status of Timber in J&K Forest Policy, 2011

The forest policy of Jammu and Kashmir stipulates that the for supply of Timber and Other Wood Based Produce :-

a. Efforts will be made to bridge the gap between demand and supply of timber by increasing productivity and actively facilitating import of timber.

b. Technologies and processes that minimize deterioration and wastage of timber during conversion, extraction and transportation will be adopted so that dry and fallen trees do not deteriorate in forests.

c. Use of timber substitutes and composite wood will be encouraged in government constructions and popularized amongst general public also.

d. Wood based industries will meet their requirement from privately raised plantations on non-forest lands, preferably in partnership with farmers or through imported timber.

e. In view of the above, and other options available for reducing the dependence on natural forests for supply of major goods, the subsidy component on timber and firewood supplied through Government Depots will be gradually phased out.

Further the policy stipulates that for the Management of Concessions and to ensure protection of forests, their scientific management, and also the needs of the inhabitants of neighbouring villages and nomadic graziers, the concessions traditionally enjoyed by them are duly acknowledged as recognized during settlement. The bonafide concessionists, particularly those living in remote areas will continue to get forest produce and other usufructs from the forests subject to the silvicultural availability.

Status of Green Felling In Jammu and Kashmir

After the ban on green felling by the direction of Hon'ble Supreme Court of India, the State Government constituted the Qualitative and Quantitative norms committee under the direction of the Hon'ble Court. The Committee recommended removal of dry/fallen trees from the commercial working circles and the quantum of marking restricted to 80 lakhs cft (2.26 lakh cum).

The Working Plan Circle accordingly has issued technical sanctions for felling of trees the following statement reveals the quantum of standing trees technical sanction for felling in the State.

S.No.	Financial year	Volume of conifer trees technically sanctioned for felling (Lakh in Cft)
1.	2010-11	54.41
2.	2011-12	68.00
3	2012-13	97.21
4	2013-14	61.82
5	2014-15	71.42
6	2015-16	70.58
7	2016-17 (Ending Dec. 2016)	46.39

(It yields approximately 60% in sawn farm)

Status of Timber import

The availability of timber from local extraction has not been sufficient for the state. The State has been importing timber. A statement showing the import of locally well known timber species at Lakhanpur Checkpost at Kathua which is the only entry point for imported timber as reported by the state Forest department in its Annual Administration Report 2013 is given below, :-

	Import in cft		
	2010-11	**2011-12**	**2012-13**
Chir	1894.91	1948.56	521.94
Deodar	48796.2	17850.63	10413.89
Fir	44201.64	9652.05	12.58.45
Kail	29491.32	32624.85	11052.94

In addition to the forest, large quantity of sawn timber is imported from outside the Country into J&K State. The following table shows the quantity of timber imported into Jammu and Kashmir State.

S.No.	Financial year	Volume of timber imported into the State (Lakh in Cft)
1.	2010-11	32.12
2.	2011-12	37.76
3	2012-13	47.02

S.No.	Financial year	Volume of timber imported into the State (Lakh in Cft)
4	2013-14	41.42
5	2014-15	44.83
6	2015-16	47.12
7	2016-17 (Ending Dec. 2016)	37.20

In addition to the locally known timber , the state of Jammu and Kashmir is also importing foreign timbers likeTurkey cedar, Douglas Pine, Radiata pine, Strobus pine, Sylvestris pine, Spruce, Arau, Ballis of Eucalyptus, Hollock, Kikar, Kapoor, Belly, Marandi, Oak, Poplar, Rusk, Sal, Sheesham, Silver oak, Steam beach, Teak, VAtica, Bansan, Mango, African roush, Mayanmar planks, Malayan Sleepers, New Zealand Yellow pine planks are also imported. Douglas Pine, Radiata pine, Strobus pine, Sylvestris pine are imported in significantly large quantities which may be due to their ability for giving good panelling finish. Teak to the tune of 45414 cft was imported in 2012-13. Sylvestris pine to the tune of 3363347 cft was imported in 2012-13. This is a good imported panel for interior finishing.

Conclusion

The state has three distinct climate zones and the usage of timber has been largely dependent on their respective climate zone. Further the Kashmir region is prone to Earthquakes. The preference for timber in the tropical Jammu province where the construction are largely concrete roofed is hardwood like Shisham, Teak and Kikar. In remote hills of Jammu region like Baderwah, Kishtwar, Poonch and Doda. The preference is like that of Kashmir . Kashmir is a temperate zone and earthquake prone where the style of construction largely uses timber for panelling, truss and beams to retain warmth and also for stability during earth quakes. The alpine ladakh region is bereft of vegetation and the construction largely uses loclly available poplar and willow are beams and pillars and sleepers from Kashmir. In spite of the State of Jammu and Kashmir being a predominantly forest state, the awareness in the state for conservation along with the direction of the Hon’ble Supreme court has resulted in protecting the existing forests of the hilly state. The state has scarce agricultural land resource which can be diverted for the privately growing Timber yielding trees. The state is largely dependent on imported timber. The scope of raising sufficient quantity of timber in the state is also not feasible . The state has enacted acts to regulate the felling of trees and transit of timber which has effectively curtailed illegal smuggling. This has resulted in the demand for timber from outside the state.

Reference

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Important timber species of Punjab – Present status and future potential

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Abstract

Indian Forestry scenario with respect to its forest and tree cover as well as the state of Punjab is on increase. However the productivity of Indian forests in terms of annual increment as growing stock per ha has been abysmally low resulting in huge imports to fill the gap between demand and supply of timber and wood products. Punjab state has been an agrarian state since independence and reorganisation hence alternative means of agro forestry, farm forestry were practiced to enhance tree cover outside its forest areas. Various species and strategies were discussed to improve the present scenario of timber demand and supply of the state of Punjab.

Keywords : Punjab forests, timber availability, demand, supply, strategies for future

Introduction

India's forest cover is 7,01,673 sq.km (70.17 mi ha) in about 21.34% of the geographical area of the country and the tree cover is estimated to be 95,572 sq.km (9.56 mi ha), representing 2.82% of the geographical area. Totally there are 79.42 mi ha of forest and tree cover amounting to 24.16% geographical area of the country. The total growing stock of India's is estimated as 5768 mi m^3 which comprises 4195 mi m^3 inside forests and 1573 mi m^3 outside forests (Anon, 2016).

Punjab, primarily an agrarian state with more than 82% of its land under net sown area is endowed with 3315 sq km of forest (6.58% of its geographical area) that includes 1544 sq km of Trees Outside Forests (TOF) (3.07% of geographical area). Growing stock present in recorded forests is 13.01 mi m^3 and in TOF is 18.14 mi m^3 (Anon, 2016). The TOF includes the trees available in all state's road, rail and canal strips, which have been notified as protected forests (PF) by notification in addition to few blocks as PF. Similarly, more than 60% of the forests are private and community owned but managed by forest department under the provisions of Punjab Land Preservation Act, 1950. The state has gradually improved its green cover over the past decade with continuous attempts of afforestation, protection and community participation. Important timber trees available in the state are Shisham (*Dalbergia sissoo*), Kikar (*Acacia nilotica*), Chirpine (*Pinus roxburghii*), Khair (*Acacia catechu*) etc. However the industrial timber demand for pulp & paper as well as for low cost furniture are met by farm grown *Eucalyptus hybrid* while plywood, veneer and packing case demand are met by agro forestry and farm forestry grown Poplar (*Populus deltoides*) in the state. The state supplies eucalyptus and poplar wood outside the state to Haryana, Himachal and U.P. for the above purposes.

Forest Types of Punjab

Based on Champion and Seth classification of forest types, the state has seven types of the forests which include northern dry mixed deciduous forests, dry deciduous scrub forests, dry tropical riverine forests, Khair-sissoo forest in foothills, Butea forests and saline/alkaline scrub savannah, dry bamboo brakes and Shiwalik chir pine forests. In northern dry mixed deciduous forests, the vegetation is xerophytic in nature and there is a preponderance of species like *Acacia catechu, A. leucocephala, A. nilotica, Anogeissus latifolia* etc.

Dry deciduous scrub forests are mostly found in Kandi tract (Shivalik hill region adjoining Himachal Pradesh state boundary). The accompanying dry deciduous scrub forest consists of *Nyctanthus arbotristis, Carissa opaca, Grewia tenax* etc. Most of these areas have remained under section 4 and 5 of the Punjab Land Preservation Act, 1900. As a result of this Act, vegetation over these areas has generally improved especially in upper parts of the catchments and along the Choe banks. Plantations of economically important species like *Acacia catechu* (Khair) and Bhabbar grass has also been undertaken in these areas.

Khair-Sissoo forests are found along the streams. They are scattered in nature. These are mostly man-made forests as a result of plantings in the foothills along choes (streams) and mand (riverine and beds) areas. In addition to Khair and Sissoo, Eucalyptus hybrid has been planted over substantial areas.

Butea forests and saline/alkaline scrub savannah have mostly been converted into plantations of commercial species like Eucalyptus species, *Dalbergia sisso* (Shisham), *Acacia catechu* (Khair), *Morus alba* (Mulberry) etc. Small patches of natural vegetation survive in village wastelands in the plains.

Dry bamboo brakes (*Dendrocalamus strictus*) are located in certain parts of Hoshiarpur and Roopnagar districts bordering Himachal Pradesh and Gurdaspur. The forests of Karanpur and Bindraban in Dasuya forest division are mainly bamboo areas where Bamboo (*Dendrocalamus strictus*) occurs gregariously.

Shiwalik Chir pine forests consist of *Pinus roxburghii* (Chirpine) found in elevations above 850 meters above mean sea level (msl) in parts of Bari Khad, Dehrian, Chattarpur, Dhar, Dunera and Nurpur Bedi forests (Anon, 2002).

Important timber species available in the state

Shisham (*Dalbergia sissoo*) - This tree is locally known as 'Tahli' and closely associated with sikh religion since time immemorial as sikh gurus have planted the stumps of this tree as symbols of eternity, which are still seen growing as living legends in many Gurudwaras of Punjab. About 23% of the total growing stock on forest land is composed of shisham and so far about 64 lakh trees have been planted outside forests (Luna and Ashok kumar, 2006). This species is declared as state tree on 15.3.1999 owing to its vigour, strength, durability and religious values. The tree loves to come up naturally on new sandy alluvial, well drained soil and primary succession species and Punjab being land of rivers, shisham is ideally suitable to its large riverine tract. Being highly useful as timber for various multiple uses such as from making agricultural implements to house construction, the species forms the primary timber species in various parts of the state and region. The wood is highly valuable with brown grain pattern. Naturally dead shisham trees are used in Wood inlaying and carving works in Kartarpur, Hoshiarpur areas. This species is second to Teak in this region in terms of wood quality, price and in demand. The current price of this species ranges from Rs 1000 – 2000 per cft. Teakwood is mostly imported in this region having two categories, superior one being termed as M.P teak and the other one farm grown Northern Indian Teak with inferior wood quality. Recently the species is affected by *Ganoderma lucidum,* resulting in large scale die back and wilt in shisham across the state.

Kikar (*Acacia nilotica*) – This is mostly found in farm lands along boundaries and community lands and forms the cheaper alternative timber species for furniture, where the affordable furniture are made. The wood is heavy and darker and found suitable for various agricultural implements and cheaper local made furnitures.

Chirpine (*Pinus roxburghii*) – This species naturally found along higher reaches of Shivalik region and is restricted to few pockets of higher elevation in the state in Hill districts of Roop nagar, Hoshaipur and Gurdaspur. Primarily used for resin tapping, the timber is valuable in terms of pacing cases and light wood furniture and wood panelling works.

Khair (*Acacia catechu*)- This species is most valuable for its katha (Paan) making from heartwood in adjoining areas around the state and is the natural succession species along with shisham in riverine tract as well as on undulating hilly tracts of Kandi region, the shiwalik foot hills. Wood is also found suitable for agricultural implements. Once most traded timber from the Shivalik region as it is naturally well distributed and regenerates well naturally is facing threat due to over exploitation from private forest areas of kandi region. However, Punjab Forest Department extensively plants this species in shivalik region in addition to its natural regeneration.

Poplar (*Populus deltoides*)- This species comes second next to Eucalyptus in terms of TOF. Enterprising farmers of Punjab have made this species very much suitable to the region in their farm lands under agro and farm forestry models. Various clones and research trials in terms of varieties, spacing and suitable practices with various crop combinations have given a boost to its introduction in the state and is grown in almost all parts of the state under agro forestry as well as pure plantations. Yield or net productivity per ha ranges from 15-20 m^3/yr.

Species composition in TOF in Punjab

The dominant species in TOF of Punjab are *Eucalyptus spp.* (23.7 %), *Populus spp.* (21.0 %), *Melia azadirach* (10.8 %), *Dalbergia sissoo* (10.4 %), *Morus sp.* (7.5 %), *Mangifera indica* (4.5 %), *Acacia nilotica* (4.2 %), *Azadirachta indica* (2.0 %), *Syzygium cumini* (1.8 %) and *Zizyphus mauritiana* (1.4 %). The report of TOF assessment was exclusively done by FSI in the year 2006 for the Punjab state. The total estimated stems in TOF in Punjab are 61.2 million of which 57.8 million are in rural areas and 3.4 million in urban areas. The number of stems per hectare in the state is estimated to be 13.12. The total estimated volume of wood in TOF is 19.85 million cum of which 94% is in rural areas and 6% in urban areas (Anon, 2006).

Demand and supply gap in fuel wood, timber and fodder in India

There is a substantial demand and supply gap in major forest products across India. This trend is reflected across most states including Punjab. This leads to a vicious circle where the unsustainable exploitation of forests contributes to their degradation which in turn reduces the supply of products and services.

Table 1. Demand and supply gap of various forest products in India (in Million Tonnes)

Category	Demand (MT)	Sustainable supply (MT)	Gap/ unsustainable harvest (MT)
Fuel wood	228	128	100
Fodder (green and dry)	1594	741	853
Timber	54.94	40.70	14.74

Source: Aggarwal *et al*., 2009

Indian forests struggle with lesser productivity of about 15 mi m^3 of industrial timber and 195 mi m^3 of firewood. The requirement of various woods in India in 2010 were projected to 344 mi tonnes of firewood & charcoal, 37 mi m^3 of industrial wood, 33 mi m^3 sawn timber, 5.7 mi tonnes of pulp and paper wood and 1.3 mi tonnes of wood based panels (Anon,1993). The mean annual increment of Indian forests is less than 1 m^3 $ha^{-1}yr^{-1}$ against the world average of 2.1 thus resulting in huge deficit and import of wood (Lal, 2000).

Table 2. Export and Import situation of wood and wood products of India

	Export of Wood & Products		Import of Wood & Products	
Year	**Wood (m^3)**	**Products (Ton)**	**Wood (m^3)**	**Products (Ton)**
2010-11	43822	24162.29	4856486	15105.74
2011-12	42718	911.43	6662807	17488.22
2012-13	39759	3149.88	7035808	21865.55
2013-14	58666	1756.96	6603482	313782.7
2014-15	31586	1914.79	6717557	412874.3

Source : IFSR, 2015 - Anon, 2016)

Demand and Yield scenario in Punjab

In the state, it has been projected that total demand for wood for the year 2005, 2010 and 2015 are 7.24 million m^3, 7.44 million m^3 and 8.14 million m^3 respectively based on approximate population growth rate of 2% (Anon, 2012). These estimates are over estimated for a total population of about 27.74 million as per 2011 census. Even if we consider half of the above estimate as demand for wood, still there is a very long way to go to meet the above demand given the present scenario of recorded removal. It has been estimated that government forests and government managed private forests altogether produce 0.14 million m^3 of wood in 2005-06 (Table 3). These were only recorded removal of forest produce from various government and private forests that were transferred to Forest Development Corporation for felling on royalty basis. In addition, there are local trading of timber, auction of stsnding trees in forests and private lands and village level un recorded usage of timber. Thus a conservative estimate of about 0.5 mi.m^3 per annum can be estimated harvest for the year 2015 with advent of agroforestry that supplies mainly Drek, Poplar and Eucalyptus. Still there is a large gap in demand and supply, which is fulfilled by either import from other states and abroad as well as from private lands through agro forestry. Growing stock present in recorded forests is 13.01 mi m^3 and in TOF is 18.14 mi m^3 (Anon, 2016). Definitely the present growing stock of the state will not be able to meet the demand of wood on a long term unless the productivity of natural forests are improved or area under TOF is enhanced with more fast growing alternative timber and multipurpose tree species with superior planting stock and remunerative packages.

Table 3. Production of different species of wood in Punjab

PRODUCTION OF DIFFERENT SPECIES OF WOOD
FROM GOVERNMENT FORESTS

Major Forest Produce (Timber +Firewood) Quantity in Cu.Mt., Value in 000Rs

Year	Shisham	Kikar	Eucalyptus	Mulberry	Chil	Khair	Poplar	Misc.	Total	Value
1	2	3	4	5	6	7	8	9	10	11
1995-96	10536	21229	16934	8	778	191	700	3505	53881	39302
1996-97	13587	19072	11125	275	310	119	102	4064	48654	39898
1997-98	23113	31671	14244	30	96	181	674	5243	75252	61207
1998-99	25495	27417	11607	28	472	198	219	4511	69947	46593
1999-2000	33635	101734	13954	272	357	330	357	5906	156545	121752
2000-01	47162	101424	15242	394	308	431	555	7268	172784	123885
2001-02	47579	54989	19956	574	419	506	596	11799	136418	91837
2002-03	38847	35797	14749	608	54	386	776	8363	99580	67945
2003-04	38639	60172	13025	-	383	422	366	8105	121112	92634
2004-05	30375	37859	14537	-	328	517	342	7350	91308	74605
2005-06	41669	33155	39843	-	-	524	1189	18173	134553	115097

Most of the amount under value column corresponds to the royalty value against the standing trees transferred for exploitation to Punjab State Forest Development Corporatior

PRODUCTION OF DIFFERENT SPECIES OF WOOD
FROM PRIVATE FORESTS

(Areas managed by Forest Department closed under Section 4 & 5 of Punjab Land Presevation Act 1900 and Section 38 of Indian Forest Act 1927

Major Forest Produce (Timber +Firewood) Quantity in Cu.Mt., Value in 000Rs

Year	Shisham	Kikar	Eucalyptus	Chil	Khair	Poplar	Misc.	Total	Value
1	2	3	4	5	6	7	8	9	10
1995-96	660	320	3024	9475	9971	-	11308	34758	
1996-97	48	6	3980	2618	107	-	2396	9155	
1997-98	566	230	5126	3821	10293	-	10553	30589	
1998-99	466	325	5234	742	3148	-	1378	11293	
1999-2000	1848	355	1096	2761	3836	-	5862	15758	
2000-01	1798	650	523	4743	20737	17	11353	39821	203129
2001-02	1260	440	172	1576	6075	-	4540	14063	69367
2002-03	3456	1069	51	3612	9266	48	16853	34355	141820
2003-04	931	167	1412	3628	5642	2848	2144	16772	65574
2004-05	1323	174	47	1243	3691	-	3229	9707	56749
2005-06	1219	308	1541	882	2302	44	2829	9125	27586

Threats to the Ecosystem & Climate Change impacts

There are various projected climate change impacts in the state of Punjab. Based on meteorological studies, it has been reported that the temperatures in the Punjab region have increased in the range of 0.5-1.0°C till 2010 as compared to the base line of 1971-2000 (Anon, 2012). The annual mean minimum temperature is also projected to rise by 1.9-2.1°C by 2021-2050 (ibid). There are projections indicating increase in rain fall by 13.3%-21.5% with respect to base line of 1961-1990 however, rainfall during winter season is projected to decrease (ibid). These climatic variations along with various anthropogenic disturbances are affecting the distribution of species across forest areas in the state. Forests in the Shivalik region of the state which are highly fragmented because of various socioeconomic pressures are further likely to get adversely affected due to changes in rainfall and temperature. However, the Net Primary Productivity (NPP) of the forest vegetation is likely to increase by 0.6 to 1.2 kg C/m2/year in 2021-2050 (ibid).

Economic species like *Acacia nilotica* and *Dalbergia sissoo* are declining rapidly in the state due to a combination of factors. A recent study on high rate of mortality of these two species attributes it to fungal and insect pests infestations and various biotic, climatic and environmental factors. The climatic factors such as variation in temperature, rainfall, relative humidity are creating favourable conditions for the growth of fungus and pest (Anon, 2012).

Ways forward to meet timber requirements

1. Enhancing the Forest and Tree Cover (FTC) of the state

The state has an ambitious green cover target of 15%, which is unachievable given the present scenario of unavailability of land due to cultivation and other demands, 82% of the area is under cultivation. However there is a vast scope of increasing to at least 10- 13% provided if the tree cover outside the natural forests are enhanced by supply of quality planting stock to the needy farmers, improving the stocking in the existing open and scrub forests, improving the net productivity of existing forests by more growing stock per ha and through community participation in forestry planning, execution and management. Such effort requires careful planning, site specific treatment, research and budgetary support for time bound planting of about 100 sq km per year to achieve results. Keshopur and Lalwan Community Reserve examples of the state in Gurdaspur and Hoshiarpur Districts, which are the country’s first ever initiatives for biodiversity conservation could be replicated in forest management as well.

Improving the natural stocking in moderately dense (to an extent of 735 sq km) and open forest (1036 sq km) categories through improved planting stock and assisted natural regeneration technologies using site specific treatment considering suitability in terms of silvicultural, climatic, biotic and edaphic conditions of the locality. These forests can be planted with improved clonal shisham and khair as most of these areas are found along shivalik hills.

All roadsides, railway strips, canals are notified as protected forests in Punjab by a single government notification, which has given a boost for forestry plantation, protection of these strips and enhanced green cover in the state. However, recent road expansion projects have denuded the existing green cover. But there is a vast scope to plant the widened roads once the expansion projects are complete. Forest Conservation Act (FCA), 1980 has also has come in handy to get the compensatory afforestation for areas diverted for such projects as well as getting equivalent areas for afforestation. The Forest Corporation buys such land banks and allots to forest department from the user agency, which pays for land cost under FCA, 1980.

2. Yield enhancement by improving net productivity of natural forests and plantations

Global Forest Resource Assessment, 2015 by FAO has estimated total growing stock in Indian forests to be 5167 mi m^3 and 73 m^3 per ha, which is far below many regions such as Brazil (196 m^3/ha), Russia (100 m^3/ha), USA (131 m^3/ha), Cango (230 m^3/ha), Cameroon (308 m^3/ha) etc. India even lacks behind Indonesia (112 m^3/ha) and Malaysia (227 m^3/ha) in terms of growing stock (Anon, 2016). The mean annual increment of Indian forests is less than 1 m^3 $ha^{-1}yr^{-1}$ against the world average of 2.1 thus resulting in huge deficit and import of wood. Plantation forestry in various countries have resulted in enhanced yield of about 45 m^3 $ha^{-1}yr^{-1}$. Promising clones of eucalyptus by ITC have enhanced the annual yield to 16-20 m^3 $ha^{-1}yr^{-1}$ under moderate rainfall at the age of 3 years against 5-6 m^3 $ha^{-1}yr^{-1}$ by seedling origin (Lal *et al.*, 1994). Such mammoth efforts of increased productivity in collaboration with research by Government, Public and Private Institutions and captive plantations in available non cultivable lands could boost the production of wood. Punjab has been successful in establishing the clonal and seedling seed orchards in shisham and few other species and thus endeavouring for enhanced productivity through such improved clonal planting material in commercially important species (Luna and Ashok Kumar, 2006).

3. Potential of TOF, Agro forestry, Extension forestry in Punjab

In Punjab, agroforestry can not only help in increasing tree cover but also meeting the demand supply gap of forest products. According to the Punjab Remote Sensing Centre survey in 2006, the state has 0.37% (188 km^2) of total geographical area of the state under agro forestry plantations. Barring districts of Gurdaspur, Faridkot and Nawanshehar, all other districts have less than 0.5% of geographical area under agroforestry plantations. The maximum area of agroforestry plantation is under Poplar, which is around 0.13% of the total geographical area of the state. It is estimated that about 4000 ha is planted annually with Poplar in three states of Punjab, Haryana and U.P promoted by WIMCO Ltd. (Jones and Lal,1989). The present productivity varies from 15-20 m^3 ha^{-1} yr^{-1}. This area can be increased upto 0.50 to 1% in Punjab state alone to enhance the tree cover and productivity in the state. Other agro forestry species such as *Eucalyptus, Shisham, Kikkar and Drek* should be promoted on large scale depending upon the agro climatic and other site conditions.

4. Alternative fast growing multipurpose tree species

Drek (*Melia species*)- Drek is commonly planted on field boundaries. However keeping view the deciduous nature of plants it is suggested to plant drek in field also. During recent years farmers have started planting drek as blocks in fields along with crops. Due to fast growing nature of drek, it can be good alternative to poplar and eucalyptus. Due to price crash of poplar in the recent past and water uptake & allelopathic effect controversy related to eucalyptus, drek can be considered as a good agroforestry tree. It can be grown on variety of soils ranging from light to heavy texture even in saline and alkaline conditions. Drek leaves are easily decomposable which improve the soil properties, thus benefitting the trees and crops. This species has been planted widely at present in Punjab. Neem and mango are few more alternative species suggested for shivalik region while *Terminalia arjuna and Syzygium cumini* are suitable for waterlogged saline alkaline affected tracts of other regions.

5. Alternative to round wood requirments

Veneers, composite wood and other alternatives are the need of the hour and need to be promoted in al large scale to reduce the demand for sawn timber. Similarly reduce, re use and re cycle are to be strictly implemented for reducing the waste generation in terms of paper etc. Wood treatment for ensuring durability have been developed in the past and must be applied extensively to utilise lesser known timber species across the nation. User friendly farm forestry and agro forestry policies and relaxation of timber transit rules within the state would also help in promoting large scale plantations of important timber species. Long term visionary planning is needed in every sector for sustainability which is at present lacking.

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Neem Timber – A Revisit

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Introduction

Neem (*Azadirachta indica*) is one of the most suitable and valuable tree species found in India. It can grow on wide range of soils upto *pH 10* which makes it one of the most versatile and important trees in Indian sub-continent. Due to its multifarious uses, it has been cultivated by Indian farmers since vedic period and it has become now part of Indian culture. In India, it occurs throughout the country and can grow well in every agro-climatic zones except in high and cold regions and dam sites. In fact in India,*Neem* trees are often found growing scattered in the farmers fields and on the boundaries of fields without much affecting the crops. Farmers practice this system just to meet the local demand for timber, fodder, fuelwood and also for various medicinal properties. Due to its deep tap root system, it does not compete with annual crops for scarce soil moisture.*Neem* tree can be labelled as wonder tree for its multipurpose uses in real sense. This has been used as a medicinal plant for long time and provides almost all the requirements of rural areas - be the ***timber, fuelwood, fodder, oil, fertilizers, pest repellant or the ubiquitous 'datun'.***

Forests are not uniformly distributed in India. Some regions have quite considerable forest cover, while others have nothing as forests. Fuelwood is the most important form of household energy in both rural and urban areas (mostly poor people) and represents about 90% of the total demand of wood. Many poor people living in and around the forests depend heavily on fuelwood and fodder for subsistence needs and income from gathered forest produce. In rural areas fuelwood provides 70% of fuel for cooking, 5% comes from commercial fuel, and rest from cow dung and agricultural residues. Only 15% of fuelwood are purchased, 62% are collected from forest and public lands, and the remaining 23% are collected from private lands.

The total growing stock in the country is estimated to be 5768 million cubic meter comprising 4395 million cubic meter inside forest areas and 1573 million cubic meter outside recorded forest areas (TOF). The growing stock of *Azadirachtaindica*is 7.31 % in total volume (FSI, 2015).

Exports and imports of wood and wood products in IndiaThe production potential of the wood generation is restricted about 0.7 cu.m/ha/yr. in the country comparing to the average demand of 2.1 cu.m/ha/yr., which shows a huge gap between demand and supply (IFPI, 2013).A large quantity of wood and wood products are being exported to many countries and also imported many countries.

Exports of wood and wood products

Year	**Quantity**		**Values**		
	Woods (m^3)	**Wood products (Tonnes)**	**Woods (₹. Millions)**	**Woods products (₹. Millions)**	**Total (₹. Millions)**
2010-11	43822	24162.29	892.93	137.99	1030.92
2011-12	42218	911.433	1126.96	140.57	1267.53
2012-13	39759	3149.883	1808.45	269.51	2077.86
2013-14	58666	1756.964	1903.74	463.56	2367.30
2014-15	31586	1914.791	2047.32	361.19	2408.51

The country has become a major importer of tropical timber, particularly logs. Of the total exports, primary products accounted for 23796 cu.m, secondary products 113679 cu.m and tertiary products 4089 cu.m. The leading products in each category were billets (12464 cu.m), air dry sawn wood 53975 cu.m and mouldings 3955 cu.m. Markets in asia imported 83797 cu.m.of Ghana's wood products mainly poles and billets destined for India, followed by African regional markets 20% and Europe 13%(TTMR, 2015).

Imports of wood and wood products

Year	Quantity		Values		
	Woods (m^3)	Wood products (Tonnes)	Woods (₹. Millions)	Woods products (₹. Millions)	Total (₹. Millions)
2010-11	4856486	15105.74	62765.15	738.71	63503.86
2011-12	6662807	17488.22	100675.70	794.33	101470.03
2012-13	7035808	21865.55	123243.11	1029.60	124272.71
2013-14	6603482	313782.7	132268.87	432744	136596.31
2014-15	6717557	412874.3	128462.31	5212.52	133674.82

Source: (FSI, 2015)

Neem Wood

The neem is member of mahogany family and properties of wood resembles mahogany. The neem sometimes called as "Indian mahogany" because it resembles mahogany. In olden days neem wood is used as fuel wood and charcoal making which yields excellent quality with calorific value of 4500 KCal/kg.

The neem in recent days has emerged as a tree of choice for afforestation projects and for meeting the fuel and timber needs under developing countries (Puri, 2003). The wood was found to be naturally decay resistant, absorb minimum amount of water, so good for outdoor use and for timber for house construction.On the basis of tests for glue adhesion, tensile strength, bending comprehensive strength amenability for preservation and fire proofing treatment, it is suitable for plywood.

Neem wood anatomy

Gross features

The wood of neem is diffuse porous. The growth rings in the wood are distinct. Vessels are medium, ranges from few to moderately few, solitary or in radial multiples of two to three, often in clusters and numerous (16-20 per mm^2).

The vessels are filled with reddish gummy deposits. Whereas the soft tissue forms bands delimiting growth ring and also associated with vessels. The Parenchyma present in wood is apotracheal which is irregularly placed, tangential and continuous bands delimiting growth rings, also the parenchyma may be paratracheal banded or Vasicentric and in tangential lines connecting vessels are seen. Then the rays arefine to medium sized, numerous and somewhat widely spaced which are uniserate to multiserate and heterocellular (Nair, 1988).

Type of wood

Wood present in neem is hardwood. The heartwood is red when first exposed, but in sunlight it fades to reddish brown. It is aromatic, beautifully mottled, narrowly interlocked, and medium to coarse in texture. It is subject to only slight shrinkage and can be readily worked by hand or machine. Although it lends itself to carving, it does not take a high polish.

The timber is durable even in exposed situations. It is seldom attacked by termites, is resistant to woodworms, and it makes useful fence posts and poles for house construction. Pole wood is especially important in developing countries; the tree's ability to resprout after cutting and to regrow its canopy after pollarding makes neem highly suited to pole production.

Wood testing in neem

Static bending test

Modulus of Rupture (Kg/mm^2) = 89 and Modulus of Elasticity (Kg/mm^2) = 9666.

Compression parallell to grain: Maximum crushing stress (MoR) **(Kg/mm^2) = 47.1.**

Drying and shrinkage

The shrinkage characteristic of neem is having high volumetric shrinkage compared to teak (Akpan, 2007).The wood dries well, green conversion followed by open stacking under cover recommended. Shrinkage occurs during drying process from green to oven dry. And shrinkage varies with direction in case of radial 4.5%, Tangential 6.2% and volumetric shrinkage is 10.7% (TTMR, 2015)

Mechanical Properties of Neem Wood

Pearson and Brown (1932) gave the following mechanical properties of neem wood:

- Compression parallel to grains lb/sq inch = 6680
- Shear parallel to grains lb/sq inch = 1326
- Module of elasticity or Young modulus = 1,008,800

Sekhar and Gulati (1971) determined the strength parameters of neem wood with respect to teak (*Tectona grandis*) as 100, which are as follows:

- Weight at 12% moisture content = 124
- Strength and stiff as beam = 87
- Retention of shape = 77
- Shear = 129
- Surface hardness = 131
- Refractoriness = 113
- Nail and screw holding power = 117

Wood working properties

It is relatively heavy, with a specific gravity varying from 0.56 to 0.85 (average, 0.68). When freshly cut, it has a strong smell. Although easily sawn, worked, polished, and glued, it must be dried carefully because it often splits and warps. It also splits easily when nailed, so that holes must be pre-bored. Nevertheless, it is a good construction timber and is widely used in carts, tool handles, and agricultural implements. In South India it is a common furniture wood.

Production of neem wood

Neem tree plantations produces a timber of 40 m^3/ha to 60 m^3/ha in 12 years (Tropical Timber Market Report, 2011). The annual production of biomass in neem plantations is reported to be between 3 and 10 m^3 per ha. This classifies it as a medium fast growing species, slightly slower than fast growing species such as *Casuarina, Leucaena, Acacia* and *Eucalyptus* (Hedge, 1991).

Neem wood usage

The wood of neem is rough grain so it doesnot polish well and wood is nevertheless, used to make wardrobes, book cases and closets as well as packing cases, because the wood is having insect repellent quality which helps to protect the content from insect damage (Orwa*et al.,* 2009).

The neem timberisclassified as high density timber and having good cleavage strength properties based on shear parallel to the grain strength. And hence it can be used in making furniture, tool handles, artificial limbs and joinery (Gillah*et al*., 2008)

Neem in Agro-forestry

The tree component in the agro-forestry systems is preferred to be of local use, easily marketable with good economic value. Although *Neem* is not considered as the best tree species under agro-forestry systems nevertheless, in many parts of India it has been found to be suitable as agro-forestry species. In arid and semi-arid conditions *Neem* along with other tree species increased the productivity of fodder can be increased from 0.5 to 3.6 tonne / hectare. *Neem* is one of the tree components used in ***"Taungya system".*** In Maharashtra, *Neem* is grown along with *Acacia* in lines in combination with agricultural crops like *cotton, sesamum, arhar*, etc. Here *neem* is used as a buffer to control insect attack on *Acacia*. *Neem* tree is also planted on farm lands in Karnataka, AP and Tamil Nadu. It has been reported that reduction in grain production under *Neem* during 2nd and 3rd year varied from 13 to 33% while this reduction under Subabul varied from 66 to 99% for 3rd year. *Neem* has been found to be very effective in wind break /shelter belts in dry areas particularly on sandy soils to protect the crops. It has been reported that three rows of *Neem* Tree 250 to 300 km long have been planted in West Africa to check the advance of Sahara desert. *Neem* is known to increase the soil fertility and water holding capacity as it has a unique property of calcium mining which changes the acidic soil into neutral ones. It has been recommended to plant *Neem* trees with intercrops for the management of effected soils. These reports have shown that *Neem* might be a good agro-forestry species, however much more experiments with large number of agricultural crops are necessary.

Conclusion

Even though neem has multifarious utilities and applications, the tree has been utilized for its seeds as source of oil and azadirachtin, leaves as fodder, green manure, traditional medicinal uses and wood to a minimum extent as secondary timbers. However the species has not been utilized to its fullest potential. The species has not yet been cultivated as plantations, even though it occupies most of the farm lands as scattered trees, roadside avenues and as shade trees in many Institutes, organizations, industries, etc. As per the recent FSI (2015) estimate, Neem contributes 7.31% of the total growing stock under ToF. It has also been estimated that India's *Neem* bear about 3.5 million tonnes of kernels every year, from which about 7 lakh tonnes of oil might be recovered. But the annual collection and procurement was only around 1.5 to 2.0 lakhs tonnes because lack of organized collection and supply and hence the cost of neem seeds went up to Rs.85 per kg during 2016-17. Hence it is recommended that a national network on neem to be formed to bring all the stake holders together to discuss and develop a neem seed procurement policy using neem village concepts, etc. Regarding neem wood as timber, more focussed research works to be taken up in collaboration with timber and plywood industries for effective promotion and utilization.

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Wood Products from lesser known timber species for Jodhpur Handicraft Industries

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Abstract

India's annual imports of logs and wood products have increased from \$500 million to \$2.7 billion over the past decade. Restrictions on domestic harvesting from forests coupled with limited forest resources have limited supply, while expanding consumer and commercial interest in wood interior products and wooden furniture have increased demand. India is also becoming a furniture exporter, turning imported wood into finished products for export. More than two thirds of log imports come from Malaysia, Myanmar (formerly Burma), and New Zealand due to a freight advantage and relatively lower prices. Major log imports from these countries include hardwood species of teak and meranti and softwood species of pine. Other major suppliers of logs to India are Cote D'Ivoire, Papua New Guinea, Gabon, Ecuador, Costa Rica, Panama and Cameroon. In 2013, imports from United States were valued at \$54 million which included log imports valued at \$20 million.

Jodhpur handicraft industry in Rajasthan, well known for its wood-work, is one of the most prominent industry and with the rise of handicraft export, Jodhpur has emerged as a mega crafts cluster within three decades. exporting goods worth 1600 crore with substantial share of wood products. Presently the industry is using woods of *Acacia nilotica* (Babool), *Dalbergia sissoo* (Shisham), *Tectnoa grandis* (Teak), *Mangefera indica* (Mango), *Azadirachta indica* (Neem) and other miscellaneous species. For sustainability of these industries, there is need to search lesser known, under exploited, locally available timber species.. However, these wood may be more susceptible to insect-pest and other

deteriorating agents. In a study conducted in AFRI, Jodhpur (2004) the combination of preservative chemicals Copper Chrome Arsenic (CCA) and Chloropyriphos was found effective against insect-pest attack on *Prosopis juliflora , Prosopis cineraria and Acacia tortolis*. Untreated wood of *P. juliflora* was not infected with any decaying agents till June 2009 after which decay was observed in the sapwood while damage is extensive in *A. tortilis* and *P. cineraria*. Value added product like sofa set, utility box and pen/pencil stand have been made from treated wood of these species. Treated *A.indica* wood converted to Coffee table as value added product. Treated wood are showing resistance till December 2016, indicating their potential for use in handicraft industry. To explore other lesser known timber species studies on *Azadirachta indica* and *Acacia senegal* are presently undergoing in AFRI, Jodhpur.

Introduction

India's annual imports of logs and wood products have increased from $500 million to $2.7 billion over the past decade. Restrictions on domestic harvesting from forests coupled with limited forest resources have limited supply, while expanding consumer and commercial interest in wood interior products and wooden furniture have increased demand. India is also becoming a furniture exporter, turning imported wood into finished products for export. More than two thirds of log imports come from Malaysia, Myanmar (formerly Burma), and New Zealand due to a freight advantage and relatively lower prices. Major log imports from these countries include hardwood species of teak and meranti and softwood species of pine. Other major suppliers of logs to India are Cote D'Ivoire, Papua New Guinea, Gabon, Ecuador, Costa Rica, Panama and Cameroon. In 2013, imports from United States were valued at $54 million which included log imports valued at $20 million. (Anon 2014)

In 2011, only 3.2 million cubic meters (mcm) of wood were produced from Indian forests, while the vast majority of domestically harvested wood was harvested from "trees outside of forests" such as tree plantations, farms, and private lands. There is no official estimate of the amount of annual production from trees outside of forests, but the estimate of the potential wood that could be harvested was 43 mcm in 2011, significantly more than the amount harvested from forests(Table 1). Land ceiling laws limit the amount of land that private firms can own for tree plantations and complex transport and cutting permits in forests and local tax laws also complicate the production and movement of forest products, limiting the domestic industry's ability to expand. (Anon 2014)

Table 1. Estimated annual production of wood from forests and tree outside forests

S. No.	State/ UT	Recorded Forest Area (Km²)	Estimated production of wood (m cum) from forests	Growing stock of TOF	Estimated production of timber (m cum) from TOF
1.	Andhra Pradesh	63814	0.138	115.683	1.939
2.	Arunachal Pradesh	51540	0.064	74.516	0.762
3.	Assam	26832	0.025	41.336	1.355
4.	Bihar	6473	0.007	47.195	1.209
5.	Chhattisgarh	59772	0.397	70.069	1.826
6.	Delhi	-	-	1.040	Negligible
7.	Goa	-	-	3.895	0.019
8.	Gujarat	18927	0.099	117.993	3.099
9.	Haryana	1559	0.108	15.268	1.975
10.	Himachal Pradesh	37033	0.231	21.146	0.939
11.	Jammu and Kashmir	20230	0.055	147.745	0.830
12.	Jharkhand	23605	0.013	51.308	1.327
13.	Karnataka	38284	0.049	101.733	2.023
14.	Kerala	11265	0.068	49.059	1.628
15.	Madhya Pradesh	94689	0.397	85.106	3.168
16.	Maharashtra	61939	0.203	147.029	3.519
17.	Orissa	58136	0.029	73.624	1.418
18.	Punjab	3084	0.090	19.305	2.650
19.	Rajasthan	32639	0.057	81.560	3.463
20.	Tamilnadu	22877	0.013	70.328	0.834

S. No.	State/ UT	Recorded Forest Area (Km²)	Estimated production of wood (m cum) from forests	Growing stock of TOF	Estimated production of timber (m cum) from TOF
21.	Uttar Pradesh	16583	0.425	81.683	5.082
22.	Uttarakhand	34651	0.250	20.917	0.697
23.	West Bengal	11879	0.317	45.693	1.436
24.	Other NE states	64988	0.124	63.136	1.553
25.	UTs	8739	0.012	2.063	0.031
	Total	**769538**	**3.175**	**1548.427**	**42.782**

(Source: Anon, 2011b)

Two policies have had a significant effect on the industry over the past 30 years. In 1988, the National Forest Policy called for greater substitution of wood wherever possible and the development of agroforestry. It also determined that forests should be used primarily to meet the needs of India's tribal people, scheduled castes, and small scale industries. Any large commercial operations required government approval of the management plan, but states could designate areas for commercial harvesting. This policy slowed timber production and removed much of the financial incentive for large scale harvesting of wood, it also ushered in the beginning of India's sustained importation of logs. (Anon 2014).

Timber production dropped again in 1997 when the Supreme Court ruled that only the central government could approve the use of forestry land for any non-forestry purposes. This effectively stopped the states from "de-reserving" certain forests for commercial harvesting and closed saw mills that did not have explicit approval from the central government to harvest in forests. The action drove domestic production even lower, especially in India's northeastern states where much of India's forests are located. The Court's action coupled with stronger economic growth over the past decade has led to a sustained increase in India's wood imports. (Anon 2014).

Jodhpur Handicraft Industry:-

The Jodhpur wooden furniture has been always in great demand across India and outside during last two and half decades. Jodhpur Handicraft Exporter's Association (JHEA) was registered in 1998 to strengthen the network of handicraft exporters, globally The rise in export is phenomenal from zero to Rs. 1600 crore in two and half decades. The industry is givivg employment to about 3 lakhs peoples comprising artisans, craftsperson, skilled, semi-skilled workers and unskilled labours. In the central budget of 2012-13, Jodhpur has been identified for the development of a handicraft mega cluster, which will further strengthen the industry.

Information's related to wood consumption, choice of tree species, treatment of timber, export etc were collected through structured questionnaire and randomly selecting 15 % industries for data collection. The data analysis revealed that industry has diversified the wood species and the commonly used wood by the industry are Mango (***Mangifera indica***) **by** 94% of the industry**,** Shisham **(*Dalbergia sissoo*)** 67.6%, Babool **(*Acacia nilotica*)** 62%**,** Teak **(*Tectona grandis*)** 15%, Jamun, Neem and Eucalyptus 3% each**.** Wood is mostly obtained from Gujarat, UP, MP, Punjab, Haryana and from IGNP in Sriganganagar in Rajasthan. The end products are exported to Europe (100%), USA (~60%), Australia & New Zealand (~10%), South America, Japan & S. Africa (~8.5%) and Gulf countries. The Govt.has opened ICDs centre at Jodhpur to facilitate export of handicrafts. (Rathore *et al*., 2011).

Table 2. Year wise export of wood based handicraft items from Jodhpur

Year	Total containers	Total export(Rs in crore)
2007-08	26,584	1300
2008-09	18,926	800
2009-10	21,567	1100
2010-11	23,846	1300
2011-12	25,048	1600
2012-13	25,686	1400
2013-14	24,961	1500
2014-15	26,986	1300

Wood availability options

The industry has responded to the changes in the availability of the wood, quality of wood and the prices of wood by shifting to lower priced Shisham wood, which is though, not mature wood and is susceptible to pest attack. The industry has introduced the concept of Seasoning and Chemical treatment of wood to overcome these poor quality aspects of cheap wood. Thus, the industry has been able to remain price competitive in the export market (Yadav, 2003). Only 21% members have their own seasoning, preservation and treatment plants, while others are dependent on the industries having treatment plants. However, 100% new wood is used after seasoning and treatment considered important steps of wood industries towards sustainable development (Rathore *et al*.,2011).

Use of alternate wood

In 2006 the commonly used wood species by the industry were Sheesham (*Dalbergia sisso*) 70%, Mango (*Mangeferia indica*),20%, Babool (*Acacia nilotica*) 10%, Kadam (*Anthcephatus chinensis*) 5% and other miscellaneous species 5% however, due to lack of large scale plantation industry complains about poor availability of Shisham and Teak.wood and with time pattern changes . As per the survey done in 2011 the wood consumption pattern in different industries is Mango (*Mangifera indica*) 94%, Shisham (*Dalbergia sissoo*) 67.6%, Babool (*Acacia nilotica*) 62%, Teak (*Tectona grandis*) 15.0%, Jamun, Neem and Eucalyptus 3% each.

To overcome the problem of wood shortage, the handicraft industry of Jodhpur had requested Arid Forest Research Institute (AFRI), Jodhpur to conduct research on locally available alternative timber species in making the Handicraft Export Industry self- sustained in local variety of wood for making handicrafts in arid region to reduce the cost and improve life span of wood by simple chemical/preservative treatment.

There are many other plant species such as *Azadirachta indica*, *Syzygium cumini Acacia leucophloea* and *Cordia myxa* whose wood is utilized sporadically. Systematic scientific studies are needed for their use as alternative wood.

Species that can be used by Handicraft industries

***Syzygium cumini* Wood:** The wood is red, reddish-gray or brownish-gray, with close, straight grain. The very small, oval pores are often connected by waxy belts of loose tissue. The modularly rays are so fine as to be clearly visible only when greatly magnified. When fresh, the sapwood is attacked by power post beetles, pinhole borers and ambrosia beetles. Both sapwood and heartwood are perforated by the borer, *Aeolesthes holosericea,* if the bark is left on for as long as 10 months. Air-dried wood is apt to crack and split. When kiln dried, the heartwood is hard, difficult to work but polishes well. It is durable in water and resistant to borers and termites; tends to warp slightly. In India, it is commonly used for beams and rafters, posts, bridges, boats, oars, masts, troughs, well-lining, agricultural implements, carts, solid cart wheels, railway sleepers and the bottoms of railroad cars. It is sometimes made into furniture but has no special virtues to recommend it for cabinetwork. It is a fairly satisfactory fuel.(Arya, R et al.2004)

Acacia leucophloea Wood.

The wood of this species is strong, heavy and hard with a specific gravity of 0.71. It seasons well and takes a good polish (Troup 1983). The brick-red heartwood is very beautiful and is used to make decorative furniture. The pale yellow sapwood is perishable. Commodities produced from the wood include poles, farming implements, carts, wheels, turnery, construction timbers and fuel. The utilization of this species is limited because its wood has irregular interlocked grain, a rough texture, is difficult to work and is not durable

P. Juliflora *is* widely distributed in India and most abundantly found in the arid western parts of Rajasthan and kutch region of Gujarat states, is mainly known for is fire wood value and as weedy infestation (J.C.Tewari *et.al*. 2000). Wood is resistance to decaying agents and displays distinctive straight or swirling grain that ranges from golden brown to dark reddish orange in colour. The wood colour compares favourably to the Indian rose wood (Shisham). In fact *Prosopis* wood equals or surpasses the physical and mechanical properties of other commonly recognized fine hardwood in India. The surface hardness of wood makes it ideal for furniture and flooring application. This wood exhibits good turning, finishing and polishing properties. In India, use of this wood in furniture industries is very limited, because of non availability of straight bole trees and also to some extent because of lack of knowledge. This call for immediate attention to better manage trees with clean bole of around 2-3 m length and 1-1.5 m girth.

Prosopis cineraria is a versatile species, providing fodder, fuel for timber, and shade, as well as affecting soil improvement and sand dune stabilization. It is commonly used in dryland agro forestry in India. *P. cineraria* provide excellent firewood (calorific value, ca. 5,000 kcal/kg) and charcoal. Its wood is favored for cooking and domestic heating (Sanderson; M.S and PJC Harris 1991). Hard and reasonably durable, the wood has a variety of uses for house building, posts, tool handles, and boat frames, its usefulness limits as timber due high infestation to pests, insects, termites and fungus. Wood is pale white light in weight having moderate to poor finishing and polishing properties as compared to *P. juliflora*.(Arya et al.2004)

Azadirachta indica:- heartwood is strong and durable.Sapwood yellow to yellowish-grey turning pale yellowish brown on exposer, heartwood reddish to reddish brown darkening on exposer; wood somewhat lustrous, hard to very hard, usually heavy (specific gravity 0.72 to 0.83 air-dry),reported to be aromatic when fresh(but specimens in the wood collection do not have any characteristic odour),interlocked-grained sometimes exhibiting ribbon-grain effect on the longitudinal surface, usually medium to somewhat coarse-textured occasionally little finer in texture when fast grown ,a good figure is often noticeable in plain sawn boards due to parenchyma bands as well as small knots.(Tewari D.N. 1992) Its grains are interlocked, and consequently the wood does not split apart very easily. Because of its strength, it serves as a material for constructing oars, cart axles and felloes for cart wheels. In spite of its coarse grain, neem heartwood is fairly easy to work. The application of either machine or hand tools yields satisfactory results. It can even be crafted into toys. The heartwood of the neem tree resists such pests as wood borers and termites. Similarly, ***Acacia senegal*** wood is locally valued in construction for poles and fencepost, the light-colored wood for tool handles and dark heartwood for weaver’s shuttles. No systematic study on the use of *A. indica* and *A. senegal* wood for use in Handicraft industry was conducted so far.

Work done at Arid Forest Research Institute, Jodhpur

For sustainability of these industries, there is need to substitute the traditionally used wood by lesser known, under exploited, locally available plantation grown timbers. Wood from three species *viz. A. tortilis, P. cineraria* and *P. juliflora* treated with combination of preservative chemicals Copper Chrome Arsenic (CCA) and chloropyriphos in June 2004. It enhanced the resistance of wood to fungal and insect pest infection and there by increased durability and shelf life compared to control samples. Value added product like sofa set, utility box and pen/ pencil stand have been made from treated wood of these species. Treated wood are showing resistance even after six years indicating their potential for use in handicraft industry. Industry is already using mango and babool wood on a very large scale (Jain et al. 2005).

In continuation to above research, further research work on *A.indica* and *A.senegal* wood is initiated under DST, New Delhi Funded project in the year 2014. Wood of *Azadirachta indica* was obtained from fallen trees inside AFRI Campus and *A. senegal* from the confiscated wood from forest depot in Barmer through DFO. A letter for collaboration is given to Sun Art Export, Jodhpur for seasoning and preservation work. The process of wood conversion to sawn wood of neem and senegal wood was completed with the help of Sun Art Export Jodhpur.

The conventional wood preservatives like copper chrome arsenic composition (CCA) is well known to protect the wood from wood –degrading organisms, but cause environmental pollution as it contain arsenic. Hence, inventions are being done to replace the arsenic compound and attempts were made by many workers to impart durability by treating the wood with natural and synthetic chemicals. Literature revealed that there is objection to the use of arsenic therefore, To find out an alternative to Chromium and Arsenic in Copper Chrome Arsenic complex mixture Institute of wood science and Technology (IWST) Bangalore has worked upon a alternative mixture replacing Chromium with Potassium dichromate and Arsenic with *P. juliflora* bark extract under laboratory conditions. We want to check it at industrial level. Therefore, Preparation of complex mixture of Copper sulphate, Potassium dichromate and *P. juliflora* bark extract was completed in laboratory.

After treatment and seasoning was done at Sun Art Export Jodhpur. Treated neem wood was converted into Value added product (coffee table) was prepared.

Previously made Value added product in 2004 like sofa set, utility box and pen/pencil stand after treatement of wood with CCA are showing resistance till December 2016, indicating their potential for use in handicraft industry.

Sofa made in 2004

Coffee Table made in 2016

Conclusion

Harvest wood products as natural materials have environmental attributes that may be preferred over other competing materials. Forest products are renewable materials that can be relatively early recycled. furthermore, most solid wood products are produced with relatively little use of energy. this results in low ‘carbon footprint’ from their production and use,which is further enhanced by the fact that carbon is stored in wood products.

Most of the wood based industries complain of non availability of quality wood material and trained labours. They want that short term training courses be organized to train skilled and semi skilledlabours engaged in wood working to latest technologies developed in Indian and overseas research institutes.

There is need of quality planting material, improvement in plantation and management practices and search for alternative wood species. However, unlike paper and pulp industry, there is no public –private partnership in handicraft industry for the supply of wood from trees outside forests, tree improvement research in USA is funded by consortium of industries, which take-up large scale tree improvement programme (Kotiyal,2011) and there is similar mechanism in India for paper and pulp industry. Some of the handicraft industries in Jodhpur are willing to raise plantation with support from SFDs and research Institutes. However policy change is required from it.

In most countries, the substitution effect of Harvested Wood Products (HWP)1 is considered to be their key impact in climate change mitigation. Coordination, cooperation and mutual information between climate change country focal points and the forest sector is needed, as well as within the forest sector, while recognizing that reporting must be fit for the purpose.

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Experiences from the field in growing native timber trees at Palani Hills, part of Western Ghats in Tamil Nadu

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Introduction

The Palni Hills Conservation Council (PHCC) is a not to profit organization working to conserve the flora and fauna of Palni Hills from 1988 onwards, through various tree growing projects aimed at meeting the growing basic needs of communities for timber from farmers fields, so as to reduce pressure on forests at hill slopes.

Two and a half decades of tree growing efforts that have provided many tree growers with their own wood for making furniture door and window frames, for own use and for sale as well are presented in this paper.

For achieving the objectives, the PHCC have operated through six tree nurseries located at major water sheds in Palani Hills and also ran a nursery at the Cauvery delta for growing mangroves and useful species for the farmers whose sole income was and still is from paddy.

Synopsis

Primary focus has been on giving farmers harvestable timber from irrigated garden lands with in a span of 12 years with tree species like ***Gmelina arborea*** and ***Grewia tiliaeifolia***

[1] **The author is a coffee grower and has an honors degree in pharmacy from BITS Pilani and was chosen an Ashoka Fellow in 2003-04 for work with trees and bees.*

Secondary thrust area has been as shade trees for coffee plantations where Coffee growers are looking for alternate specie to Australian Silver oak ***(Grvellia robusta).***

Since most tree growers would have liking for luxury timbers like **Rose wood** (*Dalbergia latifolia*) and **Red sanders** (*Pterocarpus santalinus*) as they fetch premium market price, the nurseries of PHCC produced good quantities of these seedlings as well as Teak for agroforestry purposes.

The number of success stories: Within a span of two decades, tree growers have managed to get timber from a mixed cropping with various agroforestry systems. This indicated that a judicious choice of Species selection to match soil and water profiles can indeed give the farmers a good enough cash income to meet requirements like conducting weddings or paying for higher education of off-springs without getting into debt.

Methods of PHCC have been to take precedence from forest manuals and learn from old plantations that have survived the vagaries of anthropogenic pressure and weather events plus fires.

Matching provenances for seed selection and plantation sites are considered as well. Most important aspect is in tree cultivation is growing knot free timber that has market potential. Almost all farm workers are used to using a machete for pruning lower branches which always result in permanent injury and degradation of quality of timber.

During the last decade Neem (*Azadircahta indica)* has gained popularity among European Union members for use as cabinet wood. However, the supply comes from Africa where Neem was introduced from India for combating the expanding sands of the Sahara deserts. India fails to catch such markets.

Currently, planting of species in isolation at households, urban bungalows and educational institutions are taken into consideration as well. Species that await the opportunity and can fulfill demand for domestic wood production include ***Acrocarpus fraxinifolius***, ***Adina cordifolia*** and ***Vitex altissima.***

Much needs to be done to educate tree growers with regard to marketing of species for best price as there is a growing tendency among timber shops and merchants and to downplay quality of Indian timbers as opposed to imported woods.

Case for wood lots

Aiming for harvest cycles of suitable wood for specific purpose can provide a tree grower with a diversity of woods that are harvested at regular interval thus paving the way for ***wood lots*** instead of the present system of rows or shelterbelts where tree are grown.

Ignored but durable palm species

There is a need to look into species like Fishtail Palm (*Caryota urens*) that after death at about 15 years can provide strong and durable woods for making rafters and false ceilings as well as partitions within a house or office. However, due to lack of trained wood workers much of the ornamental palms in urban areas are wasted once they stop flowering and die after about 15 years of age.

Conclusion

India once provided lumber for ships that sailed the oceans and helped open new worlds (the Americas) for the Europeans. Sadly today we have to import timber for meeting the needs of urban markets. If concerted efforts are made to grow trees from farmland along with regular crops then once again the land will provide lumber for the India's own needs as well as for worlds needs.

Tree growing and its challenges - A Farmer's Perspective

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Tree Grower, Hosur, Tamil Nadu

Everyone in the world says "Grow Trees", but when it comes to selling, existing legal and policy act as a constraints. Tree growing is a challenge by its own nature, suitability of tree species for a particular soil, soil moisture, temp, humidity, wind, rain level, rain pattern, symbiotic plants, long gestation, changing market scenario and new diseases in the long run. We are passionate enough to overcome all this, provided there is a revisit in legal and policy issues to bring suitable amendments and facilitated with a focused **"Timber Development board"**.

Case study from my farm

Mango and Tamarind crops failed in my 25 acres of sloppy, eroded, dry, gravel, red Soil with rain of 750 mm, without rain for 6 months continuously. Finally, today, ended-up with only Red Sanders trees, it suited for the worst. Success, excellent, but legal and policy provisions are not in support of such success stories.

Currently, my farms have more than 40000 trees, 100 % rain water harvesting structure to hold 200mm of rain in 2 hours rate, with native grass, sheep grazing, *Aloe vera* under the tree, 100 of species mostly native, fittest of survival concept - will not facilitate much, no soil erosion, humus not wasted, simulating forest conditions, named as Brahmavanam.

The Natural Challenges- not in our control

Different rain patterns for each area, change in rain pattern, decreasing ground water, decreasing soil moisture, different soils, increase in temperature, decreasing humidity, hot wind etc, climate change is a complex. A suitable tree a decade ago may not be suitable now.

Ground water level is going down year by year, due to excessive usage, converting dry lands to irrigated ones with bore well and farmers moving on to coconut, a proven established market, which is sucking out ground water in summer, reduces ground water. Excessive means many times more than rain water percolation. When ground water goes down, soil moisture goes down, so tree growing becomes difficult.

The water challenge - need to plan based on future scarcity

I am planning for the worst scenario. Understood that all over the world, water for drinking is priority, will be diverted to cities. A TV episode clearly depicted on diversion of water in Jordan, and farmers were made to use treated drainage water. Similarly, in Paris, no other option. Now, it is happening in Cauvery delta belt. Mysore and Bangalore cities are growing exponentially, due to software industries and agriculture in Karnataka. So, in future, perennial Cauvery River may be perennially dry. I am training trees for worst, not using water, even though, it is available in my well, in 2nd farm, make it fit for worst.

Teak, *Pterocarpus marsupium*, *Pterocarpus santalinus*, *Hardwickia binata*, *Albizia lebbek* etc are drought hardy trees. India's 60% lands are rainfed, agriculture will not be viable in that, henceforth, trees are the only solution. India is growing in population, Industries, water usage so water is becoming scarce, precious, but no water treatment plants, **still producing more Sugar, Rice, Coconut than required and trying to export, which all requires lot of water**.

I would suggest that water demanding crops like coconut can be avoided in dry areas wherein water table is at about 1000 ft deep. Similarly, exporting sugar for Rs 20 (when it requires 2500 litres of water per kg) needs rethinking.

As reported in "Irrigation Insight", a report of Australia, concepts like Water Use Efficiency (WUE), Water Use Yield(WUY) and Water Use Income(WUI) of crops can be considered for our country as well.

Change in Timber Market

Market is losing its diversity. People prefer selected imported woods, Teak & some more. Our native *Pterocarpus marsupium* is also loosing its scope, similarly other species. Merchants make money by selling other woods like *Acacia Auriculiformis* as Teak. IWST has got good program to identify wood, needs to be spread more. Need to strengthen it to make native wood more usable with some treatment.

The Social Challenges

Trees and plantations are used by anti-social persons and trespasser as a hide place which in turn invoke many security issues and also create fire problem. Red sanders in my farm survived one fire, but lot of damages. Now planting *Aloe vera*, around the tree, to make use of the humus nearby and protect the tree from fire. Legal provisions is needed to address this issue.

Need a focus on strength, monopoly items

Our valuable Rose wood, Sandal, Red sanders, Ebony, Agar etc are our strength and monopoly items, but loosing it. Sandal is, now, more in Australia, they sell Indian Sandal, grown in their land in our country. Only law is hurdle for Sandal, nothing else. It is spread by birds, grows with other fruit trees and thorny plants in the borders, evergreen, good income, a medicine, will make world smell good. But Tipu sultan started laws, continued by colonial people still not changed. In our Krishnagiri district, still farmers are removing, sprouted from birds dropping near Mango trees, to avoid forest department's procedural difficulties. A natural opportunity suppressed. Karnataka has changed policy, farmers will be able to sell to industry directly, plantation is increasing, thanks IWST for their efforts to popularize and support it.

Our Indian Rosewood is dining table of British palace, but we may not have it in future. Who will grow when there is no permission to fell. I had planted, knowing its unique features, but planning to remove to avoid hassles.

Red sanders tree is a God's gift for our degraded, gravel, dry red soils of south India. Good demand, throughout the world, for spices, musical instrument, medicine and radiation controller. Instead of promoting it, India has lot of restriction, prices have skyrocketed, and smugglers satisfy the international demand, black money. Pathetic, if it would have been allowed to export from private lands, there will be less smuggling, India will get official foreign exchange and if price goes down to affordable level, the wood can be used for furniture also, seen a pillar in Gass Forest museum and a sofa in a farmers house, grown in coconut field, no hardwood.

Legal and Policy constraints

Laws mean for betterment, not for determent, it should facilitate greening trees particularly in barren lands, meet the needs and prosper the farmers. Indian farmers are mostly small land holders, finding it difficult with selection of tree species, sapling, growing. Teak preferred by users, so farmers go for it and it is drought resistant, used in all sizes and many more advantages. Teak is not a species found in Krishnagiri forest, still it required permission from local forest department. Such legal provisions may be revisited and required amendments may be made to encourage the tree growers.

CITES, Convention on International Trade of Endangered species from Wild flora and fauna, clearly aims to restrict endangered species trade from wild forest, encourages facilitating for propagated source. Hence, India can encourage the propagated source of endangered and valuable timber trees. Malaysia exports many endangered species with NDF reports, proving that it is from propagated source. It has Timber Development Board, which is the CITES MA & SA. Similar such Timber Development Board can be established in India.

The Policy challenges

Synergized and co-ordinated efforts among various policies and programmes of Government of India is a need of the hour. As of now, Agroforestry policy 2014 framed by Ministry of Agriculture, forest extension centre promotes tree growing, timber transit permission comes under regular forest department, Handicrafts division comes under Textile ministry, National Medicinal Promotion Board (NMPB) is under Ministry of Ayush, National Bamboo Mission under Horticuture Department.

Similar to agriculture crops, loan facility in support of tree farming may be provided, may be through NABARD.

NMPB gives subsidy for few medicinal trees, similar subsidy may be extended for other trees. Paying for the environmental services of the woodlot being maintained by farmers is another avenue to encourage tree farming in the country and in turn timber supply can be enhanced.

A report says that wood demand will triple in 2021, but action plan to meet the demand is needed.

The scientific institution Co-ordination

Co-ordination of various research institutions is needed in the Country for utilization of scientific resources. USA studied the distribution of *Pterocarpus marsupium* and based on its requirement of soil, environment they mapped a areas suitable in US, which helps to promote this species in USA. Similar such studies on other important timber trees will help in matching the species for a given site conditions.

Tree growing urgently needs Reforms to Perform and Transform

We need a Reform to Perform and Transform, as our Prime Minister says. Main objectives are to achieve 33% tree cover, 3 Billion MT carbon sink, Meet the timber needs, Reduce Import, Increase farmers income, Improve the groundwater level and Environment.

So, Legal Procedures for tree growing farmers shall be simple and facilitating.

1. Farmers shall be allowed to "Grow any Tree, Cut anytime, Sell / Export to anyone"
2. Wherever essential, farmers shall be asked to submit minimum documents online, permission shall be given with a time frame, maximum a month.
3. Single window system, like for Industries, agriculturist shall contact one place, for guidance, incentive, permission etc.

4. Digital India for tree growing. Starting from Cultivation techniques, economics, reference field details, market, concern scientific offices list, laws, procedures with its changing references shall be put on web. Like, CITES website is well documented with links to references and changes.

Formation of ***TIMBER DEVELOPMENT BOARD*** **– a need of the hour**

Under Ministry of Agriculture as envisaged by Agroforestry Policy 2014

It is proven that Coconut Development board, Tea Development Board, Sugar Board, have achieved in promotion of the respective crops. . Malaysia exports wood which has Timber Development board. So, Timber Development Board is needed with the objectives may be as follows:

- To make India not to Import wood by 2040, but to Export
- Estimate Demand and Supply, in the dynamic scenario.
- Map the native or selected exotic tree species based on its requirement and suitable available areas for each timber species.
- Co-ordinate with scientific institutions, synergize the timber production initiatives
- Facilitate with Certified tree nurseries, co-ordinate with banks, facilitate Industries for value addition and facilitate sale / export.
- Recognition for Tree growers in taluk, district, state and all India level on environmental day.
- Explore the new possibilities of wood usage.
- Online portal for Timber species cultivation, management, economics, proven field details, market, procedures, application for permission

Availability makes us use more, as in the case of easy availability of carry bags, made us use more plastic bags. So, Timber Development board will facilitate tree growing, promote wood products, which is better option than steel or plastic, as an environmental / nature friendly.

The facts and reports in support of the views expressed in this paper are:

Human rights, Article 1, point 2 says

All people may, for their own ends, freely dispose of their natural wealth and resources without prejudice to any obligations arising out of international economic co-operation, based on upon the principle of mutual benefit, and international law. In no case may a people be deprived of its own means of subsistence

High level committee of MoEFCC says.

Clause 5.6 says, While there is no bar on raising plantations of poplar or eucalyptus, this should be extended to include some other indigenous species also. Farm forestry is not likely to crowd out agricultural crops due to its longer gestation period; in the case of farmers this is likely to be carried out on the outer peripheries or bunds of their land. If this is encouraged there is likely to be considerable accretion to tree cover.

Clause 5.7 says. It has been suggested that plantation of approved species which are consistent with local ecology and biodiversity should be permitted on private lands. These can then constitute tradable units which can be purchased by UAs and transferred to the State Forest Department in full fillment of CA obligations. Also speaks about definitions of Forest and Tree lands, no-go areas etc.

Shri AK Bansal committee report, 2012, elaborate on timber transit difficulties

It studied timber transit rules of all states, understood it in details and suggests as, in general: State/UT Governance are free to have more simplified procedures than suggested above, provided that they enhance the incentive to take up farm/agro-forestry household.

It concludes as Mission (Long Term Goal): Felling and transit restrictions with respect to trees planted on non forest private lands are completely removed.

Agroforestry Policy, 2014

It clearly states land uses system, trees with crop and animals to meet multiple objectives of meeting food, fodder, wood, environment in changing climate conditions. It is possible only with native trees. Clause 2.1, 2.3 speaks about Restrictive legal, regulatory regime for harvesting and transportation of trees. It clearly says like … the mandate of agroforestry falls through the cracks of various ministries, departments, agencies, state governments etc. 2.3 clause says obtaining permission permits for harvesting and transportation are cumbersome, and costly and hence, discourages farmers from undertaking tree planting on farm lands. It finally says, in 5.1.1, need to create a Mission or Board, 5.1.2 says it shall be under Ministry of Agriculture.

So everything is known, only consolidation and action is required

So, this deliberation, shall insist to implement committee reports with our additional reforming suggestion, to move on to performance stage and transform India, to Green and Prosper, in harmonious with nature.

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6. Jordan water management method - TV show.
7. Malaysia CITES organization chart - shows Timber Development Board

Complexity of Marketing and Policy Issues Derailing the Silviculture of Indian Trees

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Abstract

Wood is a commercial and industrial product derived from forests, plantations and agroforests. The harvesting, extraction and marketing of wood products is a major issue in Indian scenario due to complexity of laws, policy and marketing. The past experience of over exploitation of forests had lead to implementation of forest policy 1988 and Forest conservation act, 1980 which totally cut the market and trade lines of wood produce from the forests. Many times the laws and policy are made to strengthen the system but in Indian forestry these became a halting blocks for wood commerce as neither able to conserve the trees nor enterprise it. Further the complexity of marketing, Monopolistic approach of forest department and policy derailed the silviculture of Indian trees in forests. When commerce in wood is restricted or banned so no silvicultural practices, system are followed for regeneration and improvement of the forest. The forest trees which were called renewal resources are now became dead stuff in commerce though they are providing ecosystem services. In many places due to ineffective monitoring and corruption promoting illicit felling of trees and government is loss for forest wealth, revenue and ecosystem benefits. An analysis suggests that after forest conservation act 1980, Indian forests has been deforested at much faster rate and policy paralysis in many cases further eroded the condition. If we have promoted the forest conservation as a progressive way rather oppressive way, the people support and forestry

sector economic growth might have regained. The implementation and post analysis is always rectifying but we never look behind after enactment of these acts which in long run even congested the sustainable yield concept of forestry form progressive yield which western forest managers are still working with SFM certification. Why Indian forest are not put on Sustainable Forest Management (SFM) mode rather complete ban on all silvicultural activities for improvement of forest growth and yield. This approach widened the gap between preaching and practicing of forestry education in India as most of the application of silvicultural practices is not applied in forests. Though in some pockets there are National parks in forest area and there for wildlife habitat management some tending operations are carried out along with selective felling but not the silvicultural practices. Therefore it is time to rethink in era of globilisation and climate change to harmonize the marketing procedures, felling rules and regulations, timber transit rules and policy to derive the benefits for larges interest of nation. This will ensure the effective human resource utilization in forestry and silvicultural practices adoption for strengthening economy of the nation.

Key Words: Silviculture, Market, forestry, policy, wood, SFM

Introduction

The Sustainable Development Goals (SDGs) are the main focus of FAO by helping countries to develop national plans, policies and programmes to achieve it. The 2030 Agenda recognizes that we can no longer look at food, livelihoods and the management of natural resources separately rather a coherent and integrated approach to sustainability across all agricultural sectors and food systems. Asia has the highest proportion of agricultural land (52 percent) and the lowest proportion of forest (19 percent). Europe, including the Russian Federation, has the lowest proportion of agricultural land (21 percent) and the second-highest proportion of forest (46 percent). Globally, agriculture accounts for more than one-third (37.7 percent) of the land area, and forest and "other" for just under one-third each (30.7 percent and 31.6 percent, respectively)(SOFO,2016). Indian forests are one of the unique constellations of forest types of the world within a country. The revised classification of forest types of India still prevalent with 16 forest types which further divided into 221 sub types (Champion & Seth, 1968). Besides this Forest survey of India divided Indian geographical areas into 14 physiographic zones with diverse forest types along with variety of trees. Approximately 1000 trees species are found in India out of which 10-20% are in timber use and only 5% are designated as major timber species. Natural forests are solely depend for restocking on natural regeneration especially in Reserve Forest (RF) and Protected Forest (PF) forests and in some cases have assisted natural regeneration. Wood is a commercial and industrial product derived from forests, plantations and agroforests. The harvesting, extraction and marketing of wood products is a major issue in Indian scenario due to complexity of laws, policy and marketing. The past experience of over exploitation of forests had lead to implementation of National forest policy 1988 and Forest conservation act, 1980 which totally cut the market and trade lines of wood produce form the forests. Generally the laws and policy are made to strengthen the system but in Indian forestry these became a halting blocks for wood commerce as it neither able to conserve the trees nor enterprise them. Further the complexity of marketing, monopolistic approach of forest department and policy derailed the silviculture of Indian trees in forests.

The productivity of Indian forests is very low 0.5-0.7 m^3/ha/yr compared to the world average of about 2.1m^3/ha/year resulting in a huge gap between the demand and supply, the demand by 2020 is expected 152Mm^3. As per national forestry action program, timber requirement of India was estimated as 82 million m^3 during 2006, whereas the domestic availability has been just 27 million m^3; moreover, in the last ten years, the money spent on import of wood has increased from US$1.0 billion in 2001 to more than $5.0 billion in 2011. Due to the scarcity of domestic timber resources and rapidly growing demand, wood imports in India have doubled since 2006 in order to meet the country's growing demands for wood products (RISI, 2013).To fill the gap two key approach will be raising quality planting stock mainly clonal material of high yielding clones and secondly expansion of farm/ agroforestry. To augment the good quality planting material in natural forest plus tree selection/ good seed bearers for seed production with assisted natural regeneration will be more effective. When commerce in wood is restricted or banned so no silvicultural practices, system are followed for regeneration and improvement of the forest. The forest trees which were called renewal resources are now became dead stuff in commerce though they are providing ecosystem services. In many places due to ineffective monitoring and corruption promoting illicit felling of trees and government is loss for forest wealth, revenue and ecosystem benefits. An analysis suggests that after forest conservation act 1980, Indian forests has been deforested at much faster rate and policy paralysis in many cases further eroded the condition.

Complexity of Policy issues in Forestry

In Indian perspectives as per FSI report, 2013 from 76% natural forest 63 % is seed origin while only 6% area is plantation forests. Further, only 7.6 % forest area has big timbers, 53% has recruiters and poles and 3.39 % area under agroforestry. Recently, FSI, 2015 reported 24.16 % (21.34 % + 2.82%) is total forest and tree cover in India. The figures gives a clear indication that neither recorded forest nor Trees outside forest has much improved in coverage as well as in the productivity. The onus of productivity of forest lies on quality planting stock or seeds for regeneration or plantation which seldom priority of forest department. The awareness about the quality planting stock in timber tree species is very low comparison to fruit trees. In recent times some plantation trees for paper and pulp, plywood etc. got attention due to clonal material and quick returns in farm/ agroforestry but in forest areas even in Unreserved Forests (UF) it is yet to be adopted. Indian forestry seen three forest policy 1998, 1952 and 1988 but none of them addressed the comprehensively forest seed and planting material for forest productivity neither it is dealt in seed act, 1966 and National seed policy, 2002 of India. As we know forest is major source of germplasm for trees and also for all kind biological system but unfortunate part is tree selection and improvement was remain neglected. During these many years good germplasm from accessible areas has been lost and whatever selection we are doing is dysgenic selection resulting poor quality stock. Therefore there is urgent need for selection and collection of good germplsam for raising seed orchards and planting stock for artificial regeneration with policy and legal framework for forest reproductive material (Manmohan, 2016).

The famous quote that “Nature has given us all the natural resources in abundance to meet our need but not greed” censures us for rational utilization of resources and wood is one among such resources which is a pioneer and versatile raw material for different products and can be recycled. It is a renewable resource provided the rate of regeneration of trees and their harvest is remains in equilibrium which is not in the present global scenario. These concerns highlighted in National Forest policy, 1988 and suggested for wood substitution. During these many years as a policy decision all private, government and other infrastructure projects replaced the wood material in construction by RCC or iron or plastics. Although in hill & forested areas wood resource is by and large sustainably available but government policy and laws directives restrict the use which dampen the wood utilization. The vary question is that promotion of wood utilization is not a policy directive and also not link with availability of material in wood surplus areas for use. The policy and legal restrictions alienating the silviculturist to promote tree farming due to controlled harvesting regime for most of the trees. We say forest management is application of scientific, technical, economical and social principles of the forestry but if we are not able to harvest the forest resources sustainably for social benefits than for what purpose we are managing them. The silvicultural systems practiced earlier for rational growth and yield of forest produce specially timbers have been totally derailed. The prescriptions in new working plan code 2014 included sustainable forest management (SFM) in all forest divisions followed by forest certification but until it is supported by specific law and policy, difficult to execute it. The effective implementation of National agroforestry policy, 2014 on farms and other waste lands can at least promote tree farming with precision silviculture and increased the productivity of planted forests. The proposed draft Forest policy, 2016 framed by IIFM, Bhopal for MoEF&CC have set 13 objectives, 55 policy directions and 8 supporting elements though marks a paradigm shift by switching focus from forest to landscapes, from canopy cover to healthy ecosystems, from substituting wood to promoting sustainable wood use, from participatory approaches to empowerment, from JFM to community forest management and from qualitative policy statements to result based policy frame work. Although it should have need to made clear demarcation of area of activities in the recorded forest areas with the help of NAEB and forest department to streamline silvicultural practices in establishment of new planted forests. Still hope is there by shifting of 1/3rd of forest in next one decade to community for commercial and livelihood programmes form forests with certain checks.

Marketing and trade issues of Forest products

Marketing and trade of forest products is a complex issue in India due lack of universal state policy and regular market mechanism. Unlike in agriculture sectors the MSP price fixation, market regulation and private supplier are not in government forests as well as in farm forests produce. There is no open market mechanism in timber trade and forest department has the major say rather all other stakeholders. If we have promoted the forest conservation as a progressive way rather oppressive way, the people support and forestry sector economic growth might have regained. The implementation and post analysis is always rectifying but we never look behind after enactment of these acts which in long run even congested the sustainable yield concept of forestry form progressive yield which western forest managers are still working with SFM certification. Why Indian forest are not put on Sustainable Forest Management (SFM) mode rather complete ban on all silvicultural activities for improvement of forest growth and yield. This approach widened the gap between preaching and practicing of forestry education in India as most of the application of silvicultural practices is not applied in forests.

In climate change adaptation and mitigation measures we are advocating the afforestaion in forests and agroforestry with focus on industrial wood for paper and pulp and plywood. The short rotation forestry may benefit our immediate requirement but to counter climate change we need to reorient the long / silviculture rotation for structural and furniture solid wood / timber to meet dual demand of future. The government forest (>90%) which are presently managed under conservation approach need to develop sustainable timber harvest based approach with adoption of adequate silvicultural practices for meeting wood demand and create carbon sink to mitigate climate change effect. The new agroforestry policy promulgated for tree farming on cultivated lands for additional income to farmers along with to change micro climate adaptive mechanism in agroecosystem to meet industrial wood demand. The similar wood promotional approach is needed for creation, conservation and utilization of structural and other solid wood from indigenous/ traditional timber species in government forests by SFM mechanism of certification. The defunct state forest corporations also require trained human resource for execution of reduced/low impact logging and extraction methods from natural forest without compromising the loss to regeneration, recruiters and biodiversity. The conflicts of policy should not hinder the wood utilization for implementation of wood substitution. Adoption of forest certification is need of time to promote the wood products utilization with policy directive rather conservative approach of total ban. There is need wood products to be listed and marked for wood substitution and/or utilization to clear the confusion among the people as consumer, grower, foresters and market & business enterprises. Further incentivizing the tree faming, farm forestry, agroforestry as suggested in new forestry and agrofrestry policy need to be operational with proper guidelines for all silvicultural operations including logging for effective utilization of tree resources. Tree / forest plantations insurance schemes need to farmed for major commercially important species for large scale adoption by farmers/ foresters at national level. Green India mission need to be made nodal agency for all plantation related funding and other related matters of incentives, insurance and clearances if any. Plywood and panel products industry need to be established across the country with rational distribution looking availability of wood raw material to realize the timber production with low carbon foot prints.

Derailing of the Silvicultural practices of Indian Trees

Majority of Indian trees are LKTS (Lesser Known Tree species) because of lack of industrial promotion vis a vis development of silvicultural package for these trees. In natural forests the few important trees need to be selected for raising planting stock and replanted in regular interval to enrich the quality stock for future. Its' known fact that natural forest productivity cannot be same as plantations/ farm forestry trees but at least plan to improve 3-5 m3/ha /yr when planted forests globally have 20- 50 m^3 /ha/yr. The issue of quality planting stock began form good germplasm/ selection and establishment of seed orchards for seed production and breeding and finally raising planting material for plantation but now people's participation can enhance the awareness for the same. There has been lot of tree breeding, biotechnological and clonal work done in different laboratories but silviculture of those selected species/ clones / improved material is not worked out resulting low returns. How can we think about marginalizing silviculture in tree improvement programme? The strategy of tree improvement needs to be relook in holistic way and development of field trials based on tree improvement principles. The silvicultutre of developed clones or varieties has to be worked for their life period or at least half of rotation to confirm the results and further improvement. The laboratory and nursery results seldom trusted for perennial long gestation trees. We feel the tree breeding work has to be followed by precision silviculture to make a complete tree improvement package of a species especially in timber species. Many times in industrial wood like paper and pulp, plywood the focus is on biomass only but in case of timber wood quality parameters are equally important along with physical and mechanical properties of wood. These wood quality parameters are response of silvicultural practices over the period of time on a species. The precision silviculture is not only requiring for short rotation forestry but also in long rotation trees to achieve higher quality and quantity of wood yield. Although advancement is done in clonal forestry and development quality planting material for Eucalyptus, Casuarina, Leucena, Ailanthus, Bamboo, Teak, Anthocephalus, Mahogany, Melia etc but still many species are on the way to reach this phase. Further, the silvicultural practices of many of LKTS are still to be developed after their selection and propagation is standardised to promote indigenous species. There is also need to develop linkages with all stakeholders for better feedback and refinement of strategy in tree improvement. The plant protections aspects are also limited to nursery and not adopted at plantation level which needs to look for enhance productivity along with irrigation/ fertiliser if possible. We are sure in future tree improvement programme will redefine the role of precision silvicvulture in tree improvement and bring it form margin to main frame of research plan to achieve the desired target and will increase the productivity our trees on farm and forests. Though in some pockets there are National parks in forest area and there for wildlife habitat management some tending operations are carried out along with selective felling but not the silvicultural practices.

Conclusion

Silviculture is soul of forestry and its functionality must be retained for betterment of forest ecosystem management and sustainable extraction of wood / timber from forests. Therefore it is time to rethink in era of globilisation and climate change to harmonize the marketing procedures, felling rules and regulations, timber transit rules and policy to derive the benefits for larges interest of nation. This will ensure the effective human resource utilization in forestry and silvicultural practices adoption for strengthening economy of the nation. Therefore use of wood is needed to promote through proper regulation, certification and assurance of sustained supply form forest, farm or urban conglomerations to tag carbon foot prints with long term utilization. To conclude we can say the complexity of marketing and policy need to be addressed for promotion of precision silvicultrual practices in forests & plantations to build wood based enterprise for strengthening the national economy through forestry.

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Acacia nilotica for rural livelihood – A review

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Abstract

Acacia nilotica is a multi - purpose tree species grown in India especially by the rural population. *Acacia nilotica* was established as very important economic plants since early times as source of tannins, gums, timber, fuel and fodder. It produce strong and tough timber and nearly twice as hard as teak. Its wood is good for carts, agricultural implements, Charcoal, construction purposes, pulp and papermaking. *Acacia nilotica* is extensively planted in social forestry programme in tank bed, farmlands, watershed management projects on field bunds and wasteland.

The Tamil Nadu Forest Department introduced *A. nilotica* as plantation in tankbed plantation in 1960 and 1981 under Social forestry programme in 8,296 Tank beds covering an area of 1,37,623 ha in different Districts of Tamil Nadu. The land belongs to village panchayat and maintenance by state Forest department. These types of benefit sharing enhance the panchayat/rural livelihoods.

Introduction

Acacia nilotica is a complex species with nine subspecies, of which six are native to the African tropics and three others are native to the Indian subcontinent. *A. nilotica* is reported to be well nodulated with Rhizobium species. This nodulation behaviour helps in biological nitrogen fixation which helps to meet the nitrogen requirement in nutrient-poor soils. *Acacia nilotica* is extensively planted in social forestry programme in tank bed, farmlands, watershed management projects on field bunds and wasteland. In the Central plain of Indian subcontinent *A.nilotica* grow naturally in the agricultural fields and forms an important agroforestry system. In Madhya Pradesh, the farmers are cultivating rice along with babul trees. It is grown in around house, wells, compounds, and on farmlands. It is grown as homestead plantation because every part of this tree finds one use or the other by the farmers. In Tamil Nadu, the species is grown widely in the districts of Salem, Erode, Dharmapuri, Coimbatore etc., it is absent in coastal districts and higher hills. As mentione earlier, the species has been widely planted in tank bed plantations under social forestry programmes.

Wood Uses

The wood is very heavy, strong, very tough and extremely hard wood. The average weight is about 785 kg/m3 at 12 per cent moisture content. The wood is widely used for construction as posts, rafters, beams and in door frames. It is one of the most favoured timbers for all types of agricultural implements like ploughs, harrows, crushers and rice pounders, and is extensively used in cart building, for yokes, shafts, wheels and body work. Babul wood is also recommended for certain types of sports and athletic goods like clubs, wall bars, parallel bars, etc. As a fuel wood, it is an excellent material and is also made into charcoal. Its charcoal is considered to be superior to charcoal from other species. The wood from Acacias is good for paper and pulp making. It is reported that, rayon and paper pulp properties from *A. nilotica* compare favourably with those of *Dendrocalamus strictus* and *Eucalyptus hybrid*. However, since babul wood is highly valued for agricultural implements and house construction it is rarely available for pulp making (ICFRE).

Cultivation practices

Natural Regeneration

A. nilotica can regenerate naturally. Large natural wood lands of *A. nilotica* are not common. The species occurs in patches, usually, in wastelands and common grazing lands. The ripe pods of *A. nilotica* fall on the ground in summer months. Seeds are separated from the pod due to sun drying and are dispersed by wind and animals. Natural regeneration occurs mainly through seeds and sometimes through seedling coppice. Adequate moisture is necessary for germination. Germination starts in the early monsoon period and continues for some time. One of the problems in natural regeneration is damping-off of young seedlings. During germination, insects may damage the radical (Pandey et al, 2005)

Artificial Regeneration

Artificial regeneration involves seed collection, proper seed storage, seed treatment, nursery and planting practices, tending, maintenance etc. Direct sowing of babul is successful and is the common method for raising this species. Sowing of babul in combination with field crops has been practiced since time immemorial. However, nowadays nursery raised polypot plants are used as a common method for raising this species.

Planting Practices

Direct sowing

This is the easiest and most common method for raising babul plantation in the field. Several methods have given satisfactory result. The successful ones are by broadcast sowing (seed rate 2.5 – 3 kg/ha), dibbling in lines, patches or mound sowing during June (seed rate 1 kg/ha). The usual spacing is 4 × 4 m.

Agroforestry Plantations

Babul can be seen in agroforestry plantations right from the foot hills of the Himalaya in the north to Tamil Nadu in the south, from Rajasthan in the west to West Bengal in the east. In West Bengal, *A. nilotica* has been tried in mangrove areas and in silvipisciculture systems. It is reported that areas outside the National Park in Sunderban delta have been planted with several non mangrove species including *A. nilotica* and cultivation of fish is taken up in the areas enclosed with earthen embankments. *A. nilotica* leaf litter decomposes easily and cycles organic matter in the soils where planted, qualifying the species for its suitability in agroforestry systems. (Bremen et al, 1995).

The tree grows well in the tropical arid and semi-arid regions in India. The rotation of the *A. nilotica* for fuelwood 10 years and 20-25 years for timber. (Gupta 1970).

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Response of Indian Rosewood (*Dalbergia sissoo*) Under Drip Irrigation at Early Stage

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Abstract

Irrigation through drip system is relatively new for tree crops and much progress has already been made in productivity enhancement in agricultural crops. The seedlings of Indian Rosewood (*Dalbergia sissoo*) were planted and irrigated through drip irrigation system. The biometric attributes *viz*., height, basal diameter and diameter at breast height were recorded during 3, 6, 9 and 12 months after planting. *Dalbergia sissoo* has attained a maximum height of 5.04 m, basal diameter of 6.40 cm and diameter of 6.75 cm during 12 month after planting under drip irrigation. One year of field experiment help to conclude that irrigation of initial to 3 months an amount of 12 liters/plant/week, 3-6 months with an amount 24 liters of water/plant/week, 6-9 months was 30 liters of water/plant/week and 9-12 months was 36 liters of water/tree/week showed maximum growth response. This species is performing well under drip irrigation system and hence it can be promoted in farmlands for better returns to farming community.

Keywords: *Dalbergia sissoo*, Drip Irrigation, Growth Parameters

Introduction

Water has become a scarce resource in many parts of the world and thereby limiting agricultural and forestry develop-ment. The capacity of large countries like India to effi-ciently develop and manage water resources is likely to be a key determinant for global food and wood security in the 21st century (Seckler *et al*., 1998). In India, almost all the easily possible ways for viable irrigation potential have already been tapped. However, the water demand for different sectors has been growing continuously (Saleth 1996 and Vaidyanathan 1999), demand management becomes the overall key strategy for managing scarce water resources (Molden *et al*., 2001). Various options are available for reducing water demand in agriculture and forest crops, this include improved water management technologies/practices in agriculture and forestry. The micro-irrigation (MI) technologies such as drip and sprinkler are the key interventions in water saving and improving crop productivity. Evidence shows that up to 40 per cent to 80 per cent of water can be saved and water use efficiency (WUE) can be enhanced up to 100 per cent in a properly designed and managed drip irrigation system compared to 30-40 per cent under conventional practice (INCID, 1994). The drip technology can boost the productivity and overall production of tree crops in addition to betterment of soil and tree health especially in problematic conditions (Raman *et al*., 1996). Apart from yield increase, water and fertilizer saving through drip has been especially useful in problematic soil and water conditions. The present study was carried out to study the growth of *Dalbergia sissoo*, a multipurpose tree in plantation scale which is irrigated with drip irrigation system.

Materials and Methods

The experiment was conducted at Forest College and Research Institute, Mettupalayam (11° 19' N and 77°56' E) in altitude of 300 m above mean sea level with mean annual rainfall of 920.5 mm. The maximum and minimum temperature was 38.8°C and 17.7°C respectively. The soil in the experimental field was Illupanatham soil series with loamy sand in texture, well drained, slightly alkaline in reaction (pH-7.87) and non saline (EC-0.20 dSm^{-1}).

Seedlings of *Dalbergia sissoo* were planted in the field at a spacing of 3m X 2m. Drip irrigation system was installed and the seedlings were irrigated in alternate days based on weather conditions with a discharge rate of 4.0 liters/hour for one hour/day. Based on the availability of moisture content in soil, irrigation schedule was modified during summer and rainy season. The rate of irrigation given during initial to 3 months was 12 liters/plant/week, 3-6 months was 24 liters of water/plant/week, 6-9 months was 30 liters of water/plant/

week and 9-12 months was 36 liters of water/tree/week. The biometric observations *viz*., height and basal diameter of the planted seedlings were recorded at the time of planting, 3, 6, 9 and 12 months after planting.

a) Height

The height of the tree seedlings were measured from the ground level to the leading terminal tip using the standard scale and is expressed in metre.

b) Basal diameter

Basal diameter is measured using digital vernier caliper at the ground level and expressed in cm.

C) Diameter at Brest Height (DBH)

Diameter at breast height is measured using vernier caliper at the height of 1.37 m and the data was expressed in cm.

The height and diameter increment was measured for the growth period of 3, 6, 9 and 12 months after planting.

Result and Discussion

Global climate change is predicted to have negative effects on both agriculture production and water resources. The people will work more for higher yields per unit of irrigation water due to scarce and limited water resources in the future. Therefore, judicious utilization of available water resources to enhance productivity is the need of the hour.

In the present study, *Dalbergia sissoo* seedlings recorded a height of 1.26 m, 2.29 m, 3.01m, 4.24 m and 5.04 m during the time of planting, 3, 6, 9 and 12 months after planting respectively (Table 1). *Dalbergia sissoo* attained a height of 3.12 m after one year under drip irrigation in dryland condition (Babu, 2012). The height increment of 44.98 %, 23.92 %, 29.01 % and 15.87 % were recorded during 3, 6, 9 and 12 month after planting respectively (Table 2). The height increment in Casuarina may be attributed by irrigation at short and regular interval (Bheemaiah *et al*., 1997). Closer spacing in avocado trees tree had a positive effect in height growth and shading-out of lower branches with the

Table 1. Effect of drip irrigation on growth of Indian Rosewood (*Dalbergia sissoo*)

Sl.No	Growth Stages	Height (m)	Basal Diameter (cm)	Diameter (cm)
1	At the time of planting	1.26	1.19	-
2	3 MAP	2.29	2.16	2.07
3	6 MAP	3.01	2.85	3.68
4	9 MAP	4.24	4.46	5.09
5	12 MAP	5.04	6.40	6.21

only growth occurring in the tops of the trees (Platt, 2006). The height growth was highest in drip irrigated plants when compared to furrow irrigation (Igbal, 2005).

The stem thickness occurs as a result of cell division at the tips of stems and roots that leads to elongation and gives rise to primary tissue. The basal diameter growth in *Dalbergia sissoo* was higher due to drip irrigation. The basal diameter increments were 1.19 cm, 2.16 cm, 2.85 cm, 4.46 cm, and 6.40 cm during the time of planting, 3, 6, 9 and 12 month after planting respectively (Figure 1). The basal diameter of *Dalbergia sissoo* under drip irrigation at arid regions of Tamil Nadu was found to be highest with the value of 4.31 cm (Babu, 2012). The diameter of 2.07 cm, 3.68 cm, 5.09 and 6.21 was recorded in *Neolamarckia cadamba* at 3, 6, 9 and 12 months after planting respectively. The increase in rate of irrigation had a significant increase in tree collar diameter and vigour. The diameter increment of 43.75 %, 27.56 % and 18.26 % were recorded during 6, 9 and 12 month after planting respectively (Table 2). The transition from flood irrigation method to drip irrigation increases the biometric

Table 2. Increment Percentage of *Dalbergia sissoo* under drip irrigation

Sl.No	Growth Stages (MAP)	Height Increment (%)	Diameter Increment (%)
1	3 MAP	44.98	-
2	6 MAP	23.92	43.75
3	9 MAP	29.01	27.56
4	12 MAP	15.87	18.20

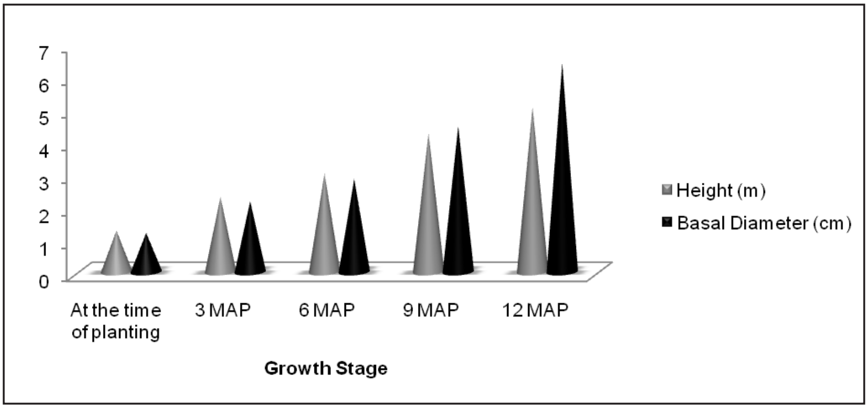

Fig. 1. Effect of drip irrigation on growth of Indian Rosewood (*Dalbergia sissoo*)

growth in trees, which is an important marketing criteria for tree growers (Kumar, 2008). This efficient growth rate under drip irrigation could be harnessed to boost the growth in early stages and the overall productivity of plantations.

Conclusion

The initial growth of *Dalbergia sissoo* under drip irrigation system was much higher with maximum height, basal diameter and diameter of 5.04 m, 6.40 cm and 6.21 cm in a short span of one year. The growth and productivity of this species is high and could be promoted as an important tree species for cultivation in farmlands under drip irrigated conditions.

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Propagation Techniques of Some Multipurpose Unconventional Timber Trees of Temperate & Sub-alpine Regions of Uttarakhand

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Uttarakhand lies on the southern slope of the Himalayan range and has a total area of 53,483 km^2, of which 86% is mountainous and 65% is reported as forest area. Most of the northern part of the state is covered by high Himalayan peaks and glaciers. The climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to subtropical pine forests at the lower elevations. The highest elevations are covered by ice and bare rock. Mount Nanda Devi is the highest peak of Uttarakhand with the altitude of 7816 metres above sea level. Western Himalayan alpine scrub and meadows exist between 3,000 and 5,000 metres- alpine meadows cover the highest elevations and *Rhododendron*-dominated scrub lands cover the lower elevations. Western Himalayan subalpine conifer forests dominate between 3,000 to 2,600 metres elevation giving way to western Himalayan broadleaf forests in a belt from 2,600 to 1,500 metres elevation. Below 1,500 metres elevation lie mainly the Himalayan subtropical pine forests. The foothills, Tarai- Bhaber areas and Shivalik ranges consist of drier savannas and mainly deciduous forests dominated by *Sal*.

Himalaya is known for conifers and deodar, fir, spruce and pine have been the major timber species since British period. Forest department had been taking special care for scientific management and extraction of these commercial species through working plans. But little attention had been paid for management and enrichment of unconventional timber species which are mainly in local use and have great potential from agro-forestry and commercial angle in changed scenario with ban on commercial felling. Some unconventional timber species have other important uses as they are valuable as fodder or fuel or source of edible fruits. They should get attention in our departmental plantation activities in addition to bringing private fallow lands under agro- forestry.

Nine important timber species which are normally unconventional and have great values for fodder, fuel, fruits and small timber have been taken to standardize their propagation techniques in departmental nurseries.

1. *Acer oblongum*

It is a middle size tree with stem slightly buttressed at base that occurs between 1500 to 2000m. It may be planted in sub tropical regions as well. Wood is moderately hard, close-grained and light reddish brown; and is used for making agricultural implements, drinking cups and handicraft items. Leaves are lopped for fodder.

Propagation

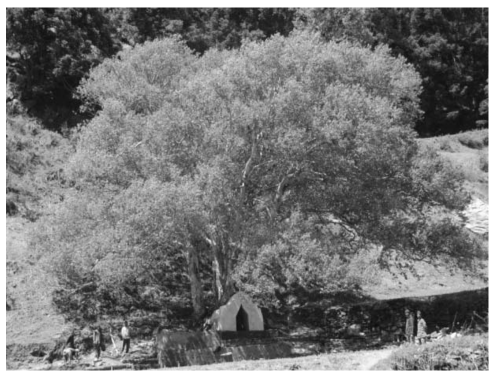
Seedlings may be raised through seeds. It flowers in April-May and winged seeds mature in November- December that remain attached to branches for pretty long period and should be collected in December- January.

Sowing should be done in February- March in open seed beds. Fine irrigation is required on alternate days and should be done preferably in the evening. In higher reaches, thatching may be required if temperature goes below 20 degree Celsius during day time. Germination starts in about 25 days and 70-


Seed Germination **Seedlings**

75% germination is observed in next 15 days. No mortality is usually observed in pricking which is done during the beginning of rainy season. Thus it is quite easy to propagate.

2. *Betula utilis*



It is a moderate size tree with brownish- white bark having numerous horizontal lenticels, and is found between 3000 to 4500m elevations. Wood is tough but elastic, even- grained and pinkish- white which does not warp and is used as building material in inner cold arid regions. Value of bark as paper for writing, for roofing houses and for lining inside hooka- tubes has been well recognised since ancient times. It is one of the most important fodder species of sub-alpine region.

Propagation

It is a little difficult to propagate and needs care. Flowering takes place in April- May and seeds mature in October-November. Seeds are minute and must be collected before they are dispersed by wind. Seeds should be sown in a mixture of sand and soil (90:10) under shade-net condition in February-March. Very fine irrigation should be done daily. Before sowing, seeds should be kept in freezer.

Catkins

Seedlings

Vivipary

Germination starts approximately after 60 days in May and about 30% germination is observed. Pricking may be done in June last on a cloudy day (before onset of rains).

Viviparous nature was observed in nature in November while collecting seeds but seeds sown in November immediately after collection did not result in germination.

3. *Boehmeria rugulosa*

It is a middle-sized tree found between upper sub- tropical and lower temperate parts of Uttarakhand between 1000 to 1500m elevations. Wood is reddish- brown, moderately hard and even-grained. It is easy to cut and work and is used for making bowls and various kinds of dairy utensils.

Propagation

It was found easy to propagate through seeds as well as vegetative method. Flowering takes place

Seed Germination

Seedlings

Vegetative Propagation

in July- August and achenes mature in December. Small seeds should be sown under shade net or mist chamber conditions in sand or vermiculite in February-March. Germination starts after 20-25 days. Quite satisfactory germination was observed (more than 50%).

70% rooting in cuttings of apical branches was observed in July after 30-40 days when treated with 4000ppm IBA.

4. *Buxus wallichiana*

It is a small or middle- sized tree with 4-sided branchlets and old stems have fissured or crocodile-pattern soft, corky, yellowish- grey bark. It is found between 1800 to 3000m in shady rocky ravines. Wood is very hard, close/ even grained and yellowish- white that is nearest approach to ivory and used for carving, engraving and mathematical instruments. Branches are used as fuel wood.

Propagation

It is propagated through seeds. Seeds have shining black testa and fleshy white albumen. Flowering takes place in March-April and seeds mature in July- August. Sowing should be done immediately after collection in poly houses. Seeds may also be sown in seed beds but should be covered with thatch and care should be taken that seed beds are not flooded during rains.

Germination starts after 15-20 days and 70-75% germination is obtained within a month.

Seedlings

Flowering

Seeds

5. *Carpinus viminea*

Seedlings

It is a middle- sized tree with irregularly fluted stem having compact grey bark with dark streaks. It occurs mainly in shady ravines and along water courses between 1600 to 2200m. Wood is white, shining, moderately hard and durable which is used mainly for making bobbins and shuttles for textile industry. Branches are used as fuel wood.

Propagation

It is propagated through seeds. Male flowering takes place first just before onset of new leaves whereas female flowering starts with leaf sprouting. Fruits mature in July- August and seeds should be sown immediately after collection or next year in February- March. Germination starts after 25-30 days and about 60-70% germination is observed in 25-30 days.

6. *Corylus colurna*

It is a moderate-sized deciduous tree with thin dark-grey bark exfoliating upwards occasionally and is found naturally. It is also cultivated between 1700 to 3000m elevations. The fruits are much more valuable as it is an important food article in the hills. Pinkish-white wood is moderately hard and is used locally for various purposes like boxes, plough and handle making.

Propagation

It is propagated easily through seeds. Flowering takes place in March- April and fruits/ seeds mature in September- October. Seeds should be preserved in cold condition before sowing in February- March. Seed beds should be kept moist with proper irrigation.

Seeds

Seedlings

Planted Seedling

Germination starts after 20-25 days. Germination is only about 50%. Pricking in bags should be done in July on the onset of rains.

7. *Salix daphnoides*

It is a small tree with greenish- grey smooth bark found between 2200-3000m. Wood is red shining and is used for building in arid tracts of the State. Pails, tubs and other similar articles are also made out of its wood.

Vegetative Propagation

Propagation

It is propagated through seeds as well as through branch cuttings. It was found easier and practical to raise seedlings vegetatively. Capsules mature in May- June and seeds should be collected and sown within 24 hrs after capsules open. Germination completes within 2-3 days and is quite satisfactory (about 75%). Cuttings are planted in February in sunken beds and about 90% rooting is obtained in 30-40days. Naked root seedlings may be planted in field.

Flowering

8. *Toona serrata*

It is a moderate-sized tree, ascending from 1500m to about 2500m, with bark showing regular longitudinal fissures from very early age. Wood is flesh coloured with foetid smell and is used for making bridges, sledge- roads, jhampan- poles etc. Leaves are lopped for fodder.

Propagation

It is propagated easily through seeds. It flowers in May- June and fruits/ seeds mature in July- August. Seeds may be sown immediately after collection or next year in March-April. Germination starts after 7-10 days and about 70% germination is observed within next 20 days.

Flowering

Fruiting

9. *Ulmus wallichiana*

It is a large deciduous tree with exfoliating rough grey bark found between 1500 to 3000m. Wood is greyish- brown, fine- grained, moderately hard with a very beautiful silver grain and capable of fine polish which is used as building material. Leaves are much prized as cattle- fodder.

Propagation

It may be propagated through seeds as well as vegetative cuttings. Flowering takes place in March- April and fruits/ seeds mature in May. Winged seeds are sown immediately after collection. Germination starts after about 15 days but low germination, about 30%, is observed in about 30 days period.

Seeds

Seedlings

Branch cuttings are taken in February- March before sprouting of new leaves. About 30 cm long cuttings from 1 year old branches are used which root and sprout in about 30- 40 days.

The experiments in the nurseries of research wing of Uttarakhand Forest Department has been successful in standardizing the propagation techniques of these important species and efforts have been made to transfer the technology to field through brochures and handouts. Officers visiting the research nurseries are provided with details of propagation techniques along with field exposures. It is expected that forest department would take propagation of these species in a big way to maintain and improve the species mix found in nature in respective zones.

Status of Beneficial Microbial Diversity in Teak Plantations of South India

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Introduction

Loss of tropical forests and its degradation are proceeding at alarming rates, eroding biological diversity and prospects for sustainability of agricultural and forest resources. The Convention on Biological Diversity (CBD) and the National Forest Policy (1988) have emphasized the importance of conservation of biological diversity within natural forests and raising of forest plantations outside the natural forest areas to meet various demands, so as to reduce the pressure on natural forests. After the formulation of the new forest policy, protection forestry came to the forefront. The role of forests as provider of vital life support systems has gained prominence. In line with this global and national prescription, several restrictions came into existence on commercial exploitation of natural forests.. Several plantations had been raised earlier by removing the original vegetation for raising pulpwood and timber species within the species rich forests all along the Western Ghats and its neighborhood. Monoculture plantations within Protected Areas and adjacent to it, in several parts of the country were managed based purely on silvicultural principles while ignoring their ecological role as potential wildlife habitats. But, recently, the trend has changed in favour of ecological considerations. Further, in tune with the evolving global conservation trend, efforts are being made to improve and conserve biodiversity in forest plantations within Protected Areas as well as outside in many areas. This is aimed at converting plantations to closest possible natural forests in terms of species composition thereby making them better wildlife habitats. There are general arguments that exotic tree plantations do not support native ground flora underneath. This necessitate knowledge and understanding of existing biodiversity in plantations and the factors contributing to positive or negative impacts on the ground flora and soil characteristics in term of chemical, physical and biological properties. Therefore, the present study focused on understanding biodiversity dynamics as applicable to forest plantations since plantations could lend themselves to experimental investigations to a great extent so as to formulate better and ecologically appropriate management prescriptions for the plantations.

Microsymbionts in Forest Ecosystem

Productivity of the forest plant community depends on the interaction of trees with the environment. One of the most important and perhaps the least understood areas of biological interactions is the soil immediately surrounding the root (rhizosphere). Numerous microorganisms colonize this region and influence plant growth through physiological effects on uptake, storage and cycling of nutrients. Despite their importance, soil organisms are rarely considered when degraded sites are replanted. Hence, interactions between soil organisms and plants are very vital to plant survival and normal growth. In nature, different microbes are present in the form of parasitic, saprophytic and symbiotic / free living beneficial forms. The beneficial microbes include nitrogen fixing, phosphate solubilizing or cellulolytic organisms used for the application to the seed, soil or composting areas with the objectives of increasing the numbers of those organisms and they help in growth of the plants. Such microorganisms accelerate certain microbial processes to augment the extent of availability of nutrients in a form which can be easily assimilated by plants. So, the beneficial microorganisms in the soil provide nutrients to the plants in available form through natural processes.

There are different kinds of microorganisms interacting with the plant community. Among them, the microbes belonging to actinomycete group is called as *Frankia*. They are highly efficient micro aerophilic nitrogen fixers that occur within the root nodules of plants. They infect non-leguminous woody plants such as *Alnus, Casuarina* etc. Other microbes like the symbiotic bacteria viz. *Rhizobium* and *Bradyrhizobium* fix atmospheric nitrogen and produce nodules in the leguminous plants of both agricultural and forestry crops. The free-living bacteria are of many kinds such as *Azotobacter, Azospirillum, Phosphobacterium* etc. The Azotobacter fixes nitrogen under aerobic conditions and makes nitrogen available for crops and other plants. The other kind of free-living bacteria, *Azospirillum* also enhances nitrogen nutrition to the plants. Another kind of bacterium, *Phosphobacterium* mainly occurs in the rhizosphere soils and helps in solubilizing phosphorus and makes it available for the plants.

The symbiotic fungal microbes are commonly called mycorrhizal fungi. The literal meaning of the term "mycorrhiza" is "Fungus Root" to denote the association between certain soil fungi and plant roots where the relationship is not pathogenic. The mycorrhizal symbiosis occurs widely throughout the plant kingdom. It occurs in 90% of Angiosperms, 100% of Gymnosperms and 70% of Pteridophytes. The mycorrhizal infections are known to be significantly beneficial for the nutritional uptake of host plants especially phosphorus and nitrogen from nutrient deficient soils. Nearly all higher plants have mycorrhizal associations. Mycorrhizas increase the rate of nutrient absorption from the soil with selective absorption of some ions. Both Ectomycorrhizal (ECM) and Arbuscular Mycorrhizal (AM) fungi can further improve plant performance in a number of ways, including improving tolerance to drought, heavy metals, soil toxins, extremes of pH and temperature. These benefits to the plants could be assumed if trees were inoculated and colonized by selected effective beneficial microbes as bio-fertilizers. It is important to know the diversity and abundance status of such microbial species in any given area. Therefore, an attempt was made in the present study to investigate the status of beneficial microbial populations such as Arbuscular Mycorrhizal (AM) fungi, Plant Growth Promoting Rhizobacteria (PGPR) and Actinomycetes in the rhizosphere soil from different Teak plantations located in Tamil Nadu and Kerala, with an objective of developing management practices to improve the nursery and field performance of Teak, which is considered as the "King of Timbers".

Methodology

Collection of samples

Roots and soil samples were collected at random from six different Teak plantations in Tamil Nadu and Kerala (Table-1). Soil from the rhizosphere was dug out to a depth of 3 to 30 cm, after scraping away the top 1-2 cm soil. The soil samples were collected in clean polythene bags and stored at 2-5°C until the samples were processed. The root samples were washed in tap water gently and immediately fixed in Formalin Acetic acid Alcohol (FAA – 50% in 200 ml of Ethyl alcohol + 5 ml of Glacial Acetic Acid + 13 ml of Formalin) for further studies to assess the AM fungal colonization.

Enumeration of microbial population in soil

The microbial load *viz.,* PGPR, soil bacteria, soil fungi and Arbuscular Mycorrhizal (AM) fungi was determined from the soil samples collected from different sample plots. Serial dilution and plating techniques as described by Parkinson *et al*. (1971) and Subba Rao (1993) were adopted for enumerating the population of bacteria and fungi. The Arbuscular Mycorrhizal (AM) fungal spore population was estimated using wet sieving and decanting technique (Gerdemann and Nicholson, 1963) and sucrose density gradient technique (Daniels and Skipper, 1982). Root colonization by the AM fungi was done following root clearing and staining techniques (Phillips and Hayman, 1970; Koske and Gemma, 1989) and data on percent root colonization of AM fungi was also estimated using gridline intersect method (McGonigle *et al.,* 1990).

Estimation of bacteria and fungal population

1g of soil sample was weighed and suspended in 100 ml sterile water blank aseptically. The flask was vortexed for 1 minute. This constitutes 10^{-2} dilution. 0.1ml from this dilution was aseptically transferred to another water blank with 9 ml of sterile water using sterile pipettes. This is 10^{-3} dilution. Similarly, successive dilutions of the samples till 10^{-6} were prepared by serial dilution method (Parkinsen *et al.* 1971).

For enumerating bacteria, one ml diluent each from 10^{-4} and 10^{-5} was transferred aseptically to labeled sterile petri dish using sterile pipettes. 12-15ml of Jensen's agar medium, Nitrogen Free Bromothymol Blue agar medium and Pikovskaya's agar medium for *Azotobacter, Azospirillum* and Phosphate solubilizing bacteria respectively were poured onto the plates. The plates were gently rocked manually for uniform distribution of the diluted sample in the medium. The plates were then incubated at 30º C for 2-3 days. After incubation, bacterial colonies were counted and CFU/g (Colony forming units/gm of soil) was calculated (Subba Rao, 1993). To enumerate fungal population, the dilutions used were 10^{-2} and 10^{-3}. Plating was performed in the same way as done for bacterial. The medium used for fungi was Potato Dextrose Agar (PDA) medium. The plates were incubated at room temperature for 3days and the fungal colonies were calculated as CFU/g (Colony forming units / gm of soil).

Processing of root samples and estimation of AM fungal colonization

The roots fixed in FAA were washed in tap water and processed for estimating colonization of AM fungi by adopting root clearing and staining technique (Phillips and Hayman, 1970). The stained roots were examined with a Nikon Optiphot No.2 Compound Microscope with Photomicrography (x 20 - 40). The percent root colonization was also estimated according to gridline-intersect method (Krishna and Dart, 1984 and McGonigle *et al.,*1990).

Identification of AM spores from soil samples

The intact and the crushed spores were examined under a compound microscope ; genus and species level identification of different AM fungi isolated from the soil samples was done using standard keys (Trappe, 1982) and Schenck and Perez (1987). Spores were identified based on spore morphology and sub-cellular characters and compared with original descriptions (Schenck and Perez, 1987). Spore morphology was also compared with the culture data base established by INVAM (http://invam.cag.wvu.edu).

Results

PGPR and Actinomycte population

Data on mean PGPR (*Azotobacter, Azospirilum* and PSB) and Actinomycte population density of different Teak plantations is presented in Table-1. It was observed that all the samples had PGPR and Actinomycete populations. The population density of PSB was found to be maximum (41.0 x 10^5cfu/g) from the samples of Aravallikavu–D, Nilambur followed by Sadivayal, Coimbatore (34.0 x 10^5cfu/g) . In the case of *Azospirillum*, the population density was maximum in Sadivayal (52.0 x 10^5cfu/g) followed by Aravallikavu–B (47.5 x 10^5cfu/g) and Aravallikavu–D, (34.8 x 10^5cfu/g). In case of Azotobacter, the population density was found more in Aravallikavu–D, (30.16 x 10^5cfu/g) followed by Aravallikavu-A (27.0 x 10^5cfu/g) Sadivayal (24.0 x 10^5cfu/g) and Aravallikavu–B, (19.5 x 10^5cfu/g) during the period of investigation. In general, the population density of Actinomycte was found less as compared to PGPR organisms in all the three locations analyzed.

Table 1. Status of mean PGPR and Actinomycte population density recorded from different soil samples of *Tectona grandis* in various study locations

S.No.	Sample locations	Population density of PGPRs (x 10^5 cfu/g)*			Population density of Actinomycetes (x 10^4 cfu/g)
		Phosphate Solubilizing Bacteria	*Azotobacter* spp.	*Azospirillum* spp.	
1	Myladi (Nilambur)	19.5ab	9.75a	18.7ab	2.0a
2	Aravallikavu (Nilambur)-A	19.5ab	27.0ab	26.5b	6.0b
3	Aravallikavu (Nilambur)-B	17.5ab	19.5ab	47.5bc	3.0a
4	Aravallikavu (Nilambur)-C	28.0ab	3.0a	37.0b	2.0a
5	Aravallikavu (Nilambur)-D	41.0bc	30.16b	34.8bc	5.0b
6	Sadivayal (Coimbatore)	34.0b	24.0ab	52.0c	2.0a

*Means, in a column, followed by common letter (s) are not significantly different at 5% level as per DMRT.

Spore population and root colonization of Arbuscular Mycorrhizal (AM) fungi

Data on percent root colonization and soil spore population of Arbuscular Mycorrhizal (AM) fungi recorded from the Teak plantations is presented in Table 2. It was observed that the root samples collected from all the sample plots had AM fungal colonization in the form of vesicles, arbuscule and hyphal structures. The arbuscular structures were seen from the samples of *T. grandis* collected from Mylandi, Nilambur (Kerala), Aravallikavu-D, Nilambur and Sadivayal, Coimbatore. The vesicular structures varied from globose to irregular shape. Maximum percent root colonization (89%) was recorded in samples collected from Aravallikavu-D followed by Aravallikavu-B and Aravallikavu-C (87% each) and Sadivayal (80%) in decreasing order. Aravallikavu-C had significantly higher soil spore population (120.5/100g soil) of AM fungi, compared to that of other samples.

Table 2. Mean spore population and percent root colonization of Arbuscular Mycorrhizal (AM) fungi recorded from rhizosphere soil and root samples of *Tectona grandis* in different study locations

S. No.	Sample plots	Mycorrhizal Colonization			% coloni - zation	AMF spore population/ 100 gm of soil
		Arbuscules	Vesicles	Hyphae		
1	Myladi (Nilambur)	+	+	+	74.5a	76.5a
2	Aravallikavu (Nilambur)-A	-	+	+	87.0bc	81.5a
3	Aravallikavu (Nilambur)-B	-	+	+	87.0bc	89.5ab
4	Aravallikavu (Nilambur)-C	-	-	+	76.0ab	120.5c
5	Aravallikavu (Nilambur)-D	+	+	+	89.0bc	88.4ab
6	Sadivayal (Coimbatore)	+	+	-	80.0b	94.0b

*Means, in a column, followed by common letter (s) are not significantly different at 5% level as per DMRT.

Frequency distribution of Arbuscular Mycorrhizal (AM) Fungi

Data on the frequency distribution of AM fungi recorded from the rhizosphere soils of Teak plantations is presented in Table 3. A total of 15 different species of AM fungi belonging to three genera such as *Acaulospora, Gigaspora* and *Glomus* were isolated and identified from various rhizosphere samples screened. Among them, the genus *Glomus* was found to be the dominant one. It was also recorded that the AM fungal genera *Acaulospora* and *Gigaspora* had one species each and *Glomus* had 13 species. Among the different AM fungi isolated, *Acaulospora* sp., *Gigaspora gigantea*, *Glomus aggregatum* and *Glomus geosporum* were the most frequent AM fungi (83.3%) recorded, followed by species such as *Glomus clarum, G. fasciculatum* and *G. fulvum* (66.6%). Maximum number of AM fungi (12 numbers) was recorded from Aravallikavu-A, followed by Aravallikavu-C and Sadivayal (10 Nos.each).

Discussion

Microorganisms play vital role in physiological processes in the ecosystem. In the present study, roots and rhizosphere soil samples collected from Teak plantations in various study locations in Kerala and Tamil Nadu and analysed

Table 3. Frequency distribution of Arbuscular Mycorrhizal Fungi (AMF) recorded from the rhizosphere soil samples collected from different sample plots of Teak in Tamil Nadu and Kerala

S. No.	AM fungi	Teak Sample Plots						Frequency (%)
		S1	S2	S3	S4	S5	S6	
1	*Acaulospora* sp.	+	+	-	+	+	+	83.33
2	*Gigaspora gigantea*	+	+	+	-	+	+	83.33
3	*Glomus* sp.	-	+	-	+	+	-	50.00
4	*Glomus aggregatum*	+	-	+	+	+	+	83.33
5	*Glomus albidum*	-	+	-	+	-	+	50.00
6	*Glomus clarum*	+	-	+	-	+	+	66.66
7	*Glomus deserticola*	-	+	+	+	-	-	50.00
8	*Glomus fasciculatum*	+	+	-	+	-	+	66.66
9	*Glomus fulvum*	-	+	+	-	+	+	66.66
10	*Glomus geosporum*	+	+	+	+	-	+	83.33
11	*Glomus intraradices*	-	+	-	+	-	-	33.33
12	*Glomus microcarpum*	-	+	-	+	-	+	50.00
13	*Glomus macrocarpum*	+	-	+	-	+	-	50.00
14	*Glomus occultum*	+	+	+	-	-	-	50.00
15	*Glomus pubescens*	-	+	-	+	-	+	50.00
	Total number of AM fungi	8	12	8	10	7	10	

(-) = Absent; (+) = Present

S1	Myladi (Nilambur)
S2	Aravallikavu (Nilambur)-A
S3	Aravallikavu (Nilambur)-B
S4	Aravallikavu (Nilambur)-C
S5	Aravallikavu (Nilambur)-D
S6	Sadivayal (Coimbatore)

for the status of different beneficial microorganisms such as Plant Growth Promoting Rhizobacteria (PGPRs), Actinomycetes and Arbuscular Mycorrhizal (AM) fungi. All the samples had PGPRs, Actinomycetes and AM fungi but variation in population density of all these organisms. The findings of the study are in accordance with the findings made by other earlier researchers. Several earlier reports indicated that isolation of *Azospirillum* from the rhizosphere samples of different host plants (Caballero-Mallado and Valdes, 1983). *Azospirillum* spp. has been isolated from many tropical trees (Subba Rao, 1984). Joseph *et al.* (2007) have isolated a total of 150 bacterial isolates belonging to *Bacillus, Pseudomonas, Azotobacter* and *Rhizobium* from different rhizospheric soil of chick pea in the vicinity of Allahabad, India. Guang-Can *et al.* (2008) have isolated inorganic P-solubilizing bacteria (IPSB) and organic P-mineralizing bacteria (OPMB) in soils taken from subtropical flooded and temperate non-flooded soils and screened for various P-solubilization abilities.

Similar trend was observed in case of percent root colonization and soil spore population of AM fungi analysed from various samples screened. The percent root colonization and spore population of AM fungi varied among different samples, which may be attributed to various factors like soil, climatic, fungal and host factors (Anderson *et al.*, 1983; Howeler *et al.*, 1987; Muthukumar *et al.*, 1994a,b). Recently, Mohan *et al.* (2011) have studied the AM fungal interaction with important tree species in quartz sand area, Tamil Nadu and they found AM fungal association in the rhizosphere soils of various plants grown in the study area but variation in percent root colonization and soil spore population. The high percent colonization and spore number may be either due to favourable edaphic conditions like low nutrient status, high aeration and optimum moisture or the undisturbed conditions of the soils, which allowed sufficient time for the buildup of mycorrhizal spores (Azizah Chulan and Omar, 1991). The results of the present study coincided with the findings of Bakshi (1974). He investigated the effect of seasonal variation on the population of AM fungal spores of *Endogone* and *Glomus macrocarpum* under hoop pine and teak in New Forest soils, Dehra Dun (India). Mohankumar and Mahadevan (1988) observed that the number of AM fungal spores and percent colonization did not coincide with each other in the study areas of Kalakkad Reserve Forest, Tamil Nadu. They also found that the number of spores was higher during rainy season than in summer. Seasonal variations of incidence of AM fungi in mangrove ecosystem of Pichavaram and Muthupet estuary, Tamil Nadu, India were recorded by Selvaraj and Subramanian (1991). Their study showed highest spore population during monsoon season and the lowest during summer season. Bohrer *et al*. (2001) also reported that the AM fungal association was positively correlated with the mean annual rainfall and negatively correlated with phosphorus concentration in the soil. Tamil Selvi (2005) studied the association of symbiotic microbes including AM fungi with *Acacia auriculiformis* and *A. mangium* plantations in Tamil Nadu. The results of her study revealed that the presence of different species of AM fungi and highest percent colonization and spore population in both the tree species during different seasonal observation.

In the present study, fifteen different AM fungi belong to three genera *viz., Acaulospora, Gigaspora* and *Glomus* were recorded from the rhizosphere samples of different study sites during the period of investigation. The findings are corroborated with the findings made by other researchers in India and elsewhere. The genus *Glomus* is reported to be the dominant AM fungus in some of the forest ecosystems (Sharma *et al*., 1986; Bhat, 1993). According to Mohankumar and Sivaswamy (1992) *Glomus* is the most dominant genus in India. Rama Bhat (1999) reported maximum per cent population of spores of *Glomus* in tarai soils and the *Myristica* swamps of Uttara Kannada respectively. Giovannetti (1985), Visalakshi (1997), Senapati *et al*. (2000), Rama Bhat and Kaveriapa (2001, 2005) and Tamuli and Boruah (2002) found that *Glomus fasciculatum* was the most dominant species. *G. macrocarpum* was reported as the dominant species in the rhizosphere of *Dalbergia sissoo* (Uniyal and Uniyal, 2000). Thapar and Khan (1985) reported 15 species belonging to 4 genera of Endogonaceae i.e., *Acaulospora, Gigaspora, Glomus* and *Sclerocystis* from forest soils in locations of 2 states in India. Among the species, *Glomus microcarpus* were widely distributed followed by *Sclerocystis* spp., *Gigaspora gigantea* and *Acaulospora* sp. and New Forest soils of FRI, Dehra Dun represents maximum number of species of endogonaceae. Mehrotra and Mehrotra (2000) reported the predominance of Gigasporaceous fungi (*Gigaspora* and *Scutellospora*) in some *Acacia* species in the nursery condition. Similarly, the association of arbuscular mycorrhizal fungi in 21 forest tree species was reported by Senapati *et al*. (2000). Tamuli and Boruah (2002) studied the association of AM fungi in agar wood tree (*Aquilaria malaccensis*) in Jorhat, Assam and their study revealed variation in the percent root colonization and number of the AM propagules in the rhizosphere soil samples. They found that the genus *Glomus* was the most dominant one. Dhar and Mridha (2006) studied the biodiversity of AM fungal colonization and spore population from different locations of Madhupur forest area. The tree species used for the study were *Acacia auriculiformis*, *A. mangium*, *Artocarpus heterophyllus*, *Dalbergia sissoo*, *Eucalyptus camaldulensis*, *Hevea brasiliensis*, *Swietenia macrophylla* and *Tectona grandis*. They found that variation in AM fungal colonization and spore population in different samples screened. Status of the AM fungi and PGPR was studied in different shola plant species in the Nilgiri Hills, Tamil Nadu by Mohan and Anandalakshmi (2012) and they reported twenty seven different AM fungi belonging to 3 genera *viz., Acaulospora, Gigaspora* and *Glomus*.

Conclusion

The beneficial microbes can be used as bio-fertilizers. Among them, the AM fungi could be used to enhance the uptake of nutrients (Phosphorus, Zinc and other essential elements) and provide tolerance for establishment of seedlings on degraded lands, waste lands including mined out areas and OB dumps. Hence, the AM fungi and PGPR organisms isolated from the rhizosphere of Teak during the present study have potential use as bio-fertilizers for production of healthy and tolerant planting stock.

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Productivity Of Teak In Tamil Nadu – A Review

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Teak (*Tectona grandis* L. f), a member of the family Verbenaceae, is a large deciduous tree with a round crown and a tall clean cylindrical bole of more than 25 m. Teak is indigenous to Indian Peninsula and the continental south-east Asian region (Myanmar-Thailand-Laos) with discontinuous distribution pattern. The natural distribution of teak covers a wide range of latitudes between 9^o - 25^o 30' N and longitudes between 73^o - 104^o 30' E.

Locality factors favouring teak growth

Teak grows from sea level to an altitude of 1200 m. It grows best in tropical climate and to a greater extent in the sub-tropical climate also. Though teak can tolerate annual rainfall as low as 750 mm and as high as 4,000 mm, it grows well within an annual rainfall range of 1,500 to 2,000 mm. It can tolerate extremes of temperature: as high as 48^0 C and as low as 2^0 C. Teak is a strong light demander. The most suitable soil for teak is deep and well-drained alluvium soil, with an optimum pH range of 6.5 to 8.0 and relatively high content of Calcium and Phosphorous. Adaptability to different eco-climatic conditions coupled with the economic importance has made teak an ideal species for raising plantations both in forests and farmlands.

Utility

The multipurpose timber of teak has favourable strength properties besides having outstanding merit in the retention of shape and working qualities like easy to saw, finish to a smooth surface and takes polish well. The heart wood is one of the most naturally durable woods and has resistance to termite and fungal attack due to the presence of polyphenols. Hence, it has been described as one of the most durable timbers of the world and designated as the 'KING

OF TIMBERS'. The entire bole and branches down to a thin end diameter of 12.5 to 15 cm is utilized. Traditional use of teak poles for electricity transmission and timber for railway sleepers are a time-tested testimony of its suitability for out door uses. The persistent demand and continued shortfall of its availability make it one of the dearest species in the tropics.

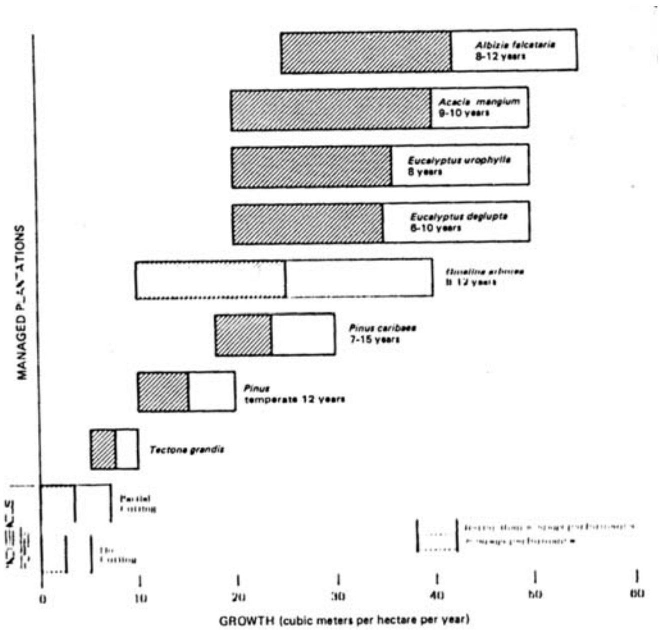
Plantation Establishment and Management

In forestlands, regeneration occurs both by artificial and natural. Since natural regeneration through seed is very poor, artificial regeneration through planting of stumps or seedlings is widely adopted. Stump planting is normally followed for large-scale plantation programme. Teak stumps of 25 cm long (with 2.5 cm shoot and 22.5 cm root) are prepared from one year old seedlings and used as planting stock and planted in auger holes (usual practice). Initial stocking ranges from 1000 to 2500 trees/ha. First thinning (Mechanical thinning) is done around the age of four to five years and the second thinning (Mechanical thinning) at ten to fifteen years as soon as the branches start to touch the adjacent trees. Both in first and second thinning the removal of trees will be as high as 50% of available stocking. A final selection thinning may be performed at middle of rotation age (around 20-25 years) with an ideal final stocking of 200 to 300 trees/ha. Final felling is normally done at the age of 60 years.

Productivity of teak plantations in forest lands

Teak has been raised as a plantation crop in India since 1842. The plantation technology was developed only in India. Currently, about 68 lakh ha of teak plantation has been reported as planted teak forest on a global basis and 15 to 25 lakh cubic meter of teak wood is being harvested annually and significant portion of this harvest is traded globally. Of which, India accounts for some 75% of global teak imports (Midgley et al, 2015). However, the existing teak plantations in India accounts for 25 lakh ha (37% of global planted teak forests). Tamil Nadu alone has teak plantation area of 19,040 ha in forest lands (FSI). A study was conducted to assess the productivity pattern in these teak plantations in Coimbatore and Tirunelveli Forest Division of Tamil Nadu during the period from 2000 to 2004. A total of 15 plantations were studied and the age of the plantations ranged from 20 to 47 years. By comparing performance in two Forest

Divisions at comparable ages, mean girth was 96 cm in Tirunelveli Forest Division and it was 80 cm in Coimbatore Forest Division. Similarly, mean height was greater in Tirunelveli (21 m) than in Coimbatore (16.7 m) The total volume production was 272 cubic meter per ha in Tirunelveli Forest Division and it was 240 cubic meter per ha in Coimbatore Forest Division. Mean annual productivity in terms of Standard Stem Timber was 9.6 and 5.2 cubic meter per ha per year (136 and 70 cubic feet per acre per year) in Tirunelveli and Coimbatore Forest Division respectively (Buvaneswaran, 2004).



This picture compares mean annual productivity of various species and the productivity reported for managed teak plantations ranges from 5 to 10 cubic meters per ha per year (70 to 140 cft per acre per year). This range of productivity can be marked as 'Benchmark Productivity' for teak and other higher claim over this productivity need to be considered for scientific assessment and confirmation.

In all the 15 plantations studied, within plantation variation of diameter between smallest and biggest trees goes to an extent up to four times. This large variation in growth of teak within an even-aged plantation can be attributed to the genetic potential of individual trees of seedling origin. There is greater scope of minimizing this variation through use of quality seeds from SEED PRODUCTION AREAS / SEED ORCAHRDS and also through promotion of CLONAL TEAK PLANTATIONS. Adoption of clonal technology in plantations of eucalypts and poplar have shown higher productivity ranging from 20 to 60 cubic meter per ha per year compared to 3-7 cubic meter per ha per year from the seedling raised plantations (FAO, 2009).

Teak as an Agroforestry component

Sustained preference to any other timber has hiked the price of teak. This, in turn, has lead to raising of teak plantations outside the forest areas, particularly in the farmer's field in the recent past. In farm fields, Teak is planted both as a sole crop in the form of block plantation as well as introduced as an agroforestry component. In block plantations, a spacing of 2 x 2 m is adopted. Under agroforestry practices, mostly the trees are grown in bunds or in wide rows of 8 m width. Within row spacing normally varies from 2 to 4 m. Though trees are grown in farm conditions, no separate irrigation is given to trees during cropping period. But, during fallow period, the tree rows receive irrigation twice a month just to assure survival of tree component. Further, such a restricted irrigation is expected to aid in formation of heartwood which is nearer (if not equivalent) to that of formed in teak grown in rainfed condition.

Productivity of teak in wide-row alley cropping system

A study was conducted in teak based wide row alley cropping agroforestry system (at an espacement of 8 x 4 m) in Coimbatore district of Tamil Nadu.). Under this teak + black gram model, at the end of five years, the teak trees attained 46.0 cm girth and 11 m height. On unit area basis, the volume of teak wood amounted to 50.4 cubic meter per ha, with an average productivity of 10.1 cubic meter per ha per year. It was also found that trees and crops can be grown together up to a period of 4 years without any significant reduction in grain yield, if compatible species are chosen and suitable management practices adopted. Since the productivity of the trees in agroforestry is significantly higher than that in forest plantations, the trees can be harvested in short rotations of 15-20 years for teak (George and Buvaneswaran, 2004).

Productivity of teak plantations in farmlands

Study was conducted in young teak plantations in farm lands up to 18 years age for productivity estimation. The total number of plantations sampled was 30. Out of 30 plantations sampled for carbon sequestration studies, 10 were block plantations with an espacement of 2 x 2 m, except one plantation with 2 x 4 m spacing. Remaining 20 plantations were raised as boundary planting in the farmland in single row with 2 m spacing between trees within the row, excepting one where the spacing between trees was 4 m. The age of sampled plantations ranged from 8 to 18 years under block plantations and from 5 to 18 years under boundary planting. Mean stem wood biomass produced was 85.5 MT ha^{-1} under block plantation with mean age of 13 years and it was 9.3 MT ha^{-1} under boundary planting system at mean age of 11 years. Correspondingly, MAI of stem wood biomass production was 6.6 MT ha^{-1} $year^{-1}$ under block plantations and 0.85 MT ha^{-1} $year^{-1}$ under boundary planting. The total biomass accumulated was 180 and 22.8 MT ha^{-1} respectively under block and boundary planting (Table 1). With reference to litter accumulation, it varied from 250 to 900 g m^{-2} and amounts to mean litter accumulation of 5.75 MT ha^{-1}. However, there was no litter accumulation observed under boundary planting, as the litter produced is ploughed in during field preparation for annual crops.

Plantation number Pl.No.2 and 3 are the adjoining plots, Pl. No.2 has spacing of 2 x 2 m without thinning operation and Pl.No. 3 has 2 x 4 m with one mechanical thinning done at 10 years age. After 5 years of thinning operation, there was greater difference in total dry matter production as well as stem wood production in these two plots. Total dry matter produced was 183 MT ha^{-1} in un-thinned plot and it was 136.0 MT ha^{-1} in thinned plot. Total stem production was also higher in un-thinned plot (100.1 MT ha^{-1}) than in thinned plot (69 MT ha^{-1}). However, on per tree basis, greater amount of dry matter accumulated in stem wood (55.2 kg per tree) in thinned plot, when compared to that of in un-thinned plot (40.0 kg per tree). In terms of commercial volume, it was 0.104 m^3 per tree (3.67 cft per tree) in thinned plot and 0.051 m^3 per tree (1.81 cft per tree) in un-thinned plot, illustrating the benefits of thinning (Buvaneswaran, 2011; Buvaneswaran et al, 2012).

Table 1: Dry matter production (MT ha^{-1}) of different biomass components of *Tectona grandis* in farmlands of Tamil Nadu

Pl. No.	Planting configuration	Tree density per ha	Age (years)	Leaf	Branch	Stem	Bark	AGB	BGB
1.	**Block plantation**	1736	8	3.9	13.9	72.1	11.6	101.6	20.3
2.		2500	15	3.7	32.9	100.1	16.5	153.1	30.6
3.		1250	15	3.9	29.9	69.0	10.6	113.3	22.7
4.		2500	12	9.8	30.8	30.2	9.9	80.7	16.1
5.		2500	18	10.1	166.2	311.3	33.8	521.4	104.3
6.		2500	13	9.6	29.1	30.2	9.9	78.8	15.8
7.		2500	13	6.2	33.2	52.0	11.5	103.0	20.6
8.		2500	12	13.5	48.2	48.1	8.2	118.1	23.6
9.		2500	11	12.3	34.6	72.4	12.1	131.4	26.3
10.		2500	10	2.5	15.8	69.4	12.7	100.4	20.1
	Mean	**2299**	**13**	**7.6**	**43.5**	**85.5**	**13.7**	**150.2**	**30.0**
11.	**Boundary planting**	200	5	0.1	0.8	1.4	0.3	2.5	0.5
12.		200	14	0.6	2.1	4.3	0.9	7.9	1.6
13.		200	10	0.9	3.1	2.8	0.6	7.5	1.5
14.		200	12	1.2	3.8	5.5	1.0	11.4	2.3
15.		200	12	1.3	1.5	4.6	0.8	8.3	1.7
16.		200	13	0.5	2.5	3.1	1.9	8.0	1.6
17.		200	8	0.6	2.3	9.3	4.7	16.9	3.4
18.		200	12	1.4	18.3	10.9	1.8	32.5	6.5
19.		200	12	0.7	7.8	9.4	2.8	20.7	4.1
20.		200	11	0.3	1.6	5.7	1.2	8.7	1.7
21.		200	10	0.5	0.9	2.6	1.5	5.5	1.1
22.		200	14	1.1	7.6	5.5	1.9	16.0	3.2
23.		200	15	1.9	6.1	4.9	1.8	14.7	2.9
24.		200	12	0.5	1.5	5.5	1.9	9.3	1.9
25.		100	5	0.1	0.3	1.4	0.5	2.4	0.5

Pl. No.	Planting configuration	Tree density per ha	Age (years)	Leaf	Branch	Stem	Bark	AGB	BGB
26.		200	9	1.4	7.3	7.4	4.3	20.3	4.1
27.		200	12	3.9	13.4	86.1	50.4	153.8	30.8
28.		200	18	0.8	5.8	11.1	2.5	20.2	4.0
29.		200	12	1.1	4.5	0.8	0.3	6.7	1.3
30.		200	7	0.2	1.3	3.9	0.9	6.3	1.3
	Mean	**195**	**11**	**0.9**	**4.6**	**9.3**	**4.1**	**19.0**	**3.8**

Productivity of teak in boundary/bund planting system

The trees in farmlands grow faster and produce more biomass when compared to plantations in the forest areas. The average girth at breast height (gbh) at 12 years age under agroforestry systems, ranged from 80-90 cm and the total height 12-15 m which in turn produced stem wood volume of 9.9 cft per tree. This higher productivity in farmland could be attributed to the fact that the trees share the benefit of intensive land management practices like irrigation and other cultural operations provided to the agricultural crops. Hence, teak can be one of the best-suited tree species for agroforestry and there exist great possibility of growing teak in farmland and harvesting at 12 years age for the production of small timber/poles (Buvaneswaran et al. 2001).

Casuarina + Teak based Windbreak system

It is reported that teak is a light demanding species (Troup, 1921) and hence will tend to modify its crown characteristics to enable capturing of greater amount of sunlight. Therefore, when teak is grown on bunds or in boundaries of farmland, it produces profuse branches and in turn height growth is limited and stem form is also bent and not straight (Buvaneswaran et al 2013). It is also reported that strong wind is a deleterious factor for growth of teak (Saravanan and Buvaneswaran, 2003). This stunted growth of teak is also recorded in block plantations of teak grown in upper hill slopes exposed to strong wind forces (Buvaneswaran, 2004). On the other hand, there are now fast growing branchy varieties (clones) in Casuarina which have been developed for windbreak agroforestry system (Buvaneswaran et al 2013). By considering these two facts, an innovative hypothetical model for cultivating teak in windbreak agroforestry system has been conceived. In this model, it is proposed that teak will be grown in the middle row of windbreak and on either side of teak row, branchy varieties (clones) in casuarina will be planted to provide protection from desiccating wind and produce competition for light to teak. This competition will benefit teak for growing tall without much production of side branches. A study was conducted agricultural fallow land in Puthanampatti village, Musiri Taluk, Tiruchirappalli district of Tamil Nadu by establishing Casuarina windbreak on either side of the teak row in the boundary planting. After land preparation by ploughing, three parallel channels at distance of 1 m were formed all along the boundary. In the outer two channels, *Casuarina equisetifolia X Casuarina junghuhniana* hybrid clone were planted at 1m spacing. In the middle channel, teak seedlings were planted at 2 m interval.

In this Casuarina + Teak based windbreak system, teak registered mean height of 20 feet (6 m) and mean girth of 21 cm at the age of three years. Thus, mean annual increment in height growth of Teak is 2 m per year in the present study. Earlier study conducted on assessing teak performance in bund planting in a single row without any windbreaks revealed that teak registered height growth of 8.2, 10.3 and 13.0 m at the age of 5, 9 and 12 years respectively and on an average the mean annual increment amounts to 1.29 m per year (Buvaneswaran et al 2001). Studies on performance of Teak in boundary plantation on Wheat fields in Eastern Uttar Pradesh, India also showed mean annual increment in height growth of Teak as 1.21 m per year (Sharma et al 2011). While comparing the mean annual increments in height growth of teak in the present study and the earlier studies, it can be arrived at that windbreaks favours height growth of teak in bund planting system. At the age of 4 years, the mean height was 9.0 m for teak and 12 m for Casuarina. The mean girth was 20.4 cm for teak and 22.9 cm for Casuarina. The farmer harvested the Casuarina trees and retained the teak trees in the boundary. The fresh weight of harvested Casuarina poles was 13 MT from the two rows of Casuarina around the boundary of 1.6 acres land. He sold at on-farm price of Rs. 5600 per MT and the revenue earned was Rs 72800.

To conclude, this new approach of growing teak trees along with casuarina windbreaks favours better height growth of teak, particularly in bund planting system and in windy localities. Self pruning of branches in teak tree in the mid of casuarina windbreaks helps to produce clean boles of teak without knots will attract good marketing. Further research on mixed planting of teak and casuarina including in large scale block plantations will pave a way for enhancing quantitative and qualitative production of teak wood in the country.

Strategies to increase teak timber production

- There is greater scope for enhancing productivity by two to three folds through Quality Planting Stock supply for the teak.
- Maximizing UTILITY of established SPA/SSO/CSOs for Teak already established in the country.
- Suitable IDEOTYPE need to be selected for various Teak based Agroforestry systems.
- Species based Agroforestry to Clonal specific Agroforestry system.
- Empowering Community for Quality Planting Stock production through Community Seed Orchard Programmes and establishment of Community Nursery for Teak as being done for Casuarina.
- Promotion of Casuarina + Teak based boundary planting model.

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Genetic Estimation Studies in *Dalbergia sissoo*

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Abstract

Investigation was carried out on twenty clones of shisham (*Dalbergia sissoo*) assembled in clonal trial at Forest College and Research Institute, Mettupalayam to study variability parameters, heritability and genetic advance. The volume registered highest phenotypic coefficient of variance (PCV) followed by clear bole height and crown height and also genotypic coefficient of variance (GCV) was highest in volume followed by clear bole height and crown height. Tree height, diameter at breast height (DBH), basal diameter, crown height, clear bole height and volume registered higher heritability whereas number of branches recorded low heritability. With regard to genetic advance as per cent of mean, volume and clear bole height was moderate while tree height, diameter at breast height (DBH), basal diameter, number of branches and crown height recorded low values. Among 20 clones evaluated the clone FCRIDS18 was found to be superior in respect of growth attributes and hence the clone FCRIDS18 could be exploited for further tree improvement programme.

Introduction

There is a growing demand for timber and timber products which ushered in a total mismatch between demand and supply. There has been a shift in the emphasis from utilization of often complex natural forests to plantation species which are relatively easy to manage and capable of producing large quantities of wood per unit area (Wilan, 1973). The gap between the demand and supply has become still wider at the middle of this century. This ever-widening gap in demand and supply could be narrowed down only by development of large-scale plantations. The increasing demand coupled with low productivity of plantation is also one of the major concerns faced by wood based industries. One of the main reasons for low productivity of industrial plantations is non-availability of genetically improved planting stock and proper management practices. Improved planting material coupled with precision silvicultural technologies will further improve the productivity of the plantations. *Dalbergia sissoo* is highly durable with excellent finishing colour and smoothness used for veneer, furniture, cabinets, paneling, carving, small timber, plywood and musical instruments (ICRAF, 2007; Lowry and Seebeck, 1997.

Dalbergia sissoo belongs to the family of Leguminosae (Papilionioideae) and commonly known as Indian Rose wood, Shisham, Sissoo and Thali. It is a medium to large-sized deciduous tree, much-branched, slender, normally with crooked bole and growing up to 30 m in height and 80cm dbh under favourable conditions. It is naturally distributed in the foothills of the Himalayas from eastern Afghanistan through Pakistan and India.

Despite being a species endowed with an amplitude of utilities and commanding extensive areas, yet it has received little research efforts in genetic improvement. A knowledge on magnitude, nature and type of variation is a pre-requisite for any tree improvement programme (Zobel and Talbert, 1984). The best gains can be made for characteristics that have a wide range of variation and are strongly under genetic control (Zobel, 1971; Lacase, 1978; Zobel and van Buijitenen, 1989). Since Sissoo is extensively being planted for different purposes and plantations are very costly to establish, it is essential that the most productive plant material be used. A detailed knowledge of genetic variation within a species is thus a pre-requisite to select clones for developing efficient tree breeding strategies. A knowledge of genetic divergence among the genotypes is essential as it helps avoid inbreeding. It is also important since use of genetically diverse parents is likely to produce higher heterotic effects (Griffing and Lindstorm, 1954). The quantitative estimation of the potential genetic diversity among genotypes is warranted in *Dalbergia sissoo*.Against this backdrop, the present investigation was undertaken to determine the variability, heritability and genetic advance of *Dalbergia sissoo* clones.

Materials and Methods

The investigations were carried out in two year old clonal evaluation trial at Forest College and Research Institute, Mettupalayam during 2012 to 2013.

Mean performance of clones at field

A clonal evaluation trial has been laid at Forest College and Research Institute, Mettupalayam in 2010. Twenty different clones were planted in a randomized block design (RBD) replicated three times. The clones were planted at the espacement of 3 x 3 m. The observations such as Plant Height, Diameter at breast height (DBH) Basal diameter, Number of branches ,Clear bole height, Crown height were recorded and Volume were calculated at 24, 28 and 32 months after planting (MAP) as described below.

Statistical analysis

The data collected from the field experiments were analysed and tabulated. The estimates of mean, variance and standard error were worked out as per the procedure described by Panse and Sukhatme (1978). The significance test was carried out by referring to the standard 'F' table of Snedecor (1961).

Estimation of genetic parameters

Genetic Parameters were tested In Following Attributes

Variability studies

These parameters were estimated as per the method described by Johnson *et al.,* (1955).

Genotypic Variance: (G.V) $(s^2g) = (s^2g - s^2e)/r$

Where,

$\sigma^2 g$ = Genotypic mean square

$\sigma^2 e$ = Error variance

r = Number of replications

Phenotypic Variance: (P.V) (s^2p) = $s^2g + s^2e$

Where,

$\sigma^2 g$ = Genotypic variance

$\sigma^2 e$ = Error variance

Phenotypic (PCV) and genotypic (GCV) coefficients of variances were computed following Burton (1952).

Phenotypic Co-efficient of Variability

Phenotypic Co-efficient of Variability was arrived by using the formula as given below

$$\text{PCV (\%)} = \frac{(\text{Phenotypic Variance})^{½}}{\text{General mean}} \times 100$$

Genotypic Co-efficient of Variability

Genotypic Co-efficient of Variability was arrived by using the formula as given below

$$\text{GCV (\%)} = \frac{(\text{Genotypic Variance})^{½}}{\text{General mean}} \times 100$$

Heritability (h^2)

Broad sense heritability (h^2) was calculated according to Lush (1940)

$h^2 = \sigma^2 g / \sigma^2 p$

Heritability percentage = h^2 x 100

Genetic advance

Genetic advance was worked out after Johnson *et al,* (1955).

Genetic advance (GA) = [(Genotypic variance / Phenotypic variance)$^{1/2}$] x K

Where, K = 2.06, a selection differential at 5 per cent selection intensity

Genetic advance as percentage of mean

GA as percentage of mean = GA/Grand mean x 100

The biometrical traits for describing the genetic parameters, the values recorded in the study were classified and presented.

The genetic estimates for biometric attributes were classified as detailed below.

Genetic parameter	Low	Moderate	High
GCV and PCV	<20	20-30	>30
Heritability	<30	30-60	>60
GA as % of mean	<30	30-60	>60

Results and Discussion

In genetic improvement programme of trees, the selection of superior genotype is very important as it forms the very basis for any tree improvement. The success of any tree improvement programme depends on the amount of genetic variability in a tree species and it has got significant importance for developing effective tree improvement strategies (Vakshasya *et al.,* 1992). The clonal evaluation trial conducted in the field showed significant differences among 20 clones of *Dalbergia sissoo* for the growth characteristics *viz.,* tree height, diameter at breast height (DBH), basal diameter, number of branches, clear bole height, crown height and volume at three growth stages (24, 28, and 32 MAP). Significant variation was found observed in relation to all growth ributes studied *viz.,* tree height , diameter at breast height (DBH), basal diameter, number of branches, clear bole height, crown height and volume among 20 clones. Considering all the 20 clones, FCRIDS18 showed consistently superior performance in all the three different stages investigated. Genetic selection of rapid juvenile growth rate was also advocated as a means of improving competitive ability of forest trees (Gall and Taft, 1973; Steiner, 1986) which extend the scope of selection of a clones in current study based on superiority during the period under evaluation.

Variability parameters

Success of any tree improvement program depends on the variability present in the material. *Dalbergia sissoo* can be considered a more exploitable tree crop and therefore, to start the improvement work in this tree crop, the assessment of genetic variability of the clonal material under study becomes imperative. Significant differences that existed among different clones could be evidenced due to the considerable range of variability with respect to almost all the characters under study. The maximum range of variation was obtained for volume (PCV - 27.67% and GCV - 33.18%) followed by clear bole height (21.84 %) and crown height (13.50 %), the low variation observed in number of branches (PCV - 5.64 %) (Table 9) in the current study.

The coefficient of variations being independent of the scale of the unit of measurement, for different mean values, etc., can be conveniently used for comparison between different populations. In the present study, volume recorded highest phenotypic coefficient of variation (27.67%) and genotypic coefficient (33.18%) of variation. Biometric characters viz., tree height, diameter at breast height (DBH), basal diameter, number of branches, clear bole height and crown height exhibited low to intermediate genotypic and phenotypic coefficient of variation. Genotypic coefficient of variation gives an idea of the quantum of genetic variability in a character and provides a mean to compare the genetic variability in the different quantitative characters and it is not possible to estimate heritable variation alone. The genotypic coefficient of variation for tree height, diameter at breast height (DBH), basal diameter, number of branches, bole height, crown height and volume recorded in the current study provided evidences for existence of adequate genotypic variations and thus lend support for exploitation of genetic variability for further improvement in this species.

In general, for all the traits, genotypic coefficients of variations were at a higher side than their respective phenotypic coefficient of variations for almost all the traits thus indicating the less environmental effect and true representation of the genotype by the phenotype as evidenced in Poplars (Lone and Tewari, 2008), *Melia dubia* (Kumar, 2013).

Heritability and genetic advance

Heritability has an important place in tree improvement programme as it provides an index of relative strength of heredity versus environment. Heritability is very important in tree improvement programme (Dorman, 1976). It is also useful for ranking importance of each trait in cross breeding programme. Heritability expresses the degree to which a character is influenced by heredity as compared to the environment. (Kumar *et al.,* 2010).

Estimation of broad sense heritability showed high values for diameter at breast height DBH (0.99 %), basal diameter (0.96 %), tree height (0.95%), crown height (0.94 %) clean bole height (0.90 %) and volume (0.69 %) while low heritability was observed for number of branches (0.29) (Table 4).

The diameter at breast height (DBH) registered high heritability (0.99 %) which might be due to the complexity of quantitative trait, prone to high environmental influences. The current study indicated the predominance of additive gene action for this character as reported in teak (Kumar, 1997). Gera *et al.* (2000) reported low heritability for collar diameter and inter nodal length but higher heritability for height, number of branches, and survival percentage was observed in *Dalbergia sissoo*. As the height, diameter at breast height (DBH), clear bole height, crown height, basal diameter and volume showed high heritability percentage, the selection for these traits would be effective and improvement could be made through mass selection.

Higher heritability indicates the effectiveness of selection based on good phenotypic performance but does not necessarily mean a high genetic gain for particular traits. Heritability estimates in broad sense is reliable if accompanied by high genetic advance (Burton, 1952). In the present study, the trend of genetic advance as per cent of mean was maximum in volume (47.53 %) (Table 4) followed by clear bole height, crown height and basal diameter indicating a wide scope of genetic improvement possibility in the species.

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Table 1. Clonal variations for tree height (m) and Diameter at breast height (cm) in *Dalbergia sissoo* at three growth periods

Clone details/ Treatments	Tree height (m)			Diameter at breast height (cm)		
	24 MAP	28 MAP	32 MAP	24 MAP	28 MAP	32 MAP
FCRIDS1	5.57	6.45	7.33	4.06	5.06	5.75
FCRIDS2	5.27	6.94	7.02	4.28	5.30	6.62
FCRIDS3	5.52	7.16	8.17	5.46	6.46	7.20
FCRIDS4	5.63	7.28	7.59	4.83	5.79	6.53
FCRIDS5	4.88	6.59	7.76	4.75	5.76	6.44
FCRIDS6	4.63	6.52	7.68	4.79	5.79	6.37
FCRIDS7	5.94*	8.15	8.53	5.98	6.98	7.70
FCRIDS8	5.42	6.42	6.68	4.15	5.84	6.76
FCRIDS9	5.84*	6.84	7.25	4.13	5.29	6.29
FCRIDS10	5.76*	5.76	7.15	5.04	6.01	6.89
FCRIDS11	5.50	7.28*	7.48	5.50	6.60	7.40
FCRIDS12	5.01	6.68	7.53	5.28	6.76	7.44
FCRIDS13	4.80	5.98	8.32	5.35	6.95	7.53
FCRIDS14	5.21	6.31	7.29	4.76	5.50	6.27
FCRIDS15	5.41	6.41	7.37	5.02	5.86	6.55
FCRIDS16	5.40	6.40	8.02	5.56	6.58	7.00
FCRIDS17	5.15	7.25	7.85	5.25	6.25	6.91
FCRIDS18	7.30	8.58	9.16	6.73	8.05	8.90
FCRIDS19	6.64	7.19	7.75	5.77	7.09	7.76
FCRIDS20	5.11	5.54	6.11	4.91	6.06	6.77
MEAN	**5.50**	**6.78**	**7.62**	**5.08**	**6.20**	**6.95**
SEd	**0.0694**	**0.0484**	**0.1313**	**0.0565**	**0.0312**	**0.0570**
CD (p=0.05)	**0.1404**	**0.0979**	**0.2658**	**0.1144**	**0.0631**	**0.1155**

* Significant at 5 per cent level

Table 2. Clonal variations for number of branches in *Dalbergia sissoo* at three growth periods

Clone details/ Treatments	Number of Branches		
	24 MAP	**28 MAP**	**32 MAP**
FCRIDS1	5.40	8.50*	14.67
FCRIDS2	4.83	8.67*	11.47
FCRIDS3	4.47	6.50	12.00
FCRIDS4	4.80	8.30	13.00
FCRIDS5	5.17	6.67	12.07
FCRIDS6	4.87	8.43	12.00
FCRIDS7	6.47	8.50*	12.50
FCRIDS8	6.00*	7.53	11.33
FCRIDS9	5.73	7.53	11.67
FCRIDS10	5.13	6.63	12.87
FCRIDS11	5.40	6.50	14.87
FCRIDS12	6.12*	7.93	12.73
FCRIDS13	5.87	7.23	12.53
FCRIDS14	4.97	8.03	12.87
FCRIDS15	5.20	8.47	12.50
FCRIDS16	7.77	9.53	11.20
FCRIDS17	5.27	6.10	12.00
FCRIDS18	7.50	8.67*	12.33
FCRIDS19	5.33	6.57	12.38
FCRIDS20	6.17*	7.43	13.00
MEAN	**5.62**	**7.69**	**12**
SED	**0.2456**	**0.3976**	**0.8857**
CD (p=0.05)	**0.4971**	**0.8050**	**1.7931**

* Significant at 5 per cent level

Table 3. Clonal variations for volume (m^3) in *Dalbergia sissoo* at three growth periods

Clone details/ Treatments	Volume (m^3) 24 MAP	28 MAP	32 MAP
FCRIDS1	0.0043	0.0077	0.0115
FCRIDS2	0.0045	0.0108	0.0148
FCRIDS3	0.0077	0.0140	0.0201
FCRIDS4	0.0062	0.0120	0.0146
FCRIDS5	0.0052	0.0103	0.0153
FCRIDS6	0.0050	0.0102	0.0148
FCRIDS7	0.0100	0.0159	0.0240
FCRIDS8	0.0044	0.0103	0.0144
FCRIDS9	0.0047	0.0090	0.0137
FCRIDS10	0.0069	0.0097	0.0160
FCRIDS11	0.0078	0.0153	0.0188
FCRIDS12	0.0066	0.0143	0.0199
FCRIDS13	0.0065	0.0135	0.0223*
FCRIDS14	0.0056	0.0089	0.0137
FCRIDS15	0.0064	0.0103*	0.0150
FCRIDS16	0.0079	0.0130*	0.0185
FCRIDS17	0.0067	0.0144	0.0164
FCRIDS18	0.0156	0.0262	0.0342
FCRIDS19	0.0104	0.0183	0.0205
FCRIDS20	0.0058	0.01056	0.0120
MEAN	**0.0069**	**0.0127**	**0.0175**
SEd	**0.0002**	**0.0002**	**0.0026**
CD (p=0.05)	**0.0004**	**0.0005**	**0.0053**

* Significant at 5 per cent level

Table 4. Genetic estimates of growth attributes of *Dalbergia sissoo* clones

Traits	PCV	GCV	Heritability	Genetic advance percentage over mean
Tree height (m)	9.88	10.11	0.95	19.89
Diameter at breast height(cm)	10.05	10.10	0.99	20.60
Number of branches	5.64	10.35	0.29	6.34
Clear bole height (m)	20.76	21.84	0.90	40.64
Basal diameter (cm)	9.95	10.13	0.96	20.15
Crown height (m)	13.15	13.50	0.94	26.38
Volume (m^3)	27.67	33.18	0.69	47.53

Genetic variability and association studies in growth traits of *Thespesia populnea* (L. Sol. ex. Correa) in progeny evaluation trial in Tamil Nadu

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Abstract

Twelve month old twenty phenotypically superior half-sibs of *Thespesia populnea* were raised in progeny evaluation trial at Forest College and Research Institute, Mettupalayam, Tamil Nadu during the year 2013. The half-sib progenies of *T. populnea* were evaluated for variability, heritability, genetic gain, correlation and path analysis at 6 months after planting. The half-sib progenies differed significantly to all the three parameters *viz.,* plant height, basal diameter and volume index. The half-sibs collected from Tiruppur-1 recorded higher growth traits *viz.,* height (101.60 cm), basal diameter (2.73 cm) and volume index (756.77 cm^3), followed by Avinashi and Palapalayam among 20 progenies at six month after planting. Volume index registered highest phenotypic coefficient of variation, genotypic coefficient of variation (48.14%, 46.99%) followed by basal diameter (17.29%, 16.19%) at six month after planting. Maximum heritability was observed for plant height (97.90%) followed by basal diameter (92.58%) and volume index (87.71%). Volume index and height were found to be associated with higher genetic gain of 94.49 and 31.85 percentage respectively while it was low for basal diameter (31.24 %). Volume index had positive but non-significant correlation with height and basal diameter. Path analysis showed that basal diameter (0.742) and height (0.315) contributed directly to the volume index. The half-sib progenies collected from Tiruppur-1, Avinashi and Palapalayam were found to be the best on the basis of mean growth characters in progeny evaluation trial. The preliminary investigation will be useful for further genetic improvement of *T. populnea*.

Introduction

Thespesia populnea is one of the fast growing and multipurpose trees and the wood is excellent for carving. It is widely used for making bowls and plates, clubs, paddles, agricultural implements, musical instruments, gunstocks, carts, wheels, boats, tool handles, furniture, cabinet work, utensils, jewellery and turnery. It is also considered suitable for light construction, flooring, wall panelling, interior trim, precision equipment, toys and novelties, and pattern making. The wood can also be used as firewood. Friday and Okano (2006) reported that tree is suitable for dry locations because it develops a long taproot in porous soils; it may tolerate a dry season of up to 8 months. It thrives on sandy coastal soils as well as volcanic, limestone and rocky soils with a pH of 6.0-7.4. It tolerates heavier soils, soil salinity and occasional inundation, but does not grow on permanently inundated soils.

Friday and Okano (2006) also reported the density of the wood is about 770 kg m^{-1} at 12 per cent moisture content. Trees should be pruned to develop clear boles for timber production. In Asian mangrove areas, it is planted to consolidate ridges and bunds in an aqua-silvicultural system for prawn production.

Pokharkar *et al*. (2008) examines biodiesel production from nonedible oil extracted from *T. populnea* plant seeds. The effects of catalyst concentration, time, water content, and temperature on trans-esterification were studied to get large yield of fatty acid methyl ester (biodiesel) of the *T. populnea* oil. It was found that the yield of biodiesel made from the *T. populnea* oil under various conditions was found 50-92 per cent. Biodiesel produced from this non-edible oil was tested on a diesel engine to study the effect of biodiesel fatty acid composition on the engine exhaust emission.

Orwa *et al.* (2009) reported young shoots are used as fodder and as green manure. The tree can yield 2-3 kg of green fodder and this goes up to 10 kg in the 15 years.

Friday and Okano (2006) also reported in South-East Asia and India the young leaves, flowers and unripe fruits are eaten raw, boiled or fried as a vegetable and also it have medicinal properties. The leaves are applied to inflamed and swollen joints. When cut, the young fruit secretes a yellow sticky sap used to treat ringworm and other skin diseases. Various parts of the plants have high tannin contents and plant extracts have been shown to have anti-bacterial and anti-viral activity. The bark yields a tough fibre used for cordage, fishing lines, basketry, coffee bags and for caulking boats. The outer bark may be used for rope and the inner bark for finer cordage.

The flowers and fruits yield a water-soluble yellowish dye, while the wood soaked in water gives a solution that is used in Asia to dye wool deep brown. In old Hawaii, a dye made from the seed capsules yielded a yellowish green colour (Krauss, 1993). The wood may produce a yellow dye used to dye wool in East and South-East Asia, and the leaves are used to make a black dye (Clark and Thaman, 1993). The bark contains high levels of tannins and has been used for tanning leather. *T. Populnea* is valid for its timber is lacking in genetic improvement work. Genetic improvement of planting stock, both through the seed route and clonal route can play a very significant role in improving the yield, productivity, quality of the produce and profitability of plantations. The improvement through seed sources facilitates for the production of commercial planting stock from field tested and identified genetically superior seed sources will result in substantial gains in a short period of time, by capturing the useful genetic variation existing in the population. The most successful tree improvement programmes are those in which proper seed sources and provenances are used. Success in the establishment and productivity of forest tree plantations is determined by the species used and the seed source of propagules used within the population (Larson, 1954; Callaham, 1964, Lacaze, 1978). It was deserved that most growth attributes to be heritable and considerable genetic gains could be achieved through selection. The assessment of genetic variability is key to progress in tree improvement (Zobel, 1981). The effective tree improvement programme depends upon the nature and magnitude of existing genetic variability and also on the transmission of the desired traits. Knowledge on association among components of economic importance can help in improving the efficiency of selection. Path coefficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficients into components of direct or indirect effects. The present study on progeny evaluation trial of *T. populnea* was, therefore, undertaken to assess the genetic variability with respect to growth characters and the degree of their transmission by estimating heritability, genetic advance, genetic gain, correlation and path analysis in this most valuable species.

Materials and Methods

The study was conducted at Forest College and Research Institute, Mettupalayam situated between 11°18'N and 76°56'E longitude. The area enjoys semi-arid type climate with mean annual rainfall of 830 mm. Twenty half sibs of *Thespesia populnea* were collected from various locations of Tamil Nadu. The twelve months old plants were planted in November, 2013 in field in Randomized Block Design (RBD) with three replications in already dug up pits of 30 cm x 30 cm x 30 cm. The spacing adopted was 2 m x 2 m of five seedlings per replication per seed source. The field was irrigated once in ten days. The plants were maintained in the field and observations on plant height (cm), basal diameter (cm), and volume index (cm^3) 6 months after planting. Volume index was calculated using the formula (Hatchell, 1985; Manavalan, 1990)

$$\text{V. I.} = (\text{Collar diameter})^2 \times \text{Height (cm)}$$

Coefficient of variability (PCV and GCV) was worked out by formula suggested by Burton (1952). Heritability and genetic advance were calculated by the formula used by Lush (1940) and Johnson *et al.* (1955). Genetic gain was calculated by the method suggested by Johnson *et al.* (1955). Genotypic and phenotypic correlations were determined as per the methods suggested by Goulden (1952), while path coefficients, also at genotypic and phenotypic levels, were estimated according to Dewey and Lu (1959).

Results and Discussion

Significant variations in plant characters like height, basal diameter and volume index were observed under field conditions among half sib progenies of *T. populnea* at 6 months after planting. Among half sib progenies, half sibs collected from Tiruppur-1 attained maximum height (101.60 cm), basal diameter

(2.73 cm) and volume index (756.77 cm^3), which was observed to be statistically at par with Avinashi half sib progenies for height (100.90 cm), basal diameter (2.45 cm) and volume index (607.23 cm^3) and followed by Palapalayam half sibs for height (98.67 cm), basal diameter (2.28 cm) and volume index (514.53 cm^3) (Table 1.). The results are conformity with findings of Kumar (2011) in 20 seed sources of *Melia dubia*.

The extent of variability is also assessed by genotypic and phenotypic coefficient of variation. In the present study (Table 2), volume index registered maximum phenotypic and genotypic coefficient of variation (48.14%, 46.99%) followed by basal diameter (17.29%, 16.19%). Higher phenotypic coefficient of variation and genotypic variation reported in *Eucalyptus globulus* (Jude sudhagar, 1999) and *E. tereticornis* (Balaji, 2000).

Table 1. Mean performance of *T. Populnea* in progeny evaluation trial at six months after planting

Half-sib progeny details / Treatments	Height (cm)	Basal diameter (cm)	Volume index (cm^3)
Mettupalayam	70.70	1.87	246.48
Umapalayam	74.63	1.82	247.55
Gandhipuram	98.13*	1.89	350.66
Coimbatore (GCT)	71.33	1.70	205.45
Coimbatore (TNAU)	68.53	1.76	212.42
Karamadai	61.17	1.75	187.66
Tiruppur-1	101.60*	2.73*	756.77*
Tiruppur-2	81.07	2.23*	403.22*
Avinashi	100.90*	2.45*	607.23*
Rayapuram	73.37	1.79	234.96
Erode	80.47	1.68	228.32
Bhavanisagar	97.19*	1.84	331.40
Palapalayam	98.67*	2.28*	514.53*

Half-sib progeny details / Treatments	Height (cm)	Basal diameter (cm)	Volume index (cm^3)
Hogenakkal	75.13	1.90	271.93
Periyampatti	75.20	1.45	157.68
T. Nagar	97.35*	2.03	402.63*
Ennore	97.07*	2.25*	492.78*
Jakkampatti	89.20*	2.19*	429.07*
Aundipatty	71.50	1.41	142.33
Theni	92.17*	1.92	343.17
Grand mean	**83.77**	**1.94**	**338.51**
SEd	1.564	0.089	28.903
CD (0.05)	3.167	0.179	58.512

* Significant at 5 per cent level

Heritability values for height and volume index were observed to be high *i.e.* 97.90%, 92.58% respectively while it was low for basal diameter (87.71%) (Table 2). Similar results had been reported earlier in *Tectona grandis* (Anmol Kumar, *et al.,* 1997) and in *Eucalyptus globulus* (Jude sudhagar, 1999).

Volume index and height were found to be associated with higher genetic gain of 94.49 and 31.85 percentage indicating a wide scope of genetic improvement to these parameters (Table 2). This results are conformity with the findings of Anmol Kumar *et al.* (1997) in *T. grandis* and Jude sudhagar (1999) in *E. Globulus.*

In the present investigation, volume index registered non-significant association with height and basal diameter at both phenotypic and genotypic levels (Table 3). Similar results were reported in *Melia dubia* (Saravanan, 2012).

Results obtained in path coefficient analysis half sib progenies for growth traits for volume index revealed that basal diameter and height showed positive direct effect on volume index. Basal diameter showed maximum positive direct effect (0.742) on volume index followed by height (0.315). Saravanan (2012)

Table 2. Genetic estimates for field performance of half-sib progenies in *Thespesia populnea*

Characters	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance as per cent of mean
Height	15.79	15.62	97.90	31.85
Basal diameter	17.29	16.19	87.71	31.24
Volume index	48.14	46.99	92.58	94.49

Table 3. Correlation co-efficient among growth traits in half-sib progenies of Thespesia populnea

Characters		Height	Basal diameter	Volume index
Height	**G**	1.000	0.701**	0.836**
	P	1.000	0.652**	0.814**
Basal diameter	**G**		1.000	0.964**
	P		1.000	0.950**
Volume index	**G**			1.000
	P			1.000

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4. Path coefficient analysis showing direct and indirect effects of growth traits on volume index under field condition in half-sib progenies of *Thespesia populnea*

Characters	Height	Basal diameter	Volume index
Height	0.315	0.520	0.836
Basal diameter	0.221	0.742	0.964

Residual Effect = 0.1425

observed the plant height and diameter at breast height on volume could be used as selection criteria in *Melia dubia* genetic resources which conformity with findings of present study.

Conclusion

From the present investigation, it is inferred that considerable variations in plant height, basal diameter and volume index exist among half sib progenies of *Thespesia populnea*. The heritability and genetic gain were high in the volume index, which strengthens the probable reason that they are more under genetic control. The study suggests that judicious screening/selection on the basis of these growth parameters can be an effective technique in selecting trees for maintaining good quality planting. At this stage, half sib progenies Tiruppur-1, Avinashi and Palapalayam may be recommended to meet the immediate planting programmes in the regions of Tamil Nadu for enhancement of growth and productivity of *T. Populnea.* High positive genotypic correlation coefficient in growth traits reveals that the traits are genetically controlled and selection can be very effective in tree improvement programme of these species.

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Tree Cultivation in Tamil Nadu – A SWOC (Strength, Weakness, Opportunities and Challenges) Analysis

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Introduction

Over the last two decades, concern about the world's forests has risen dramatically. Large forest areas have been converted to other land uses, or severely degraded. At the same time it has been increasingly recognized that forests and trees provide crucial economic, environmental and social needs in many countries. Trees outside forests i.e. trees and tree systems found on agricultural land, on meadows and grazing lands, on unproductive lands, along canals, railways, roads and in human settlements, have numerous often essential roles and functions. They make a critical contribution to Agriculture, food security and rural household economies. They supply many products and services. As agroforestry systems, they serve a number of ecological and economic functions that are similar to that of forests. The use of trees in farming systems dates back to the beginning of domestic agriculture. Recently interest in partnerships between the private and public sectors, communities and individuals for the production of goods and services outside forests have been increasing.

Materials and methods

In this context, the present study was conducted to investigate the strength, weakness, opportunities and challenges faced by the tree growers in Tamil Nadu. The study was analyzed with a structured interview schedule and data was collected from 90 members of the Consortium of Industrial Agroforestry (CIAF) during the first annual workshop of CIAF. Farmers, industries, nursery growers, scientists and representatives from financial organizations were the respondents. The major silviculture practices analyzed for the study were varietal preferences, quality seedling material, practices of intercrops, application of fertilizers, pest and disease management and marketing. The interview schedule had three parts one with the basic data collection, the second part includes the extent of adoption of tree crops and the third part with the socio economic determinants to analyze the various components related to strength, weakness, opportunities and challenges of tree cultivation in Tamil Nadu.

Results and inferences

The technologies taken for measuring the extent of adoption were knowledge on varieties, selection of quality planting material, site selection, time of planting, spacing, pit size, Fertilizer application, integrated pest and disease management, irrigation, weeding, intercrops and marketing. The following table explains the details on extent of adoption by the tree growers.

Table1. Extent of adoption of tree cultivation practices

n = 90

Sl.No.	Practices	Frequencyn = 90	Percentage
1.	Knowledge on varieties	75	67.50
2.	Selection of quality planting material	60	54.00
3.	Site selection	52	18.00
4.	Time of planting	56	50.40
5.	Spacing	65	58.50
6.	Pit size	80	72.00
7.	Fertilizer application	25	22.50
8.	Integrated pest and disease management	22	19.80
9.	Irrigation	17	15.30
10.	Integrated weed management	15	13.50
11.	Intercrops	82	73.80
12	Tree insurance	30	27.00
13.	Marketing	76	68.40

The table reveals that around 70 % of the farmers had knowledge on varieties on important tree species and 60 % of the farmers were aware of the availability of quality planting material. Around 50 per cent of the farmers adopted the site selection, spacing and time of planting. Nearly 80 per cent of the farmers were adopting the exact pit size for various tree species. But regarding fertilizer application, integrated pest and disease management, irrigation and mulching only 10-20 % of adoption could be seen. Among the cultivation practices almost 80 % of the farmers followed the intercrops cultivation in tree plantation and nearly 80 per cent of the farmers were aware of the marketing techniques for the major tree species.

The determinants were given in a closed end format in order to narrow down the responses towards tree cultivation alone. Totally twenty determinants were finalized to fit in five major determinants in one group i.e five in each of Strength, Weakness, Opportunities' and Challenges categories. Analysis of the rank order was done using the Garret scoring Technique.(Garrett, 1969). In this method the tree growers were asked to rank the given statements according to the magnitude of their own preferences. The order of merit given by the respondents were converted into ranks by using the percentage position.

$$\text{Percentage position} = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where, R_{ij} = Rank given for i^{th} item j^{th} individual

N_j = Number of items ranked by the j^{th} individual

The percentage position of each rank thus obtained was converted into scores by referring to the table given by Henry Garrett then for each factor the scores of individual respondents were added together and divided by the total number of respondents for whom the scores were added. These mean scores for all the factors were arranged in the order of their ranks and inferences were derived.

The major strength of tree cultivation in Tamil Nadu is higher income for the tree species; the major weakness is non availability of quality planting

Table 2. SWOC analysis of tree cultivation

Sl.No		Reason	Mean score	Rank
1.	Strengths	Higher income	50.75	I
2.	Weakness	Non availability of quality planting material and monopoly in price fixation	57.56	I
3.	Opportunities	Increasing area under cultivation and intercrops	49.53	I
4.	Challenges	Inadequate Credit flow and Policy decisions	49.28	I

material and monopoly in price fixation. Considering the opportunities, the increasing area under cultivation and intercrops was the foremost. The major constraint of tree cultivation in Tamil Nadu is inadequate credit flow and Policy decisions.

Conclusion

Tree cultivation in Tamil Nadu is shifting towards a livelihood option of majority of the small and marginal land holders. It was found that there is a gap between the recommended practices and adoption of the technologies. The extent of adoption of the recommended practices of tree cultivation could be enhanced by improved awareness measures and training programmes. Quality planting material and certified nurseries could be another opportunity to enhance the extent of adoption of the technologies among the growers. ICT enabled extension strategies and policy interventions could be derived exclusively for important tree species for credit flow and marketing.

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Information and Communication Technology (ICT) for Enhancing Tree Cultivation in Tamil Nadu

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India has brought revolution in the area of information technology and made everyone to utilize the concept of "Knowledge society". Knowledge society is one which uses knowledge to empower and enrich its people. The application of information technology can change the system of delivering knowledge to the rural community. Extension system especially Forestry Extension will be rejuvenated its vigor by the application of ICTs. ICTs will improve the linkage between research subsystem and farmers' subsystem. ICTs can help the Forestry extension worker to gather, store, retrieve and disseminate a broad range of information needs. Information technology provides the database management systems, expert systems and site specific information systems. Following are the areas of empowerment in Forestry Technology and Extension. Forestry cyber cafe as farmer's hub to obtain latest information, use of ICTs in extension service, as the present day extension service requires modification to meet the needs of the changing agricultural scenario, at the global level. To equip individual farmer for active participation in global market ICTs have to be used. Intensification of Human Resource Development initiatives through institutionalization opportunities are to be provided for reservoir of unemployed youth for supporting agricultural production process by undertaking agribusiness ventures to meet the felt needs of technical and extension service support to the farming community. The resource institution situated in a locality should take lead in developing specific, need based expert systems for different agricultural, horticultural and animal husbandry practices. Evolving mechanisms for developing situation based expert system for dissemination of information consisting of appropriate media mix. This type of expert system will serve on a model for dissemination of situation based information in different parts of the country.

Forestry expert system may be constituted. It should concentrate on creation of comprehensive database pertaining to the local needs of the farmers and demand in the market. The department of expert systems on forestry be provided with internet and latest multimedia facilities and should have readily available team of experts for solving any situational problems. Utilizing Geographical Information System and Global Positioning System for Forestry Research purpose with the help of ICTs. The farmers and developmental workers may be facilitated to get access to the information pertaining to land, water, market, pest, weather, etc. through these systems.

Forestry centre in the country should play the role of coordinating agency for various electronic, modern media and traditional media providing extension service. This can be achieved by pooling expert information on forestry available with different media at one place and disseminating them in an appropriate mode. Educate farmers on use of computers. The resource institutions should provide training to the end users on the use of computer and internet besides agriculture. In this regard a campaign can be launched to open e-mail account of farmers, so that farmers could be provided door to door email information through a centralized agency of the area. Economics can be effectively used for linking the local commercial and production activities directly to the retailer and trade purchases and to the suppliers. It is helpful in providing the interaction among the researchers, extension workers and farmers. Information Technology can provide a question and answer services where experts respond to the queries on the specialized subjects. Provision of IT services to the developmental officials leads in efficiency in delivering the services for overall agriculture development. It helps in providing upto date information services to the farmers, such as on package of practices, market availability etc. can be provided at the earliest possible time.

Helps in creation of database of local resources of villages and the villagers, site specific information systems, expert systems. Facilitation of land records and online registration services. Serves as an information source regarding forest business and management. Increasing the efficiency and the productivity of the cooperative societies is possible with the computer communication network and latest database technology. Providing Tele-education to the farmers is another area where information technology can be used effectively. The forestry education and research institutes can launch the websites where latest information can be made available to the extension worker. These institutes can also get the first hand information from the grassroot level.Multimedia is usually recorded and played, displayed or accessed by information content processing devices, such as computerized and electronic devices, but can also be part of a live performance. *Multimedia* (as an adjective) also describes electronic media devices used to store and experience multimedia content. Multimedia is distinguished from mixed media in fine art; by including audio, for example, it has a broader scope. The term "rich media" is synonymous for interactive multimedia. Hypermedia can be considered one particular multimedia application.Communication is now one of the central issues in developing societies. The discussions at various forums in the third world and elsewhere confirm that communication should be treated as an integral component of the total development process. Knowledge expansion, information technology and information dissemination are the three very important dimensions of any development systems be it agriculture, industry or whatever. Multimedia has influenced the quality of extension work. Multimedia (MM) which encompasses all the traditional forms communication like – video, stills, graphics, audio, animation and text, is an excellent tool for extension communication. Each learning task is most effectively taught through the optimum usage of relevant media. Multimedia refer to a synthesis of text, data, graphics, animation ,optical storage, image processing and sound. Using the multimedia data types such as video, graphics, images or animation, any participant can introduce illustrative material into the meeting to facilitate better communication.

It informs, educates, persuades and entertains us with dazzling pictures and animations, engaging sounds, compiling video clips and raw textual information. We can electrify the thought and action centers of people's mind. The technologies developed within the four walls of laboratories and research field, must reach the farmers at the earliest to speed up the process of transfer of technology among the farmers. The importance of information dissemination in promoting agricultural and rural development is widely recognized. India has potential to encourage the use of high-level information technology such as multimedia communication. Impact of multimedia on extension services promoted a variety of technologies varied across crops and regions within the country. The use of multimedia as a training tool is advantageous to turn agriculture into industry and enhance turnover, reducing training costs., improving morale of an employee and increase the efficiency and effectiveness of training programmes and reducing the cost of delivery of information.The multimedia technology could function in the field of agricultural extension in the following areas which may include, a range of media technologies, including text, sound, diagrams, pictures, video clippings animation and cartoons can be used to present the subject matter in an interesting, interactive and effective format. Photographs, pictures etc. of symptoms of diseases, insect pest damage and of insects can be made available using multimedia for their effective monitoring and management. Solutions of the problems can also be depicted using figures, photographs or pictures. Using a chat room, crop pest specialists can be consulted to know how to identify accurately and control the pests. Quality of extension material and process can be supplemented time to time by multimedia and virtual library.

Government policies and other related circular and announcements from government can be made available to farmers and extension workers from time to time with the use of multimedia. The information on weather parameters, cropping systems availability of high yielding varieties, other related information on varieties, irrigation, fertilizer management, IPM etc. can be made available to farmers using multimedia and convince them easily. Multimedia offers immense potential today as well as for the future and it will help extension worker and scientist to integrate modeling, visualization and decision making processes associated with farming systems. This will definitely accelerate development in the field of Forestry extension.

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Pathological Problems of Economically Important Timber Tree Species and its Management – An Overview

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Introduction

Forests provide multipurpose benefits such as timber, fodder, fuel and minor forest produces. They also help in conserving soil and water, offering food and shelter for wild life, adding to the aesthetic value and recreational needs of man. Forestry has the prime objective of developing and protecting forests for their maximum productivity. In the wake of afforestation drive launched in the country, a large number of tree species are now being raised under (i) Social forestry, (ii) Agro forestry and (iii) Farm forestry. The purpose of these plantations is to augment forest productivity, provide green cover to otherwise barren landscape and reduce pressure on the reserve forest by making available timber, fuel, fodder and other forest produce to urban and rural masses.

Diseases and insect pests constitute major biological determinants of forest productivity, particularly in nurseries and plantations. They cause heavy damage to seedlings and hence reduce both quantity and quality of planting stock. Large-scale mortality in the nursery due to diseases and insect pests could seriously affect the plantation programme by reducing the stock of seedlings. In plantations, they cause major problems resulting in the reduction of biomass production or loss of valuable germplasm collections. Further, the infected seedlings are weakened and unable to withstand the adverse field/plantation conditions. Thus, the economic loss resulting from nursery diseases and insect pests are considerable. Therefore, raising disease free, healthy tree seedlings is not only important for maintaining a good nursery stock but also essential in establishing a healthy stand in the field for better productivity. Hence, it is essential to identify the various diseases of important tree species in nurseries and plantations and develop suitable management strategies for their better productivity. This paper highlights the major disease problems of economically important timber tree species in nurseries and plantations. Effective management of these disease problems by integrating control methods like cultural practices, sanitation, fungicide application, use of bio-control agents and bio-fertilizers is also provided.

Disease problems of important timber tree species

Seed Diseases

Seeds and seedlings are frequently affected by physical and physiological disorders and the diseases caused by fungi, bacteria, and viruses. Deterioration of tree seeds by fungi involves various problems, for example, tree seeds are exposed to many conditions before storage that permit the development of mold fungi. Seeds are prone to attack by the fungi while still on the tree, during post harvest operations in the field, storage and subsequent handling prior to sowing. The fungi may be borne as surface contaminants or they may be present in the seed coat or may penetrate the seeds even deeper attacking the embryo and thus damage the seeds to varying extents. Losses due to seed borne pathogens include reduced seed germination, increased damping-off, and mortality of older seedlings in nursery beds. The effect of seed borne pathogens on seed and seedling production can go unnoticed until extreme germination failures have occurred in seedbeds (Fisher, 1941, Epners, 1964) or losses have occurred in containers (Campbell and Landis, 1990).

It has been recorded that seeds of some leguminous (pod bearing) tree species are quite susceptible to attack by fungi while they are inside the pods on the trees and they are also damaged considerably in case they are not timely collected and properly stored. Number of fungi belonging to Mucorales and Fungi Imperfecti such as *Alternaria, Aspergillus, Cladosporium, Colletotrichum, Curvularia, Fusarium, Gloeosporium, Lasiodiplodia, Mucor, Penicillium, Phoma, Phomopsis* etc. are associated with seeds of various forestry species of which species of *Fusarium, Lasiodiplodia, Gloeosporium* and *Phoma* cause deep seated infection and damage the embryo.

By extraction of seeds from Teak fruits revealed that emptiness which is very common in Teak fruits and also seeds inside the locules were also deteriorated and covered with fungal mycelium (Mohanan *et al.,* 2005). The organisms such as *Alternania alternata, Aspergillus* spp., *Aspergillus niger, Curvularia* spp., *Drechslera* spp., *Fusarium, Mucor, Phoma, Verticillium, Pestalotia* spp. were found in Teak seeds (Mohanan *et al.,* 2005). Pods of *Dalbergia sissoo* is attacked by *Phoma* sp. Other fungi recorded on pods include *Glomerrella cingulata* and *Septothyrella dalbergiae* (Pavgi and Singh, 1971). *Fusarium* spp. on seeds of *Albizia lebbeck* have been found to cause both pre-emergence and post-emergence damping-off disease together with *Rhizoctonia solani*, a soil inhabitant fungus.

Nursery Diseases

Wide range of fungal and bacterial pathogens attack seedlings and saplings of both exotic and indigenous tree species like Acacias, Ailanthus, Albizias, Artocarpus, Casuarinas, Dalbergias, Deodar, Eucalypts, Gmelina, Melia, Neem, Pines, Sandal, Sal, Tamarind, Terminalia, Teak etc. in different parts of the country (Bakshi, 1951; 1976; Mehrotra, 1990; Sharma *et al.,* 1985; Sankaran *et al.,* 1986; Mohan, 2014; Mohan and Manokaran, 2001, 2013; Mohan *et al*., 2002; Mohanan, 2008). The major nursery diseases of economically important timber tree species are detailed below:

Damping off

Among the nursery diseases, damping-off is the most prevalent and highly destructive disease and cause heavy loss of tree seedlings. It is referred to a group of diseases namely pre-emergence and post-emergence damping off depending on the stage of growth of seedlings when they are attacked. It is caused by different soil fungi such as *Pythium, Phytophthora, Fusarium* and *Rhizoctonia* of which the last two fungi are quiet prevalent in forest nurseries in different parts of India. High soil temperature, excessive soil moisture, high soil pH (alkaline), high nitrogen content, low light intensity due to shading, stiffy or clayey soil with poor drainage, dense sowing are the conditions which favour the disease development in serious proportion.

Damping-off disease caused by *Fusarium solani* was recorded on *Santalum album* in SFD research nursery at Varattupallam and Bhavanisagar (Bamboo

Division) in Tamil Nadu (Mohan, 2014). Symptom of the disease occurred within two weeks of germination of seeds, when the first pair of leaves was just emerging, and caused up to 56.7 percent mortality of seedlings. Dark shade over the seedbeds and excess watering favoured the disease development. The disease appeared in the form of irregular patches in seedbeds. These patches enlarged rapidly from the periphery affecting the neighbouring, healthy seedlings under high soil moisture conditions. Water-soaked lesions appeared on the hypocotyl near the ground level. The lesions turned brown in colour and the affected portion got damaged due to collapse of cells, resulting into a prominent constriction. Hence, the seedlings fell over the seedbed and eventually died.

Leaf spot

It is another important disease problem in nurseries, vegetative multiplication areas, seed and clonal orchards of different tree species. It is caused by different fungi *viz., Alternaria, Cercospora, Colletotrichum, Cylindrocladium, Phoma, Phomopsis, Pestalotiopsis* etc. and bacteria *viz., Xanthomonas* and *Pseudomonas.* It has been recorded as serious problem in clonal nursery, VMGs and seed and clonal orchards of different tree species. The pathogen causes leaf spots which increase rapidly in size covering large leaf areas. The infected leaves present a blighted appearance and are eventually shed. Severely infected seedlings show premature defoliation. Leaf spot disease on *Gmelina arborea* is caused by *Pseudocercospora ranjita* was reported from Assam and Kerala. *Deptoshaeria gmelinae* causing leaf spot and die-back of twigs has been reported from Madhya Pradesh. Other leaf spot fungi recorded from Madhya Pradesh are *Phoma tropica, Alternaria laternata* and *Macrophomina phaseolina* (Jamaluddin *et al.,* 1988) and *Corynespora cassicola* is from Kerala (Sharma *et al.,* 1985). Paling of foliage and shedding of leaves are the common symptoms. Low to severe incidence of leaf spot caused by *Alternaria alternata, Colletotrichum gloeosporioides* and *Curvularia brachyspora* was observed both in nurseries and young plantations of *G. arborea* (TCPL fields) in Tamil Nadu (Mohan, 2014).

Different fungi *viz., Cercospora sissoo, Colletogloeum sissoo, Phyllachora dalbergiae, Phyllachora spissa, Phyllosticta sissoo, Mycosphaerella dalbergiae, Myrothesicum roridum* and *Alternaria alternata* cause leaf spot disease on *Dalbergia* *sissoo.* The pathogen, *Cercospora sissoo* attacks the leaves mostly on the lower surface, producing yellowish to grayish-green discoloration. Pustules are mostly intra-epidermal. Stomata are brown with simple or forked conidiophores (Sydow and Mitter, 1933). The pathogen, *Colletogloeum sissoo* causes imperceptible leaf spots and is recorded from Varanasi, Uttar Pradesh (Pavgi and Singh, 1971). The pathogen, *Phyllachora dalbergiae* attacks the upper leaf surface and produces shining black cushion-like stromata which may occur scattered or in clusters. The pathogen, *Phyllachora spissa* attacks the leaves and forms densely aggregated dot-like dark stromata on irregular brownish infection spots and recorded from Wynaad, Kerala and Meghalaya (Bakshi, 1976); Khandala, Maharashtra (Ananthanarayanan, 1964). The pathogen, *Phyllosticta sissoo* causes infection on leaves. The spots are round to irregular, greyish-brown which sometimes cover the entire leaf surface. Dark brown pycnidia are produced on lower leaf surface in densely aggregated groups (Saccardo, 1931). The pathogen, *Myrothecium roridum* causes leaf spots in seedlings of sissoo from Bareilly and Dehra Dun (Uttar Pradesh) and Ambala (Haryana). Infection spots appear in June or eearly July. They are grey or light brown with dark brown margin on the concentric sones, coalescing to form larger leaf spots. The necrotic tissues usually fall off resulting in formation of shot holes (Tivari *et al.,* 1991). The pathogen, *Alternaria alternata* appears in July continues throughout humid months and declines after September in Dehra Dun. The disease incidence is reported be as high as 100 per cent and almost 80-100 per cent leaflets are infected. Infection spots are dark brown, vary in size and shape and coalesce to form larger spots. The fungus sporulates on the lower surface of the leaves. The heavily infected leaves are shed prematurely (Mehrotra, 1992a).

Leaf Blight

Incidence of leaf blight disease was recorded on one month old seedlings of different species of *Artocarpus* raised and maintained in the IFGTB nursery, Coimbatore (Maheshwar Hegde *et al.,* 2004). The pathogen responsible for the said disease was *Alternaria* sp. Disease appears in the month of May and June and continued up to October and November. Affected leaves of *A. gomezianus* ssp. *zeylanicus* show light yellow to dark yellow coloration on the leaf tip and spreads all over lamina at the initial stage of infection. Later the infected leaves become brown to dark brown and severely infected ones shed off. In case of *A. heterophyllus* and *A. hirsuta,* the affected leaves show greyish white colour on the tip and spread slowly to all over the lamina. At the advanced stage, the affected leaves are fully whitish to greyish brown and dark brown in colour. Severely infected leaves fall off and the whole plant gets dried from tip downwards later on.

The incidence and severity of the disease varied from 5.8 to 27.7%. Infection was noticed in 3 to 6-months old container seedlings during monsoon to late monsoon seasons. Initial symptom of the disease was the appearance of water-soaked lesion on the tip of leaves and later spread to margin of the leaf and then the whole leaf area. The lesions enlarged and coalesced to give rise larger irregular spots, which occasionally covered a considerable part of the lamina. Severely infected leaflets fall off prematurely. The leaf blight disease caused by *Cercospora pongamiae* was recorded on *Pongamia pinnata* in different nurseries in Tamil Nadu by Mohan (2014).

Leaf blight on *Gmelina arborea* caused by *Colletotrichum* state of *Glomerella cingulata* in association with *Fusarium solani* has been reported from Kerala (Sharma *et al.,* 1985) causing severe blight disease in 5-6 month old seedlings during May and June. The disease spreads rapidly after initial appearance in patches, causing large scale mortality of nursery stock. Infected plants exhibit blighting of shoots and leaves and subsequent colonization by *Fusarium solani* hastens blighting. Leaf blight disease caused by *Colletotrichum gloeosporioides.*was also recorded on *G. arborea* in young plantations (TCPL) at Namakkal, Tirupur and Vellore districts of Tamil Nadu during March to October months by Mohan (2014).

Leaf blight on Teak is caused by *Rhizoctonia solani.* The infected plants show water soaked grayish brown patches that enlarge rapidly and cover a large part or the entire lamina. The blighted leaves often show holes in the infected portion as a result of shedding of infected tissues during heavy rains. The infected leaves dry up and are eventually shed. The disease spreads laterally in the nursery through overlapping foliage of the adjoining seedlings often resulting in group blighting of seedlings. In each case of severe infection, defoliation is high.

Powdery Mildew

This disease is caused by *Oidium* spp. on different tree species in nurseries and young plantations. White patches seen on the surface of the leaves. These patches coalesced and covered the whole leaf lamina giving grayish white appearance. Severely infected leaves and leaflets defoliated prematurely. The powdery mildew disease caused by *Oidium* sp. was observed on *Santalum album* in nurseries during March to June (Mohan, 2014). The disease appeared in the form of superficial powdery patches on the upper surface of the leaves. Under warm and humid conditions these patches enlarged and coalesced to give rise to large patches. In severe cases, the infection also extended to the lower surface. Severely infected leaves become yellow and defoliated prematurely.

Phyllactinia dalbergiae causes powdery mildew on *Dalbergia sissoo* seedlings and recorded from Dehra Dun and Allahabad (Uttar Pradesh), Pusa (Bihar), Poona, Bombay and Nagpur (Maharashtra) and Chichrauli and Seonti (Haryana) (Pirozynski, 1965; Mukerji, 1969; Singh, 1973; Mehrotra, 1992b). The fungus produces yellowish, persistent, dense mycelium on the lower surface of sissoo leaves.

It is caused by *Phyllactinia suffulta* var. *gmelina* on *Gmelina arborea* in Maharashtra. The pathogen produces infection spots on the lower surface of the leaves with corresponding pale yellow colour on the upper surface (Patil, 1961).

Members of the family Erysiphaceae have been recorded to cause mildews in Teak. *Phyllactinia corylea* is recorded to attack Teak laves (Bagchee, 1952). *Phyllactinia guttata* is also recorded to attack Teak from other countries. *Uncinula tectonae,* widely occurs in nurseries and forests in central and southern India. The fungus forms white powdery coating on the undersurface of Teak leaves and later develops dark coloured cleistothesia over the white fungus weft (Spaulding, 1961). *Uncinula tectonae* is restricted to the upper leaf surface and the infected leaves are coated with a dull white mycelium and conidia borne on conidiophores. Conidia are air-borne which are produced abundantly and cause fresh infection. The metabolic changes in plants take place which lead to drying of infected leaves.

Leaf Rust

This is another important disease in nurseries and young plantations of economically important tree species. Leaf rust disease on Teak is caused by the fungus *Olivea tectonae.* The infected leaves are almost plastered with yellowish brown fruit bodies of the fungus. The upper leaf surface presents a grey appearance due to the formation of fleeks, which correspond to the position of sori on the lower surface. Infected leaves fall off prematurely resulting in retardation of plant growth. The disease has been reported in nursery and young plantations of Teak in Tamil Nadu (Mohan, 2014).

Uredo terminaliae causes leaf rust disease on clonal plants of *Terminalia chebula* in the research nursery of State Forest Department, Coimbatore (Mohan and Manokaran, 2005). The disease (less than 25%) started appearing during the month of November. Very severe infection (95%) was noticed during January. Infected leaves were plastered with light brown to yellowish brown fruit bodies of the pathogen at the lower surface of the leaves. The corresponding upper surface showed greyish brown appearance. Severely infected plants showed premature defoliation.

Maravalia achroa is recorded on seedling of *Dalbergia sissoo* in nurseries from Uttar Pradesh, Bihar, Maharashtra and Assam (Patil and Thirumalachar, 1971; Bakshi, 1976; Mehrotra, 1987). The disease also occurs on young plantations but not in as severe form as in the nurseries. The disease appears in February-March on leaves and juvenile twigs and continues attacking the foliage and young twigs up to July-August. The infection declines following monsoon rains. The affected parts are killed resulting in die-back and subsequent death of affected seedlings. Uredinial sori are yellowish and formed on the lower surface of the leaves. Telia are colourless and pulvinate. The infected leaves are often deformed and the infected plants show perceptible retardation in growth and look stunted and weak. The disease incidence is recorded as high as 100% in the nursery at Dehra Dun.

Root-rot and Collar rot

These diseases are caused by *Sclerotium rolfsii* and recorded in 1-2 months old seedlings of *Gmelina arborea* in Kerala, Paling and shedding of leaves and subsequent death of the seedlings. In Kerala, the disease causes premature defoliation and is reported to be in mild form (Florence and Sankaran, 1987).

Stem rot

Stem rot disease caused by *Phoma nebulosa* is recorded in 3-4 months old seedlings of *Gmelina arborea* from Kerala (Sharma *et al.,* 1985). The disease flares up under warm and humid conditions especially in overcrowded seedlings. The infected seedlings wilt and eventually die. Numerous pycnidia develop on dead stem, and spore masses ooze out from them on maturity.

Plantation Diseases

Many fungal pathogens cause diseases on saplings and grown up trees in plantations of different economically important tree species. The common disease problems recorded on various tree species in plantations is given below:

Bacterial Wilt

Bacterial wilt disease on Teak is caused by *Pseudomonas solanaceaum*. It appears as small patches of brown tissue between the veins which on spreading give the leaf a scorched appearance. The infected plants subsequently wilt. A brown stain occurs in the vascular system of attached plants. Suitable site should be selected for nurseries and good drainage. Fully infected and dead plants should be removed and burnt them outside the clonal plantations.

Root Rot

Root-rot disease is caused by a pathogen *Ganoderma lucidum*. This pathogen occurs all over the plains and the sub-temperate region of the hills attacking a wide variety of trees mainly broad leaved species. Root rot due to *G. lucidum* on *Dalbergia sissoo* is reported in natural forest and plantations. It attacks trees of advanced age. The pathogen is found in light as well as heavy textured soils. The pathogen spreads rapidly in the root systems of the trees growing on the light textured soils. It's relatively slow in heavy textured soils. Trees may die within short span. Its spreads through root contact and hence it damages pure plantation very quickly, resulting in the death of tree. The diseased tree present a stag headed appearance and die after a few years. *Polyporus gilvus* causes root and but rot in *D. sissoo* and many other species. It attacks through injuries or wounds, mainly in plantations, with trees of advanced age being more prone to this disease. It causes root and but rot; restricted decay as white rot in the sapwood and to some extent also in the heart rot. Affected tree become stag headed. Sporophores develop readily on the bases of the roots and stems. Root rot caused by *G. lucidum* is a serious disease in many *Acacia catechu* (Khair) plantations and natural forests being worked under the coppice system. Mortality may be significant in stands not cleared of residual roots and stumps. The root rot disease can be managed by adopting following measures:

Mechanized soil working (mainly by tractors)

Residual roots and stumps are removed. Better soil working creates conditions favourable for the growth of the trees thereby increasing their vigour and resistance to the pathogen.

Stump extraction

To extract roots and stumps in the lines or rows where planting to be done. Usually this is done only up to the certain depth.

Isolation trenches

It is dug for preventing root contact between the healthy and diseased individuals. The trenches are to be made about 1 m deep, 1.5 m long and up to 0.5 m wide. The diseased trees can thus be isolated.

Resistance species

Planting resistance species in first rotation in reforested areas also helps to prevent the occurrence of this diseases as by the end of it the residual roots and stumps would have decayed and the source of infection would no longer be present.

Mixed plantations

Mixed plantations of resistance species may be raised with Khair and other susceptible species. This helps to prevent the rapid spread of the pathogen.

Heart Rot

Heart rot disease causes extensive damage to standing forest crops and perhaps they are the single most destructive disease responsible for loss to forests. Decay usually does not set in till the heart wood is formed in a tree and this takes about 15 to 30 years depending on the species and locality factors. Normally the outer living sapwood and bark afford enough protection to the inner heart wood from attack by decay causing fungi. But when the latter is exposed through openings in the bark and sapwood, the process of decay is initiated in the form of heart rot which spreads over time. Some of the fungal organisms causing heart rot are *Ganoderma* spp, , *Polyporus* spp., *Fomes* spp., *Hymenochaete* spp., *Trametes* spp., *Armillaria* spp. Some of the tree species generally affected by heart rot disease are Sal, Teak, Deodar, Sissoo, Acacias, *Albizia* spp., *Terminalia* spp., etc. The following measures should be followed to control the said disease problem:

- Avoid injuries during the weeding, controlled fire, or cleaning process.
- Use of resistant varieties.
- Early removal of affected plants from the plantation.

Pink Disease

The pathogen has wide host range. It is widely distributed in the tropics and sub-temperate regions. Pink disease on Teak is caused by *Corticium salmonicolor*. The disease occurs commonly in Teak in high rainfall areas of Kerala and Karnataka states (Bakshi, 1976). The pathogen attacks trees of all ages, infection occurring through lenticels and wounds. Infected young branches may be killed outright, while infection in older branches results in the formation of cankers and longitudinal bark cracking. Cankers resulting from the pathogen probably serve as infection courts for heart fungi which subsequently decay the heartwood and cause hollowness when decayed wood gets disintegrated. Recently, severe incidence of this disease was recorded in young plantations (1-2 years old) of Teak raised in high humid tracks of Kerala (Mohanan, 2008). It is reported that outbreak of the disease occurred immediately after the south west monsoon (July-August) and plantations raised with both root-trainer grown seedlings and conventional stumps were found equally affected with the disease.

Disease incidence ranged from 3-60% in different Teak plantations in Kerala. Disease incidence as well as severity was noticed more in plantation sites where weed growth is more and with high precipitation and relative humidity.

Disease Management Strategies

Accurate and timely diagnosis of the cause of a disease or disorder is essential for adoption of effective control/ management measures. Disease control measures can be broadly grouped into five categories and details are as under:

Exclusion : To prevent introduction and spread of pathogens into areas that are currently free of them.

Eradication : Eradication or reduction of pathogen inoculum of the host can be brought about by elimination of all plants infected by the pathogen, thus preventing further spread of the disease.

Avoidance : Diseases can be avoided by choosing an appropriate region or site for planting, the time of planting, avoiding injury/ wounding and providing right storage conditions.

Protection : Direct protection of plants from diseases can be achieved by timely application of safer chemicals or biological control agents.

Host Resistance : The most cost-effective, safe, easy, and environmentally desirable way to control plant diseases is the use of resistant varieties.

The following measures should be followed for proper management of different disease problems in different tree nurseries and plantations:

Quarantine Measures

Seeds and clonal plant materials should have proper quarantine certificate from the point of origin. Certified quality seeds and clonal planting materials should be used.

Cultural Practices

- Potting media should be properly sterilized (solar heating) before use in nurseries in order to avoid damping off, collar rot and root rot diseases.
- Cleanliness and hygiene are very important inside the mist chambers, poly tunnels and shade house. Infected tissues should not be taken inside these structures.
- The nursery and its surroundings should be kept neat and clean. Remove unwanted weeds, leaf litters and other host plants which may act as primary source of infection by the pathogens should be removed regularly.
- Avoid excessive moisture and shade in clonal complex structures and nurseries.
- Regular surveillance should be made in mist chambers, poly tunnels, shade house, nurseries and clonal multiplication areas in order to check the incidence of different diseases at the initial stage.
- Proper drainage system should be provided in the nursery beds.
- Avoid injury to the seedling roots or stem or any part of the plants at the time of weeding, shifting and watering.
- Mechanical removal of affected portions of the plant parts and burnt them outside the clonal complex and nursery areas in order to prevent the inoculum build up and disease spread.
- Severely infested/ diseased plants should be kept in isolation. The fully affected and dead plants should be removed and burnt them outside the clonal complex area and nurseries in order to prevent the pathogen inoculum build up and disease spread.

Biological Control

- Beneficial microbes can be used as bio-fertilizers or bio-inoculants which are ready to use with suitable carrier based formulations. They can be applied to seed, root or soil/ potting media.
- The bio-fertilizers make availability of major plant nutrients to the rhizosphere region of the plants. They secrete plant growth hormones (IAA,

Auxins, Gibberlic Acid) and they enhance the growth of the plants. They help for better seed germination, more root proliferation and also increase number of root hairs and make the plants stronger. They control plant diseases and improve quality and quantity of produce. They improve fertilizer use efficiency and provide more biotic and abiotic stress tolerance to plants. The bio-fertilizers improve soil health and make the ecosystem more sustainable and eco-friendly.

- Application of bio-fertilizers such as Arbuscular Mycorrhizal (AM) fungi, Ectomycorrhizal (ECM) fungi, *Rhizobium, Azospirillum*, *Azotobacter*, Phosphobacterium etc. and bio-control agents such as *Trichoderma viridae, T. harzianum*, *Pseudomonas fluorescence* etc. during raising of seedlings.
- *Rhizobium* bio-fertilizer can be applied along with AM fungi and phosphobacterium to leguminous plant species like Acacia, Albizia, Dalbergia, Pongamia, etc. *Azospirillum* or *Azotobacer* bio-fertilizer can be applied along with AM fungi and phosphobacterium to all non-leguminous plant species.
- When added to the potting media in bags or any containers, these bio-fertilizers can act as bio-control agents and decrease or stop the growth of various soil-borne or root borne pathogens. Hence, suitable bio-fertilizers and bio-control agents should be applied in nursery stage for production of high quality and healthy planting stock for their better survival and establishment in field conditions.

Chemical Control

- Application of suitable safer chemical fungicides like Bavistin, Dithane M-45, Sulfax, Blitox etc. for controlling different diseases in nurseries, VMGs, CMAs, etc. Mohan and Manokaran (2005) effectively controlled leaf rust disease caused by *Uredo terminaliae* on *Terminalia chebula* by using sulphar based fungicide in germplasm bank in SFD nursery, Coimbatore. Mohan *et al*. (2002) effectively controlled collar rot disease caused by *Lasiodiplodia theobromae* on *Casuarina junghuhniana* by using Bavistin fungicidal solution in IFGTB experimental nursery.

Method of Preparation of Fungicide Solution

Requirement:

1. Fungicides
2. Sprayer
3. Bucket (5 litre, 10 litre, 25 litre)
4. Water
5. Soap liquid (Teepol etc.)

Method of preparation

If any fungicide solution is to be prepared at the concentration of 1%, the following formula can be used:

$$\text{Weight of Fungicide (W)} = \frac{\text{Dosage of fungicide}}{\text{Active ingredient of fungicide}} \times \text{Volume of water}$$

(Wettable Powder percent)

For example:

$$W = \frac{1\% \text{ of Bavistin}}{50 \text{ (WP) of Bavistin}} \times 1000 \text{ ml of water}$$

W = 2 gm Bavistin can be mixed in 1 litre of water

Fungicide solution should be prepared normally with low concentration (0.01% to 0.1%) by adopting the above formula at the initial incidence of the disease symptoms. After weighing the fungicide, it can be thoroughly mixed with required quantity of water. (For example: 1 litre water) and then add 10 drops of liquid soap and mix it thoroughly. The liquid soap helps to attach the leaf, stem and other parts of the plant without drop in to the soil. Fungicides and bactericides should be sprayed during early morning (between 6.00 - 7.00 am) or evening (5.00 – 6.00 pm). Chemicals should not be sprayed during rainy days. All the chemical fungicides and bactericides should be properly stored.

Selection of disease resistance

- Screening of naturally existing populations and also selection of disease resistant CPTs from Provenance Trials.
- Conventional breeding or Genetic engineering programs (varieties resistant to one or more diseases are available in several crop and ornamental species).
- Selection of disease resistance/ tolerance phenotypes.
- Identification of Genes against dreadful diseases through molecular techniques.
- Establishment of Clonal Gene Bank.
- Laboratory screening of CPTs for disease resistance.
- Field Resistance Trials will be established in multilocations.
- Collect and use quality and disease resistant seed and clonal planting materials.
- Disease problems in Clonal Multiplication Areas (CMAs) and plantations can be controlled to a greater extent by ensuring the genetic diversity of the crop, by increasing the number of clones and manipulating their spatial distribution in planting area. Because the genetic uniformity of the plants render them high incidence of fungal pathogens and high spread to all the plants in CMAs.

Conclusion

Selected genetically superior seeds as well as disease resistant planting materials are essential for successful forestry programme in order to withstand and overcome adverse environmental factors and emerging disease problems. Hence, genetic improvement of clones should be undertaken continuously creating more and more population of genetic variability for further selection of improved genotypes against pest and diseases for better production of plantation forestry.

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Timber Resources from Homegardens in Humid Tropics of Kerala

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Abstract

The increasing demand for timber and timber products has resulted in diminishing availability of tropical hardwoods from natural forest. Therefore, increased demand has to be managed either by imports or increased plantation grown timbers species. However, there seems to be no studies on identification of preferred commercial timber species in Kerala. This study has helped in planning strategies for improving the tree resource base in the homegardens. The study has been carried out in six districts of Kerala such as Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Ernakulam and Thrissur by surveying key stakeholders including farmers, timber traders/saw-millers and furniture manufacturers for identify important commercial timber species. The result showed that rubber is mostly found in pure plantations whereas other species like Teak, Jackfruit, Anjily and Mahogany are either found as trees on bunds or as scattered plantations on farmland and homestead gardens in the state. A quantitative understanding of relations between concept of ecosystem services and human well-being is critical to a range of decisions, and the interest in assessing ecosystem services has been growing exponentially among environmental scientists and policymakers.The estimated area under Rubber (*Heveabrasiliensis*) plantations is 5, 49,955 ha followed by Jackfruit (*Artocarpusheterophyllus*) at 92,203 ha and Teak (*Tectonagrandis*) at 23,461 ha. The estimated area under Anjily(*Artocarpushirsutus*) and Mahogany (*Swieteniamacrophylla*) comes to 1286 ha and 1169 ha respectively. Rubber spp., owing to its short rotation period and regular returns, occupies around 95%

share, whereas Teak, Jackfruit, Anjily and Mahogany vary from 0.8% to 1.7% in the order of preference by the farmers in Kerala.

Introduction

The total forest and tree cover of the India is 79.42 million hectare which is 24.16 percent of the total geographical area of the country an increment of 3,775 sq. km. and 1,306 sq.km. is seen in total forest cover and tree cover respectively (ISFR, 2015). The total forest area of Kerala is 1.082 million hectares which constitutes 27.83% of the total geographical area of the state. The total area under plantation/TOF is 0.59 million hectares which is 37.92% of total forest area in the state. The total growing stock of Kerala in forest area is 154.99 million cum & in TOF is 49.063 million cum (ISFR, 2015). Forest productivity of our forest is just 0.7m^3/ha which is very low against world average of 2.1 m^3/ha. The pressureof increasing population puts a heavy toll on forest resources in form of collection of fuel wood, NTFP's collection, grazing, illegal hunting, timber harvesting, human wildlife conflict etc.

Indeed, well established traditional homegardenswith high crop plant diversity and low intensity management observed in humid tropical region in India such as Kerala and playing an important role in the supply of their needs, sustain food security and preservation of biodiversity (Kumar 2011; Kumar et al. 2016; Kumar, 2017). Homegardens agroforestry system structure has includes several strata combining domesticated crops, wild plants with multiple uses and floristic composition attributes depends on many other factors, such as species selection, soil fertility, available area, homegarden age, economic needs, availability of resources, infrastructure (water), availability of labour (Kumar and Tripathi 2017), soil seed bank, surrounding vegetation, food requirements, aesthetic values (Goddard et al. 2009) and personal preferences (Kumar and Nair 2004).The most important commercial and economically important timber species grown in homestead gardens of Kerala are Teak (*Tectonagrandis* Linn.), Jack (*Artocarpusheterophyllus*Lamk.), Anjily (*Artocarpushirsutus*Lamk.), Matty (*Ailanthus triphysa*Dennst.) and Mango (*Mangiferaindica* Linn.) (Krishnakutty, 2011).

Timber Scenario in Kerala

The FAO study conducted in 2011 estimated the total production of 14.6 million cum of wood in Kerala out of which 83% comes from homestead gardens, 10 % from plantation of Rubber, cardamom, coffee and tea and only 7% from forest areas (FAO, 2011). The total wood production in 2008 is 11.714 million m^3, the contribution of forest is 10 % andrest 90% is contributed by trees outside forest in Kerala (Krishnakuttyetal. 2008). The production of timber in Kerala is 50.60 thousand m^3 in 2010 (Ministry of Environment and Forest, Government of India).The annual potential production of timber and fuel wood from tree outside forest in Kerala is 1.628 million m^3 and 0.439 million m^3 in 2011 (Ministry of Environment and Forest, Government of India).The species for which no permission is necessary for cutting and removal in Kerala are Coconut, Rubber, Cashew, Tamarind, Mango, Jack Fruit tree, Kodapuli, Matti,Arecanut, Konna, Seema Konna, Nelli, Neem, Murukku, Jathi, Albezia, Silk cotton, Acacia auriculiformis, Mangium, Anjili, Kilimaram, Manchadimaram, Vatta, Palm tree, Aranamaram, Eucalyptus, Seemaplavu and Paala (Kerala promotion of tree growth in non forest areas (amendment) act 2007).All kinds of timber including industrial wood, fuelwood and charcoal are defined as wood (Krishnakuttyetal. 2008). The timber produced from forest contributes only 3% of the total timber produced in Kerala and if Rubber plantations are excluded the contribution is merely 1% from forest. The production of timber from forest is diminishing and will not be able to meet future timber requirement of the state. Promotion and enhancement of production from forest is limited and will show a declining trend in the future (KFRI, 2012). The contribution of plantation and social and farm forestry in supply of wood is projected to increase from 53 million m^3in 2006 to 88.7 million $m^3$and account for 58% of total wood supply in 2020 (Dubey 2009).Tree outside forest contributes 90% of fuel wood requirements of the state. Coconut is the major contributor which accounts for 70% of total fuel wood supply of the state (Krishnakutty, 1990).

In order to promote plantations of hardwood timber species the State Government has started an incentive scheme named VanadeepthiProgramme with an objective to increase area under tree cover to achieve self-sufficiency in timber production in the state. This will also supplement the existing farm returns and promote tree farming as secondary agrarian practice. The tree species covered under this scheme are Teak, Sandalwood, Mahogany, Anjily, Plavu, Rosewood, Kambakam, Kumbil, Kunnivaka and Thembavu. The amount of incentive under this scheme is Rs. 50 per plants for 50 to 200 plants; Rs.40 per plant for 201 to 400 plants with minimum of Rs. 10000/-, Rs. 30 per plant for 401 to 625 plants with minimum of Rs. 16000/-.(Kerala Forest Department).Therefore, it is hypothesized that homegardens are helpful to conserving forest in all the aspect especially healthy ecological, economical and gene resources. However, there is little or scanty knowledge of local factors, size of homegardens, species utility, land management practices, input of agrochemicals, plant diversity and structure is still limited especially in tropical humid Kerala, India.

Materials and Methods

Kerala has been chosen for study accounting to its long history of plantations. There are fourteen districts in Kerala. Out of the fourteen districts six districts namely Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Ernakulam and Thrissur were chosen for study on the basis of literature review as most of referred literature suggested that these districts have higher concentration of plantations (Fig. 1 &Table 1). Another reason for selection of

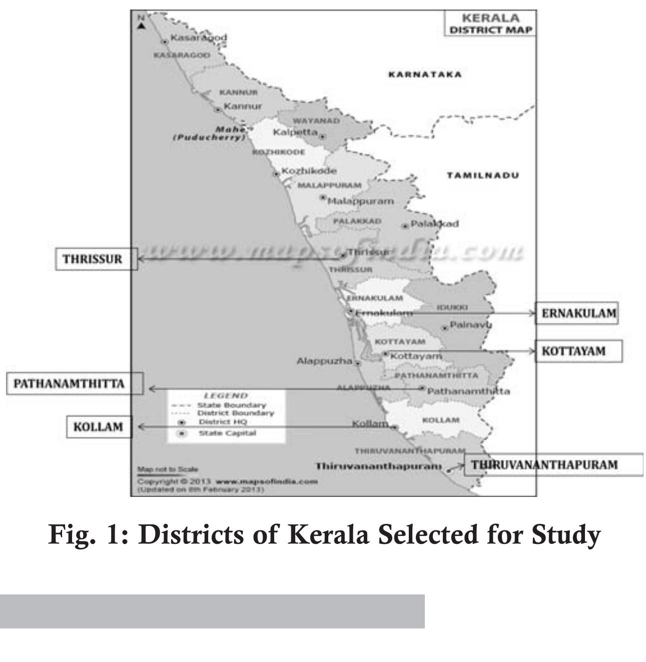

Fig. 1: Districts of Kerala Selected for Study

these districts is their proximity to the largest wood market in Kerala which is situated in Perumbavoor in Ernakulum district. Perumbavoor serves as the largest wood market in Kerala and also caters to neighbouring states of Karnataka and Tamil Nadu. Third reason for the selection is higher of wood based industries, Saw Mills Association (SOPMA), Timber Traders Association, and Furniture Manufacturers Association (FUMMA). Fourth reason is location of Research Institutions and Forest Headquarters in the districts selected for study.

Table 1: Targeted Stakeholders from six districts in Kerala

Sl. No	Name of District	No. of Farmers	No. of Timber Traders & Saw Millers	No. of Furniture Manufac turers	No. of People from Forest Department	No. of Experts
1	Ernakulam	10	5	15		6
2	Kollam	10				
3	Kottayam	10	5	3		
4	Pathanamthitta	10			2	
5	Thiruvananthapuram	10	5	3	13	
6	Thrissur	10				2

Research Instrument

The instrument for the study is self-designed as no such study was found through literature review. The questionnaire was consulted with experts who from time to time gave their suggestion for further improvement in the questionnaire. The questionnaire was designed keeping in mind all the possibilities to capture the information necessary for the study. The Questionnaire was discussed with the experts during field visit and necessary suggestions regarding improvement were recorded and added.

Data Collection

Primary Data: The present study focuses on data collection from stakeholder's i.e. Tree Growers/ Farmers, Saw millers, Timber Trader, Plywood

Manufacturers, Wood based industries, research institutions, Forest department and agricultural university.

Secondary Data: The documents related to the earlier study were referred to study about plantations in Kerala. The secondary data was collected from publications from Kerala Forest Research Institute, Kerala Agricultural University, and Published data from Rubber board, related publications and research papers.

For the study all the stakeholders were identified and divided into two groups namely Institutions and Departments.

A. Institutions: Tree Growers/Farmers, Saw Millers, Plywood Industries, Veneer Industries, Rubber Board, Timber Traders, Paper & Pulp Industries, Furniture Manufacturers.

B. Departments: State Forest Department, Forestry Department of Kerala Agricultural University, Research Institutions like KFRI, Trade Association, Horticulture Department of Kerala.

Results and Discussion

In all six district identified for the study 10 farmers from each district are targeted for interview, 15 traders and sawmillers and 21 furniture manufacturers have been identified for interview from three districts namely Kottayam, Ernakulum and Thiruvananthapuram because of presence of more number of saw mills and trading units. 15 Forest officials were consulted to know the status of plantation in the districts.Major saw miller and traders operating in three districts of Kerala were identified using snow ball technique. This technique was feasible in identifying top Saw miller and Timber trader in all three districts. The total of 119 respondents were selected and interviewed for study representing stakeholders from each category.

Sample Characteristics: Data was collected through structured questionnaire filled by various stakeholders namely tree growers, saw millers, timber traders, furniture manufacturers and various wood based industries. Interview with experts also helped in collection of necessary data for the study. Three questionnaires were designed for Tree Grower/Farmer, Saw miller and Timber

Trader to capture statistics pertaining to study. Total 119 respondents filled questionnaire during interview representing 15 (12%) respondents from Forest Official and Staff, 8 (7%) Experts, 15 (13%) Saw millers and timber traders, 21 (18%) Furniture Manufacturers and 60 (50%) Tree Growers/ Farmers.Based on the review of literature commercial woody species name were listed in Table 2.

Table 2. Commercial woody species found in humid tropics kerala

Sl. No	Common Name/ Local Name	Scientific Name	Trade Name	Family
1	Anjily/Anjili/Ayani	*Artocarpus hirsutas/ Artocarpushirsutus*Lamk.	Ayani	Moraceae
2	Mahagany	*Swieteniamacrophylla*King	Mahogany	Meliaceae
3	Mangium	*Acacia mangium*Willd.	Mangium	Leguminosae
4	Perumaram/Matti	*Ailanthus triphysa*(Dennst.) Alston	Maharukh	Simaroubaceae
5	Plavu	*Artocarpusheterophyllus* Lamk.	Jack/ Kathal	Moraceae
6	Rubber	*Heveabraziliensis*(H.B.K) M.-A	Rubber	Euphorbiaceae
7	Thekku	*Tectonagrandis*L.f.	Teak	Verbenaceae

Status of Commercial wood species

1. **Anjily (*Artocarpushirsutus*Lamk.):** In forest Anjily is mostly found inThiruvananthapuram in southern circle division of Kerala (Table 3).

Table 3. Division wise Forest plantation of Anjily in Kerala

Anjily Plantation in Kerala 2010 to 2014						
Sl. No.	**Divisions**	**2010**	**2011**	**2012**	**2013**	**2014**
I	Southern Circle					
	Thiruvananthapuram	593.555	566.137	566.137	566.137	566.13
II	Highrange Circle					
	Kothamangalam	10	10	10	10	10

Anjily Plantation in Kerala 2010 to 2014						
Sl. No.	**Divisions**	**2010**	**2011**	**2012**	**2013**	**2014**
III	Northern Circle					
	Kannur	7.284	7.284	7.28	7.284	0
IV	Agasthyavanam					
	Thiruvananthapuram	0	0	0	54.24	0
	Grand Total	**610.839**	**583.421**	**583.417**	**637.657**	**576.137**

(Source: Division/Species wise distribution of plantation area (ha), Forest department Kerala)

2. Mahogany (*Swieteniamacrophylla*King): Mahogany is well distributed in all the districts of Kerala major districts being Kottayam, Ernakulam and Thrissur where it is raised as plantations, avenue tree and road side tree (Table 4). The division wise plantation details of Mahogany in forest area are given below in the Table 5.Forest Mahogany trees are mostly found in Northern circle in Kannur and Kasargod districts of Kerala.

Table 4. Distribution of Mahogany in districts of Kerala

Sr. No.	Type of Stands	Locality	District
1	Road side trees	Punalur, Thenmala	Kollam
2	Road side trees	Aryenkavu, Arippa	Kollam
3	Road side trees & Plantation	Edappalayam	Pathanamthitta
4	Plantation	Naduvathumuzhy	Pathanamthitta
5	Road side trees	Ambalapuzha	Alappuzha
6	Avenue Trees	Pattom	Thiruvananthapuram
7	Avenue road side trees	Attingal	Thiruvananthapuram
8	Road side trees	Angamaly, Perumbavoor	Ernakulam
9	Avenue Trees	Muvattupuzha	Ernakulam
10	Plantation	Neriamangalam	Ernakulam
11	Avenue road side trees	Vazhoor	Kottayam
12	Avenue trees	Kozha, Changanacherry	Kottayam
13	Plantation	Kuruvilankadu	Kottayam

Sr. No.	Type of Stands	Locality	District
14	Road side trees & Plantation	Kodanad	Kottayam
15	Plantation	Adimaly	Idukki
16	Plantation	Perunthode	Thrissur
17	Avenue trees	Ayyanthole	Thrissur
18	Road side trees	Kannara	Thrissur
19	Plantation	Dhoni, Karimpuzha	Palakkad
20	Road side trees & Plantation	Chaliyarmukku, Nellikuthu, Nedungayam in Nilambur	Malapuram
21	Road side trees & Plantation	Bovikanam	Kasargod
22	Road side trees	Kozhikode	Kozhikode
23	Road side trees & Plantation	Nidumpoil	Kannur
24	Avenue trees	Kalpetta, Manathavady	Wayanad

(Source: Chacko etal., KFRI Research Report 224)

Table 5.Division wise Forest plantation of Mahogany in Kerala

Mahogany Plantation in Kerala 2010 to 2014						
Sr.No.	**Divisions**	**2010**	**2011**	**2012**	**2013**	**2014**
I	Southern Circle					
1	Ranni	2.87	2.87	2.87	2.87	0.6
2	Konni	0.6	0.6	0.6	0.6	2.87
	Total	3.47	3.47	3.47	3.47	3.47
II	Highrange Circle					
1	Kottayam	16	16	16	16	16
2	Kothamangalam	15.24	15.24	15.24	15.24	15.24
3	Mankulam	3.5	3.5	3.5	3.5	3.5
	Total	34.74	34.74	34.74	34.74	34.74
III	Central Circle					
1	Malayattoor	20	20	20	20	20

Mahogany Plantation in Kerala 2010 to 2014						
Sr.No.	**Divisions**	**2010**	**2011**	**2012**	**2013**	**2014**
IV	Northern Circle					
1	Kannur	45.53	45.53	85.49	37.496	73.88
2	Kasargod	0	0	0	88.624	127.378
	Total	**45.53**	**45.53**	**85.49**	**126.12**	**201.266**
	Grand Total	103.74	103.74	143.7	184.33	259.476

(Source: Division/Species wise distribution of plantation area (ha), Forest department Kerala)

3. **Mangium (*Acacia mangium*Willd.):***Acacia Mangium* is mostly found in Southern circle in Thiruvananthapuram, Kollam and Pathanamthitta districts of Kerala (Table 6).

Table 6. Division wise Forest plantation of *Acacia mangium*in Kerala

***Acacia Mangium*Plantation in Kerala 2010 to 2014**						
Sr. No.	**Divisions**	**2010**	**2011**	**2012**	**2013**	**2014**
I	Southern Circle	+				
1	Thiruvananthapuram	1022.83	1475.598	1374.18	1362.518	1374.18
2	Punalur	1910.05	2002.4	2002.4	1943.998	2002.4
3	Achencoil	19.2	0	0	0	0
4	Ranni	123.79	123.79	123.79	123.79	123.79
5	Konni	114.5	139.21	139.21	139.21	139.21
	Total	3190.377	3740.996	3639.58	3569.52	3639.58
II	Highrange Circle					
1	Kothamangalam	235.47	235.47	235.47	235.47	235.47
2	Mankulam	12.75	12.75	12.75	12.75	12.75
	Total	248.227	248.227	248.227	248.227	248.227
III	Central Circle					
1	Malayattoor	71.85	209.45	239.2	294.2	294.2
2	Vazhachal	10	10	10	10	10
	Total	81.85	219.45	249.2	304.2	304.2

	***Acacia Mangium*Plantation in Kerala 2010 to 2014**					
Sr. No.	**Divisions**	**2010**	**2011**	**2012**	**2013**	**2014**
IV	Northern Circle					
1	Wayanadu (N)	63	63	65	65	65
	Total	63	63	65	65	65
	Grand Total	**3583.454**	**4271.673**	**4202.003**	**4186.943**	**4257.007**

(Source: Division/Species wise distribution of plantation area (ha), Forest department Kerala)

4. **Jackfruit (*Artocarpusheterophyllus*Lamk):** Jackfruit is found in all the districts of Kerala. The total area under jack cultivation in 2014-15 is 92,203 ha. Idukki, Kozhikode and Malapuram are the leading districts standing

Table 7. District Wise Area under Jack Cultivation (in ha) in Kerala from 2010 to 2015

Sr. No	District	2010-11	2011-12	2012-13	2013-14	2014-15	Ranking
1	Idukki	11191	13866	14631	14636	14727	1
2	Kozhikode	8651	10456	10011	9805	10351	2
3	Malapuram	7003	8405	8161	8390	9175	3
4	Waynad	6780	7928	7854	8031	8727	5
5	Kannur	7273	8267	8447	8400	8300	4
6	Thiruvananthapuram	5170	5994	6066	7232	7052	8
7	Palakkad	5871	6972	7062	6936	6753	7
8	Kollam	6143	7520	7383	6680	6663	6
9	Thrisuur	4067	5331	4949	4865	4748	9
10	Ernakulam	3598	4373	3955	4097	4235	10
11	Kottayam	3362	3946	3997	3824	3791	11
12	Pathanamthitta	2310	2512	2554	2699	2813	12
13	Kasargod	1723	2375	2433	2372	2553	13
14	Alappuzha	2047	2388	2199	2258	2315	14
	Sub Total Kerala	**75189**	**90333**	**89702**	**90225**	**92203**	

(Source: http://www.ecostat.Kerala.gov.in)

1st, 2ndand 3rdwith share of 16%, 11% and 10% respectively in terms of area under plantation. The last 10 years' analysis of area under jack plantation reveals that in 2005-06 the area under jack plantation was 94,902 ha. There is increase in plantation of Jackfruit from 75189 ha in 2010 to 92203 ha in 2015 (Table 7).

5. **Rubber (*Heveabraziliensis*(H.B.K)M.-A):** Kerala is leading producer of Rubber in India accounting for 70.4% of total Rubber Area under Rubber plantations followed by Tripura (9.2%), Assam (6.1%), Karnataka (6.04%), Tamil Nadu (2.7%) and Meghalaya (1.8%) (Rubber Board, 2013-14) (Table 8).

Table 8. Total Rubber Area (in ha) in India

Sr.No	State	2013-14	% share in 2013-14	Rank
1	Kerala	548,225	70.4	1
2	Tripura	71,370	9.2	2
3	Assam	47,945	6.1	3
4	Karnataka	47,055	6.04	4
5	Tamil Nadu	20,890	2.7	5
7	Meghalaya	13,875	1.8	6
8	Others	29,040	3.7	7
	Sub Total	**778,400**	**100**	

(Source: Rubber Board Statistics and Planning Department, Kottayam)

Distribution of Rubber in Kerala: The Rubber plantation started in Kerala in 1902.The Rubber is raised primarily for extraction of latex. The total area under Rubber plantation in 2001-02 is 475039 ha which increased to 549955 in 2014-15 (Agricultural Statistics, 2014-15). The table 5.8 gives the details of Rubber plantation in Kerala from 2001 to 2015.

Species wise summary of area under plantation in forest and outside forest of wood species for study: Teak has largest area under plantation in forest followed by Mangium, Anjily,Matti and Mahogany and Rubber.Teak has largest area under plantation in forest followed by Mangium, Anjily, Matti and Mahogany and Rubber (Table 10).Rubber has largest area under plantation outside forest

Table 9. Area under Rubber Plantation (in ha) in Kerala from 2001 to 2015

Sr .No	Year	Area under Plantation (in ha)	percentage increase in area under plantation
1	2001-02	475039	0.212193104
2	2002-03	476047	0.494699053
3	2003-04	478402	0.472197023
4	2004-05	480661	2.858355473
5	2005-06	494400	1.585760518
6	2006-07	502240	1.952253903
7	2007-08	512045	1.060453671
8	2008-09	517475	1.533020919
9	2009-10	525408	1.67907607
10	2010-11	534230	0.998633547
11	2011-12	539565	0
12	2012-13	539565	1.605144885
13	2013-14	548225.8	0.315417479
14	2014-15	549955	-

(Source: Agriculture Department Statistics & Department of Economics and Statistics, Kerala)

followed by Jackfruit and Teak. The area outside forest for other species is not available (Table 11).

Table 10. Species wise area under plantation (in ha) of wood species in forest

Species wise area under plantation of wood species in forest (Area in Hectares)						
Sr.No	**Trade Name**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
1	Teak	77483.917	76720.241	76813.58	77258.9	74836.971
2	Mangium	3583.454	4271.673	4202.003	4186.943	4257.007
3	Anjily/Ayani	610.839	583.421	583.417	637.657	576.137
4	Matti	546.5	510.62	497.41	502.91	493.91
5	Mahagany	103.74	103.74	143.7	184.33	259.476
6	Rubber	86.47	86.47	86.47	86.47	86.47

(Source: Forest Statistics (2010-2014), Kerala Forest department)

Table 11. Species wise area under Plantation (in ha) of wood species outside forest

Species wise area under Plantation of wood species (Area in Hectares) in TOF						
Sr.No	**Trade Name**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
1	Rubber	534230	539565	539565	548225.8	549955
2	Jack	75189	90333	89702	90225	92203
3	Teak	19909	20214	19462	21243	23461

(Source: Agricultural Statistics (2010-11 to 2014-15), Economics and Statistics department, Kerala)

Uses of Commercial Wood Species and their Market: Perumbavoor in Ernakulam districts is the largest timber market in Kerala. Apart from this Adoor in Pathanamthitta district and Kannur also serve as timber market in Kerala. The Timber market of Perumbavoor is operational round the year. The major timber trading starts at around 8 p.m. in night till morning. The timber trade during day hours is less as compared to night hours SOPMA is association of Sawmill Owners and Plywood Manufactures is located in Perumbavoor. It is regulatory body for timber trade in Perumbavoor in Kerala. On daily basis 350-500 trucks of 20 25 tonnes capacity reaches Perumbavoor for timber trade. On daily basis quantity of timber traded in the market constitute 98% of Rubber wood. The rest 2% is other timber referred to as jungle wood which constitute of Anjily, Mahogany, Jack wood, Mangium, etc.

Table 12. Uses of commercial wood species

Sr. No.	Local Name	Trade Name	Uses
1	Anjily/Anjili/Ayani	Ayani	Construction, Furniture and Cabinet, Boat and Ship building, Carving, Agricultural Equipments, Lorry and Bus Bodies
2	Mahagany	Mahogany	Construction, Furniture, Shipbuilding, Musical Instruments, Medicines
3	Mangium	Mangium	Paper and Pulp, Furniture and Cabinet, Construction, Agricultural Implements, Doors and Window Frames, Boxes and Crates.

Sr. No.	Local Name	Trade Name	Uses
4	Perumaram/Matti	Maharukh	Match Splints and Boxes, Veneer, Plywood, Packing Cases, Toys and Blackboards
5	Plavu	Jack/ Kathal	Construction, Furniture and Cabinet, Plywood, Veneer, Block boards, Musical Instruments, Boxes and Packing Cases
6	Rubber	Rubber	Furniture and Cabinet, Flooring, Packing Cases, Wood Carvings, Wooden Shuttle Block, Laminated Veneer Lumber, Block Board and Flush Doors, Fibre Boards, Pulp and Paper, Bent Wood Articles
7	Thekku	Teak	Construction, Railway Sleepers, Furniture and Cabinet, Shipbuilding, Flooring, Veneer,Panelling

Important timber wood species marketed by traders in Kerala: The data showed the volume of wood processed by saw millers and timber traders of three districts namely Thiruvananthapuram, Kottayam and Ernakulam. The volume of wood processed Rubber, Teak, Anjily, Jackfruit and Mahogany constitutes 22108 m^3, 240 m^3, 163 m^3, 60 $m^3$and 50 m^3respectively by saw millers and timber traders. All 15 saw mills and timbers trading units are found to be owned by same person.

Table 13. Volume of wood processed by Saw millers/ Timber Traders in three districts of Kerala (n=15)

Ranking on the basis of Volume of wood processed by Saw miller/Timber Traders		
Sr.No	**Name of Species**	**Volume of wood processed (in m3)**
1	Rubber	22108.212
2	Teak	239.82
3	Anjily	162.65
4	Jackfruit	59.67
5	Mahogany	50

(Note: Volume of Rubber wood processed is shown on left hand axis and volume of Teak, Anjily, Mahogany&Jackfruit rocessed is shown on the right handaxis)

Value of timber traded by timber traders in three districts of Kerala: The value of timber traded by timber traders in threedistricts namely Thiruvananthapuram, Kottayam and Ernakulam is summarized in table 5.20.The value of Rubberwood is Rs 3918 million followed by Teak, Anjily, Jackfruit and Mahogany at Rs 228.80 million, Rs 59.19 million, Rs 19.51 million and 15.72 million respectively (Table 14).

Table 14. Value of timber traded by timber traders in three districts of Kerala (n=15)

Sr. No	Name of Species	Volume of wood processed (incum)	Prices of timber per cum (in cum)	Value of timber (in million Rs.)
1	Rubber	22108.212	177222	3918.06
2	Teak	239.82	954059	228.80
3	Anjily	162.65	363954	59.19
4	Jackfruit	59.67	327069	19.51
5	Mahogany	50	314485	15.72

Comparative prices of wood species in Kerala: The second objective of this study is to study comparative prices of five priority species in Kerala. The prices recorded from the responses of various stakeholders from six districts of Kerala. The prices of wood species for year 2010, 2013 and 2015 are taken (Table 15).The percent change in inflation for 2013 and 2015 is calculated to assess the net change in prices of wood (Table 16) and price change net of inflation from 2013 to 2015 (Table 17).

Table 15. Comparative prices of wood species in Kerala. (Prices in Rs per Cubic feet)

Sr. No	Name of Species	Prices in 2010	Prices in 2013	Prices in 2015
1	Rubber	190	210	280
2	Teak	1700	1900	2000
3	Anjily	650	750	800
4	Jackfruit	950	1000	1100
5	Mahogany	650	750	950

Table 16. Inflation rate in India from 2010 and 2015

Sr. No	Year	Year wise Inflation rate in %	Inflation 2010 to 2013	Inflation 2013 to 2015
1	2010	12.11		
2	2011	8.87		
3	2012	9.30		
4	2013	10.92	29.09	
5	2014	6.37		
6	2015	5.88		12.06

(Source: http://www.inflation.eu/inflation-rates/india/historic-inflation/cpi-inflation-india.aspx)

Table 17. Net of Inflation for wood species in Kerala

Sr. No.	Name of Species	2010	2013	2014	%age change in price from 2013 to 2015	Price change net of inflation between 2013 to 2015
1	Rubber	190	210	280	33.33	21.27
2	Teak	1700	1900	2000	5.26	-6.8
3	Anjily	650	750	800	6.66	-5.4
4	Jackfruit	950	1000	1100	10	-2.06
5	Mahogany	650	750	950	26.66	14.6

(Source :Indiastat data)

Conclusion

The data analysis shows that Rubber is the most preferred commercial plantation species in Kerala with an area of 5, 49,955 ha of plantations. Other prominent tree species under plantations in farmlands include Teak, Anjily, Jackfruit and Mahogany on the basis of plantation area. Farmer's choice for cultivation of tree crops depends on short-term economic gains from plantations. Other traditional factors such as fruit-bearing, medicinal uses, shade providing etc also considered by farmers while selecting tree species for plantations.

Rubber plantations cover large plantation area both in forest and outside forest in Kerala. However, the most of Rubber plantations are found outside forest. It seems that Rubber plantations have gained its acceptance amongst farmers and tree growers because of economic gains. These economic gains arise as a result of suitability of the species in the agro climatic conditions of the state (hence grow fast), Rubber tree requires less labour,economic returns starting from 7thyear of plantation through latex collection andopportunity for mix-cropping with crops like pineapple and bamboo.

The declining availability of hardwood species like Teak, Anjilyetc has generated interest in Rubberwood as a timber option. Therefore, Rubber plantations is emerging as an alternate source of timber in the state with the use of chemical treatment and seasoning of Rubberwood which improves quality of Rubber wood and adds to its timber value.

In real terms there is an increase in prices of Rubber which is 21.27% as compared to prices in 2013. This seems to be one of the factors that encourage farmers to go for Rubber plantation in their farmlands.

Jackfruit is found in abundance in farmlands and homestead gardens in Kerala. Apart from timber value it yields fruits from 4thyears of plantation. Kerala has largest area under Jackfruit cultivation amongst all horticultural crops. Jackwood is widely used for construction and furniture manufacturing in the state. The agro climatic conditions in Kerala are highly favourable for Jackfruit plantations and therefore Jackfruit occupies 92,203 ha and found to be second most preferred commercial species in plantations after Rubber.

In real terms the prices of Jack wood has not increased which seems to be one of the factors for stagnant area under cultivation of Jackfruit.

After Rubber and Jackfruit plantations, Teak is found to be third most preferred commercial species with 23461 ha area under plantation. The area under Teak plantations in forest is almost three times the area outside forest. The fewer plantations outside forest seem to be the because of strict harvest rules for Teak. However, new incentive scheme introduced by forest department in 2012 has renewed interest among farmers/tree growers. Teak has been considered as one of the best timber species for various uses such as shipbuilding, house construction and furniture making. The agro climatic conditions in Kerala are highly favourable for Teak plantations and therefore Teak still finds prominent place in commercial plantations in the state.

In real terms the prices of Teak has not increased which seems to be one of the factors for slow increase in area under Teak plantation.

Anjilyis commonly observed species in homestead gardens and forest across all districts of the state. Anjily wood is used for construction, furniture, boat making and is considered as important sacred groves species. It is also considered as "Poor Man's Teak" but because of low price and long rotation period it is not preferred for commercial plantations.

In real terms the prices of Anjily has not increased which seems to be one of the factors for not considering Anjily for commercial plantations.

Mahogany is a popular species found both in forest and outside forest. This tree is commonly observed as avenue, road side and plantation tree. The tree is widely used for furniture making in the state. It has not gained status of commercially important species on account of its low prices as compared to Teak.

In real terms there is an increase in prices of Mahogany which is 14.6% as compared to prices in 2013. This seems to be one of the factors which has created interest in farmers to go for Mahogany plantation in their farmlands.

With the incentive scheme for tree plantations in place it is expected that more and more farmers will go for plantations of hardwood species like Teak, Jackfruit (Plavu), Anjily and Mahogany which may ensure future timber availability in the state as envisaged in the private forestry incentivisation scheme of the state.

Implications of the study

- The study contributed to the literature related to the availability of timber species in Kerala.
- The study provides close insight of the important timber species to the variety of stakeholders such as farmers/Tree growers, timber traders, furniture manufacturers and wood based industries.

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Influence of Bioinoculants on the Growth of *Adina Cordifolia* (Roxb.) Hook.f. in Nursery Conditions

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Abstract

Nursery experiments were conducted to select the suitable bio-inoculants and their combinations to improve the planting stock production of *Adina cordifolia*. Seeds were germinated and one month old seedlings were transplanted to polythene bags with a potting mixture of unsterilized substrate (Sand : Red soil : Farm Yard Manure)in the ratio of 2:1:1 and bioinoculants such as *Azospirillum brasilense,* AM fungi (*Glomus fasciculatum*) and *Pseudomonas fluorescens* were inoculated separately and in combination. Control plants also maintained for comparing growth performance. Shoot length, root length, collar diameter, number of leaves, biomass and seedling quality index were assessed under nursery conditions. The results showed that an enhanced shoot length, root length, number of leaves, total biomass (shoot and root) and nutrient uptake was higher in seedlings treated with *Azospirillum,* AM fungi and *Pseudomonas.* It was recorded, individual inoculation of *Azospirillum* showed 35.36 % of total length and 38.15% of biomass increase over the control.

Introduction

Organic farming is getting more popular these days, which accentuates shift from high volume production system to high value production system. For achieving this, management practices that conserve soil health, efficient nutrient supply systems that rely on organics instead of chemicals and integrated pest management play vital role. Among these, efficient, cheap and reliable nutrient supply system will ensure sustainability of the organic farming system.

Biofertilizers in combination with organic manures found as effective component in organic farming for reliable and cheap supply of nutrients. These combinations were ecologically safe and improve soil fertility by improving the soil physical, chemical, and biological condition. At present the pinch on fertilizer consumption is being felt more in India, since the country cannot afford to either import the required fertilizer at high cost and subsidize the sale to the farmers or build new fertilizer plants at formidable cost. Hence farmers are prepared to take to organic farming by using bio-inoculants.

Among many timber yielding plants, *Adina cordifolia* a large deciduous tree belonging to Rubiaceae family. It grows on a wide range of soils, and will tolerate soils with high pH values, up to 8.3. It is susceptible to frost damage and to fires (Cooke, 1901). It grow well in Southern part of Tamil Nadu, Particularly in Madurai and Sivagangai District. There is a high demand in quality planting stock of *Adina cordifolia* in Southern part of Tamil Nadu. To fulfill the demand, the nursery managers are using different substrates in combination with nutrient solution. This strategy is not eco-friendly, further it is not economically viable also. The nursery managers need to practice an agro-biotechnological approach to produce quality planting stock with sustainable nutrient management. There is a need for standardization of potting media using suitable bio-inoculants to ensure an adequate plant nutrient concentration and combination. Hence, the present research work was aimed to select the suitable bioinoculants and their combination to produce quality seedlings of *Adina cordifolia* using locally available beneficial microorganisms to reduce the cost of seedling production.

Materials And Methods

Seed collection

Adina Cordifolia seeds were collected from a single plus tree, located at the semi-arid region of Alagar hills in Madurai district of Tamil Nadu, India. Seeds were separated by removing the pulp and dried in shade, graded and uniform size seeds were used for raising seedlings. Seedlings were raised in a mixture of unsterilized sand in germination tray in room temperature.

Isolation of *Pseudomonas*, *Azospirillum* and AM Fungi

Pseudomonas fluorescens was isolated by the serial dilutions and pour plate method using King's B medium (King *et al*., 1954). N-free semisolid Malate medium (NFB) was used to isolate *Azospirillum* (Dobereiner *et al*., 1976). AM fungus (*Glomus fasciculatum*) was isolated and recorded as dominant species in the rhizosphere soil of *Adina Cordifolia.* It was multiplied in pot culture in the sterilized mixture of sand: soil (1: 1 v/v) and maintained in the roots of *Sorghum vulgare* as the host plant. The inoculum contained extrametrical hyphae, chlamydospores and infected root segments were added in the root zones of each seedling.

Treatment

Seedlings were transplanted in 13´ 26 cm. size polyethylene bags with a potting mixture of unsterilized sand: red soil: farm yard manure (2: 1: 1). Ten days after transplantation in polyethylene bags, 10grams of peat soil based culture of *Azospirillum*, *Pseudomonas* and AM fungus were inoculated by making holes in the rhizosphere of seedlings.

T_1- *Azospirillum* (*Azospirillum brasilense*)

T_2-Arbuscular Mycorrhizal Fungi (AMF) (*Glomus fasciculatum)*

T_3-*Pseudomonas* (*Pseudomonas fluorescens*)

T_4- *Azospirillum* + AMF

T_5- *Azospirillum* + *Pseudomonas*

T_6- *Pseudomonas* + AMF

T_7- *Azospirillum*+ *Pseudomonas* + AMF

T_8- Control (Sand: Red soil: Farm Yard Manure 2:1:1)

Experimental design

Nursery experiments were conducted at the Tamil Nadu Forest Department nursery located at Madurai, Tamil Nadu, India. The experiment was set up in a completely randomized block design (RCBD) with 8 treatments and twenty four replicates. All the plants were kept under identical nursery condition up to 180 days.

Harvesting and measurement

180 days after transplanting from each treatment, a total of 12 seedlings were randomly selected height and basal diameter were recorded. Seedlings were carefully uprooted without disturbing the root system and washed in running tap water. Excess of water was wiped out by placing them between folds of blotting paper. The seedlings were cut at collar region, dried separately at 70^{o} C in a paper bags placed in hot air oven and estimation of biomass (root and shoot dry weight) was carried out using top pan electronic balance.

Seedlings Quality Index

Seedlings Quality Index was calculated using the formula of Dickson (1960).

$$\text{Seedlings Quality Index (SQI)} = \frac{\text{Total weight (g/ plant)}}{\dfrac{\text{Height (cm)}}{\text{Root collar diameter (mm)}} + \dfrac{\text{Shoot weight (g/plant)}}{\text{Root weight (g/plant)}}}$$

Nutrient Analysis

The oven-dried plant samples were ground to pass through a 0.5 millimeter plastic sieve before digestion and samples were taken for the bio-chemical analysis.

Nitrogen and Phosphorous

The dried plant material was ground in a mortar and pestle and the total nitrogen content was estimated by the conventional micro-Kjeldahl method. Total phosphorus was estimated by the method of Fiske-Subbaro as modified by Bartlett (1959).

Estimation of total potassium, calcium and magnesium

One gram of plant sample was digested with tri-acid mixture with HNO_3: H_2SO_4: $HClO_4$ in the ratio of 9:2:1 until it became colorless. After digestion it was filtered and the volume was made up to 100 ml. Potassium in the extract was determined using a flame photometer. Calcium and Magnesium were determined by the Versenate method as described by Jackson (1973).

Statistical analysis

The data were statistically analysed by analysis of variance (ANOVA) and treatment means were separated using Duncan s Multiple Range Test ($P<0.05$) (Duncan, 1955).

Results and Discussion

Results

Shoot length, Root length and Collar diameter:

Significant differences in shoot length, root length and collar diameter were recorded in *Adina cordifolia* seedlings inoculated with the different microbial inoculants compared to the uninoculated control (Table 1).

Shoot length

From the analysis of growth data the individual inoculation of *Azospirillum* (T_1) treated seedlings was found to be the most effective in increasing the growth and biomass. Among all the treatments, combined inoculation of *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* (T_7) recorded maximum shoot length. The individual inoculation with *Azospirillum* (T_1) recorded maximum shoot length and it was 27.72% increase over the control followed by combined inoculation of *Azospirillum* + AMF (T_4) with 23.60 % increase over control, Seedlings treated with combination of 180 days after inoculation (Table 1).

Root length

Significant differences in root length were recorded in *Adina cordifolia* seedlings inoculated with different microbial inoculants compared to the uninoculated control (Table1). From the analysis of growth data, the individual inoculation of *Azospirillum* (T_1) was found to be the most effective in increasing the root length of seedlings.

Table1. Effect of bio - inoculants on the growth of *A. cordifolia* seedlings (180 DAI)

Treat ments	Growth				
	Number of Leaves	Collar diameter (mm)	Shoot length (cm)	Root length (cm)	Total length (cm)
T_1	32c (34.37)	0.63^{c} (49.20)	27.72^{e} (28.78)	65.32^{d} (38.15)	93.04 (35.36)
T_2	30c(30.00)	0.61^{c} (47.54)	22.42^{e} (11.95)	62.14^{c} (34.98)	84.56 (28.87)
T_3	27^{b} (47.61)	0.49^{b} (34.69)	21.26^{ab} (7.149)	40.90^{a} (1.222)	62.16 (3.249)
T_4	33^{d} (36.36)	0.57^{b} (43.85)	23.60^{cd} (16.35)	55.76^{b} (27.54)	79.36 (24.21)
T_5	27^{b} (22.22)	0.51^{b} (37.25)	22.42^{cd} (11.95)	50.60^{b} (20.15)	73.02 (17.63)
T_6	25^{b} (16.00)	0.51^{b} (37.25)	21.80^{abc} (9.449)	41.84^{a} (3.441)	63.64 (5.515)
T_7	41^{de} (48.78)	0.69^{d} (53.25)	29.42^{e} (32.90)	71.44^{d} (43.44)	100.86 (40.37)
T_8	21^{a}	0.32^{a}	19.74^{e}	40.40^{a}	60.14

Values in parenthesis are % (Percentage) increased over control

DAI – Days after inoculation

Means followed by a common letter(s) in the same column are not significantly different at the 5 % level by DMRT

T_1- *Azospirillum*; T_2-ArbuscularMycorrhizal Fungi (AMF) ; T_3-*Pseudomonas* T_4- *Azospirillum* + AMF; T_5- *Azospirillum* + *Pseudomonas*; T_6- *Pseudomonas* + AMF; T_7- *Azospirillum*+ *Pseudomonas* + AMF; T_8- Control (Sand: Red soil: Farm Yard Manure 2:1:1)

Among all the treatments, combined inoculation of *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* (T_7) recorded maximum root lentgh71.45 and it was recorded 43.44%increased over control seedlings. The individual inoculation with *Azospirillum* (T_1) showed maximum root length 65.32 cm (38.15% increases over the control).

Shoot biomass

The data pertaining to dry matter accumulation of shoot, root and total biomass are presented in Table 2. Significant differences were observed among the treatments evaluated 180 days after inoculation. The highest biomass in the shoot was recorded in seedlings inoculated with *Azospirillum* + AM Fungi

+*Pseudomonas fluorescens* (T_7). It was statistically on a par with seedlings treated with *Azospirillum* (T_1). They registered 30.01% and 27.24% increase over control. (Table 2).

Root biomass

Statistically highly significant difference was found in different type of microbial inoculation on root biomass of *Adina cordifolia* seedlings. Inoculation of A*zospirillum* (T_1) alone and in combination with other inoculants was found to significantly increase root biomass when compared to other treatments. Root biomass was highest in *Azospirillum* (T_1) followed by *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* (T_7) (Table 2).

Total biomass of seedling

Seedling biomass was the highest in the *Azospirillum* (T_1) treated seedlings and it was 77.47 % more than that of the control and it was statistically on a par with seedlings treated with *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* (T_7). In the dual inoculation seedlings inoculated in combination with *Azospirillum* recorded more biomass than the control (Table 2).

Table 2. Effect of bio-inoculants on biomass of *A. cordifolia* seedlings (180 DAI)

Treatments	Leaf biomass	Shoot biomass	Root biomass	Total biomass
T_1	8.22^c	27.24^c	42.01^c	77.47
T_2	7.20^b	21.01^b	39.83^c	68.04
T_3	7.44^b	19.87^b	26.89^b	54.2
T_4	7.96^b	21.08^b	38.43^c	67.47
T_5	7.65^b	20.04^b	35.14^b	62.83
T_6	7.55^b	18.87^b	30.27^b	56.69
T_7	9.48^d	30.01^d	51.43^d	90.92
T_8	5.88^a	15.60^a	24.19^a	45.67

Seedling Quality Index

Good quality seedlings were obtained from seedlings inoculated with Azospirillum (T_1). *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* (T_7) showed the next highest seedling quality index, followed by *Azospirillum* +

Pseudomonas (T_5). Among the double inoculations *Azospirillum* + *Pseudomonas* (T_5) showed the highest seedling quality index (Figure 1).

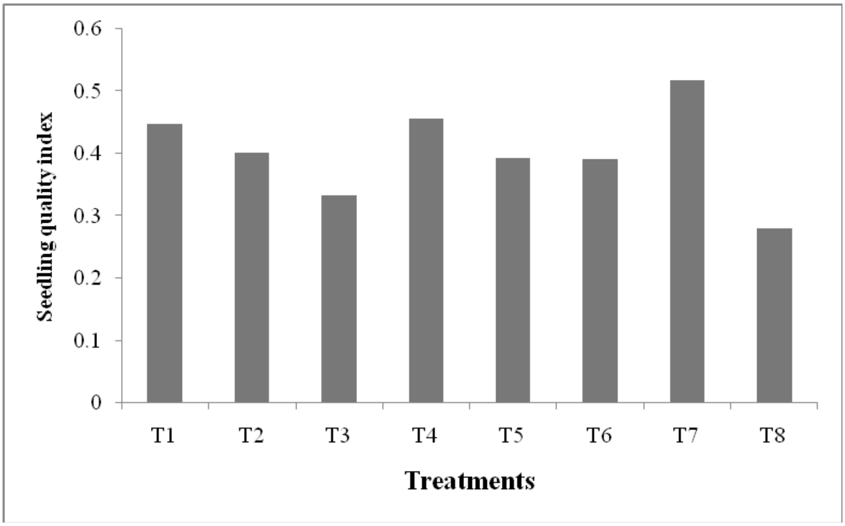

Fig 1: Seedling quality index of *A. cordifolia* inoculated with bio-inoculants

T_1- *Azospirillum*; T_2-ArbuscularMycorrhizal Fungi (AMF) ; T_3-*Pseudomonas* ; T_4- *Azospirillum* + AMF; T_5- *Azospirillum* + *Pseudomonas*; T_6- *Pseudomonas* + AMF; T_7- *Azospirillum*+ *Pseudomonas* + AMF T_8- Control (Sand: Red soil: Farm Yard Manure 2:1:1)

Nutrient content

Seedlings inoculated with bioinoculants had significantly higher nutrient content in their tissues as compared to the control (Table 3). Changes in total nitrogen, phosphorus, potassium, calcium, magnesium content of seedlings inoculated with bioinoculants and control are presented in table**.** The nitrogen phosphorus, potassium, calcium, magnesium content reached the maximum in T_7 *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* treated seedlings. (Table 3). Nutrient content in tissues was in the order of Nitrogen>Calcium> Potassium>Magnesium>Phosphorus.

Discussion

Potting media play a key role for developing quality planting stock in forestry species. A medium based on mineral soils, air spaces and it compacts down very quickly. Hence, the use of bioinoculants are recommended to overcome these difficulties (Mohit, 1999). There is no single growth induction

Table 3. Effect of bio-inoculants on nutrient concentration of *A. cordifolia* seedlings (180 DAI)

Treat ments	Nutrient % concentration and nutrient accumulation (mg/plant)				
	N %	P%	K %	Ca%	Mg%
T_1	2.00 (1.549)	0.96 (0.743)	1.316 (1.019)	1.406 (1.089)	0.27 (0.209)
T_2	2.20 (1.496)	0.98 (0.666)	1.315 (0.894)	1.401 (0.953)	0.26 (0.156)
T_3	2.40 (1.300)	0.99 (0.536)	1.321 (0.715)	1.422 (0.770)	0.29 (0.157)
T_4	2.02 (1.363)	0.96 (0.647)	1.316 (0.887)	1.401 (0.945)	0.27 (0.182)
T_5	2.02 (1.269)	0.97 (0.609)	1.317 (0.827)	1.401 (0.880)	0.27 (0.169)
T_6	1.98 (1.122)	0.095 (0.053)	1.300 (0.736)	1.402 (0.764)	0.8 (0.533)
T_7	2.42 (2.200)	0.104 (0.094)	1.384 (0.258)	1.482(1.347)	0.33 (0.300)
T_8	1.90 (0.867)	0.93 (0.424)	1.295 (0.591)	1.396 (0.63)	0.25 (0.114)

Values in parenthesis are nutrient accumulation (mg/plant)

medium that can be used for all purpose but general horticulture properties have been underlined (James, 1987; Swanson, 1989). These include slightly acidic pH (5.5- 6.5), high cation exchange capacity, low inherent fertility, adequate porosity and freedom from pest. Growth induction media for forestry seedlings generally contain 2- 3 components. Similarly, the results of the present experiments also corroborate with above statement, when the seedlings treated with *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* (T7) produced best quality seedlings. The highest growth, biomass and quality seedlings were obtained in seedlings inoculated with *Azospirillum* + AM Fungi +*Pseudomonas fluorescens* which might be due to favorable physicochemical properties of the respective potting medium.

In the present study, *Azospirillum* inoculated *Adina cordifolia* seedlings showed better growth and root biomass when compared to the control. Growth may be attributed due to increased root biomass and accumulation of nitrogen (Wong and Sternberg, 1979; Rajendran *et al*., 2003) and the production of gibberellins and cytokinin like substances (Tien *et al*., 1979) which promote the growth of the seedlings. The above results corroborate with earlier studies on quality seedling production of *C. equisetifolia* by Rodriguez-Barrueco *et al*., 1991; Rajendran *et al*., 2003. *Casuarina* trees treated with bioinoculants in farm forestry

(Rajendran and Devaraj, 2004), *Moringa oleifera* by Kasthuri rengamani *et al*., 2006 and Mohan and Rajendran (2014) in *Feronia elephantum*. In the present study *Pseudomonas* inoculated seedlings produced better plant height, stem girth and total biomass. It may be due to inoculation of phosphate solubilizing microorganism *Pseudomonas* which has shown stable and consistent capacity to solubilize insoluble phosphorus and thus making it available to plants.

Nutrient management has been well recognized since early times, which has become highly relevant with the advent of commercial forestry, where there is always a thrust to increase the production and biomass removal besides maintaining the soil fertility. Estimation of essential mineral elements in plants is an important aspect in the study of plant growth and ecosystem structure. Growth in case of fast growing species, it becomes more essential to study the geochemical cycle of the essential elements in support of their survival in future (Faizmohsin *et al*., 2005). In the present estimation nutrient uptake was higher in seedlings treated with bio inoculants**.** Nutrient accumulation of seedling is in the order of nitrogen>calcium>potassium>magnesium>phosphorus.

Conclusion

Bioinoculants act as perpetually renewable inputs helping in better tree improvement through sustainable nutrient management and maintenance of soil health, better soil and water management leading to improved farm forestry and agr-forestry practices. It is inferred that under appropriate technology, the use of efficient microbial inoculants yield increased growth and biomass of *Adina cordifolia* seedlings. The present study clearly shows that the application of *Azospirillum* along with AM Fungi and *Pseudomonas fluorescens* plays a significant role in increasing the growth response of *Adina cordifolia* seedlings in a stipulated period, thereby producing good quality planting stock. These treated seedlings may perform better in nutrient impoverished soil too.

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Early Growth Response of Cadamba (*Neolamarckia Cadamba*) Under Drip Irrigation System Suitable for Intensive Farming

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Abstract

A field experiment was conducted to study the growth of Cadamba (*Neolamarckia cadamba*) under drip irrigation system with the objective to promote intensive tree farming as income generation option of farmers. The biometric attributes *viz*., height, basal diameter and DBH were estimated at different growth intervals namely 3, 6, 9 and 12 months after planting. The preliminary growth information revealed that *Neolamarckia cadamba* exhibited highest growth with maximum height of 7.11 m, basal diameter of 9.02 cm and diameter at breast height of 7.41 cm in one year of age under drip irrigation. The height and diameter increment also shown remarkably good result. One year of field experiment help to conclude that initial-3 months an amount of 12 liters/plant/week, during 3-6 months of growth 24 liters of water/plant/week, during 6-9 months 30 liters of water/plant/week and during 9-12 months of growth 36 liters of water/tree/week showed maximum growth response. The filed study is in progress and the growth performance will be evaluated with the objective to reduce the rotation and increase the yield.

Introduction

Wood from forest is the world's major renewable commodity and the demand for *wood and* other forest products are in an increasing trend. The increasing growth rate of human population would likely to keep the demand for forest produce at a higher order. In order to bridge the widening gap, forest productivity has to be maximized to meet the increasing demand by adopting new area for plantations outside conventional forest area coupled with techniques to increase productivity. The demand for Indian industrial wood rose from 58 million cubic meters in 2000 to 123 million cu.m in 2013 and expected to cross 150 million cu.m by 2018 (Wood news, 2014).

Water is a precious commodity and its judicious utilization is very much essential for maximizing crop yield. In recent times, the mean annual rainfall is decreasing, the length and severity of dry season has become a limiting factor for crop growth and productivity. The moisture requirements of agricultural crops are met with drip irrigation system in many parts of the water deficit nation. The deficit of forest biomass production can be compensated in farmlands by raising plantation coupled with assured irrigation facilities. Thus irrigated plantation raised with fast growing species could address the wood deficit to certain extent due to its fast growth rate. The present study was conducted at Forest College and Research Institute, Mettupalayam to study the early stages of tree crops under drip irrigation.

Materials and Methods

The field experiment was carried out to investigate the effect on growth of Cadamba (*Neolamarckia cadamba*) under drip irrigation during the year 2015-16. The study was conducted at Forest College and Research Institute, Mettupalayam (11° 19' N and 77°56' E) with an altitude of 300 m above MSL and mean annual rainfall of 920.5 mm. The soil was loamy sand in texture, well drained, slightly alkaline in reaction (pH-7.87) and non saline (EC-0.20 dSm^{-1}).

Neolamarckia cadamba was planted with the spacing of 3m x 2m in potential scale and irrigated with drip irrigation system. The discharge rate of drippers was 4.0 liters/hour for one hour/day. The quantity of water irrigated is followed with initial-3 months an amount of 12 liters/plant/week, during 3-6 months of growth 24 liters of water/plant/week, during 6-9 months 30 liters of water/plant/week and during 9-12 months of growth 36 liters of water/tree/week. During summer and rainy seasons, the irrigation was carried out based on soil moisture status. The following biometric observations *viz.*, height, basal diameter and diameter at breast height were recorded at the time of planting, 3, 6, 9 and 12 months after planting. The height and diameter increment was measured for the growth period of 3, 6, 9 and 12 months after planting.

Result and Discussion

Drip irrigation is a modern agro-technique to improve water use efficiency that saves water by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly into the root zone. Drip irrigation confirms to increase in water productivity with water saving of 27.4 per cent over the conventional irrigational system (Bouman *et al*., 2007).

In *Neolamarckia cadamba* seedling height were 1.25 m, 3.03 m, 4.44 m, 6.06 m and 7.11 m at the time of planting, 3, 6, 9 and 12 months after planting respectively (Table 1 and 2). Maximum height increment in Casuarina may be attributed by drip irrigation at short interval (Wood *et al*., 1975). Pressurized irrigation systems have potential to increase water productivity by providing water to match crop requirements, reducing runoff, deep drainage losses and reducing soil evaporation (Parthasarathi *et al*., 2017). The basal diameter in

Table 1. Growth of Cadamba (*Neolamarckia cadamba*) under drip irrigation

Sl. No	Growth Stages (MAP)	Height (m)	Basal Diameter (cm)	Diameter (cm)
1	At the time of planting	1.25	1.23	-
2	3 MAP	3.03	3.11	2.56
3	6 MAP	4.44	5.26	4.22
4	9 MAP	6.06	7.73	5.94
5	12 MAP	7.11	9.02	7.41

Table 2. Increment Percent of *Neolamarckia cadamba* under drip irrigation

Sl. No	Growth Stages (MAP)	Height Increment (%)	Diameter Increment (%)
1	3 MAP	58.75	-
2	6 MAP	31.76	39.34
3	9 MAP	26.73	28.96
4	12 MAP	14.77	19.84

Neolamarckia cadamba were 1.23 cm, 3.11 cm, 5.26 cm, 7.73 cm and 9.025 cm at the time of planting, 3, 6, 9 and 12 months after planting respectively (Figure 1). The increase in rate of irrigation have a significant increase in tree collar diameter and vigour (Narayanamoorthy, 2003). The diameter of 2.56 cm, 4.22 cm, 5.94 and 7.41 was recorded in *Neolamarckia cadamba* at 3, 6, 9 and 12 months after planting respectively. Drip irrigation registered superior performance in terms of growth indices (Plant height, tiller density, root biomass and total dry matter accumulation), physiological parameters (WUE, total chlorophyll, catalase activity and leaf malondialdehyde value), yield and its components

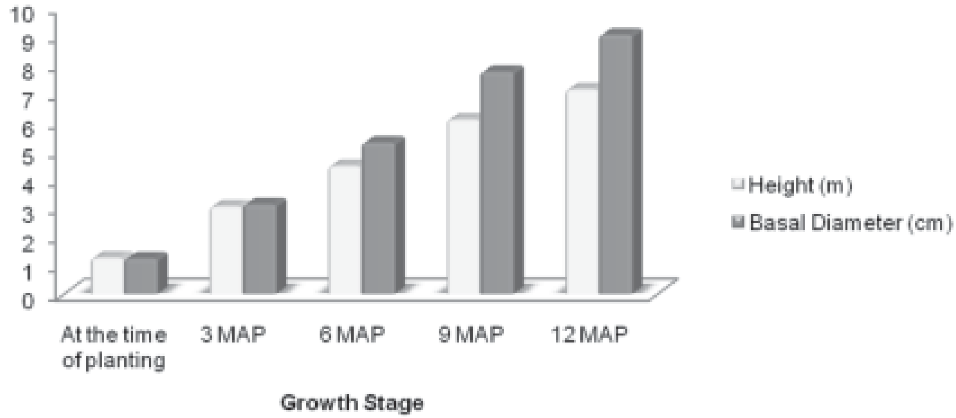

Figure 1. Growth of Cadamba (Neolamarckia cadamba) under drip irrigation

along with increased water potential values (Kato *et al.*, 2008). This tree plantation established under drip irrigation system may fetch better returns to tree growers in terms of increased productivity and biomass accumulation in trees.

Conclusion

Neolamarckia cadamba was performed well under drip irrigation system in farm lands and was proven with the increment in height and diameter at periodic intervals. Drip irrigation was helpful in enhancing the water use efficiency and improved the growth in their early stages, which may reflect considerably in subsequent growth and development in tree crops at later stages.

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Influence of Drip Irrigation on Growth and Productivity of Pink Cedar (*Acrocarpus Fraxinifolius*) at Early Stage

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Abstract

Drip irrigation aims in efficient use of water in crop productivity. A field experiment was conducted at Forest College and Research Institute, Mettupalayam to study the growth of Pink cedar (*Acrocarpus fraxinifolius*) an indigenous fast growing tree under drip irrigation. The biometric attributes *viz.*, height, basal diameter and diameter at breast height were studied at the time of planting, 3, 6, 9 and 12 months after planting. *Acrocarpus fraxinifolius* has attained a maximum height, basal diameter and diameter of 6.24 m, 7.64 cm and 6.21 cm in one year of growth. The drip technology can boost the productivity of tree crops, betterment of soil and tree health especially under resource scarce conditions.

Keywords: *Acrocarpus fraxinifolius*, Drip Irrigation, Farm lands, Growth

Introduction

Forest and tree cover in India has stabilized over the years at around 24.16 per cent of geographical area. The National Forest Policy (NFP), 1988 lays down the National goal of 33% of forest and tree cover for ensuring ecological security and environmental balance. The establishment of forest plantations is a means to meet the increasing demand for industrial wood and to reduce the pressure on the shrinking supply from the nature forests for rehabilitation of the waste lands and unproductive lands.

Increasing demand coupled with low productivity of tree plantations is one of the major concerns faced by wood based industries. Improved planting material coupled with location specific silvicultural technologies with the idea of **"Precision Silviculture"** will improve the productivity of the plantations (Petronela, 2010) to a greater extent. Low soil fertility and moisture stress conditions of the field are important limitations for a low productivity in tree crops. In Tamil Nadu, the average annual rainfall is very less and hence practically, it is not possible to meet the demand of irrigation by rainfall alone. Further for the traditional system of irrigation practice, more water resource and manpower are required. These limitations can be narrowed by following drip irrigation to increase soil fertility and decreasing soil moisture. Drip irrigation system has the benefit of providing the highest water use efficiency (WUE) of all forms of irrigation, nearly 90 percent (Jake, 2003). Adoption of drip irrigation systems may help to increase the irrigated area, improve the productivity of tree crops and water use efficiency. On the above understanding, the present work was carried out at Forest College and Research Institute, Mettupalayam to study the growth of *Acrocarpus fraxinifolius* under drip irrigated conditions.

Materials and Methods

The experiment was conducted at Forest College and Research Institute, Mettupalayam (11° 19' N and 77°56' E) in altitude of 300 m above mean sea level with mean annual rainfall of 920.5 mm. The maximum and minimum temperature was 38.8°C and 17.7°C respectively. The soil in the experimental field was Illupanatham soil series with loamy sand in texture, well drained, slightly alkaline in reaction (pH-7.87) and non saline (EC-0.20 dSm^{-1}).

Seedlings were planted in the field at a spacing of 3m X 2m in rational scale. Drip irrigation system was installed and the seedlings were irrigated in alternate days based on weather conditions with a discharge rate of 4.0 liters/ hour for one hour/day. Based on the availability of moisture content in soil, irrigation schedule was altered accordingly in summer and rainy season. The biometric observations *viz*., height and basal diameter were recorded at the time of planting, 3, 6, 9 and 12 months after planting in *Acrocarpus fraxinifolius* tree seedlings.

a) Height

The height of the tree seedlings were measured from the ground level to the leading terminal tip using the standard scale and is expressed in metre.

b) Basal diameter

Basal diameter is measured with the help of digital vernier caliper at the ground level and expressed in cm.

C) Diameter at Brest Height (DBH)

Diameter at breast height is measured using vernier caliper at the height of 1.37 m and the data was expressed in cm.

The height and diameter increment was measured for the growth period of 3, 6, 9 and 12 months after planting.

Result and Discussion

In drip irrigation system, water is effectively utilised and directly reaches the rhizosphere without any runoff loss. A drip irrigation system delivers water directly to the root zone of a plant, where it seeps slowly into the soil. Almost no water is lost through surface runoff or evaporation and soil particles have plenty of opportunity to absorb and hold water for plants. It also means very few nutrients leach down beyond the reach of plant roots.

The height of *Acrocarpus fraxinifolius* seedlings at the time of planting, 3, 6, 9 and 12 months after planting were 1.18 m, 2.91 m, 3.95 m, 5.10 m and 6.24 m respectively under drip irrigation system (Table 1 and 2). Drip irrigation benefits can be seen throughout the growing cycle, especially in plant height and basal development (Marsal and Girona, 2007). The height growth of tree crop was significantly highest in drip irrigation treatment in tree crops (Parthasarathi *et al*., 2017). Ibragimov *et al*. (2007) compared drip and furrow irrigation in agricultural crops and inferred that 18-42 per cent of the irrigation water could be saved with drip systems with increased irrigation water use efficiency (35-103 %) compared to furrow irrigation methods.

Table 1. Growth of Pink Cedar (*Acrocarpus fraxinifolius*) under drip irrigation

Sl. No	Growth Stages	Height (m)	Basal Diameter (cm)	Diameter (cm)
1	At the time of planting	1.18	1.16	-
2	3 MAP	2.91	2.87	2.07
3	6 MAP	3.95	4.76	3.68
4	9 MAP	5.10	6.01	5.08
5	12 MAP	6.24	7.64	6.21

Table 2. Increment Percentage of *Acrocarpus fraxinifolius* under drip irrigation

Sl. No	Growth Stages (MAP)	Height Increment (%)	Diameter Increment (%)
1	3 MAP	59.45	-
2	6 MAP	26.33	43.75
3	9 MAP	22.55	27.56
4	12 MAP	18.27	18.20

The basal diameter of 1.16 cm, 2.87 cm, 4.76 cm, 6.01 cm, and 7.64 cm were registered at the time of planting, 3, 6, 9 and 12 month after planting respectively in *Acrocarpus fraxinifolius* (Figure 1). The drip irrigation treatment had more effective tillers, maximum biometric growth, more roots in topsoil, higher WUE and greater economic benefit in tree crops (He *et al.*, 2013) compare with conventional flooding irrigation. In the rapid vegetative growth, drip irrigation distributes nutrients directly to the root zone to allow for peak uptake of critical nutrients (Stern *et al.*, 2008). The diameter of 2.07 cm, 3.68 cm, 5.08

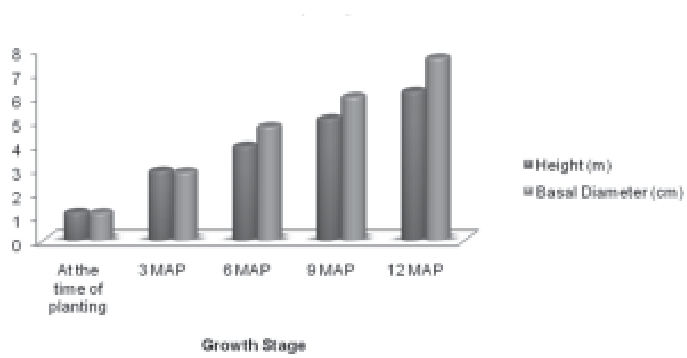

Figure 1. Growth of Pink Cedar (Acrocarpus fraxinifolius) under drip irrigation

and 6.11 was recorded in *Acrocarpus fraxinifolius* at 3, 6, 9 and 12 months after planting respectively. The drip irrigation effectively improved the growth and development of afforested seedlings at early stage of growth period.

Conclusion

The growth of Pink cedar (*Acrocarpus fraxinifolius*) under drip irrigation was highest in shorter period than the conventional irrigation. Therefore, *Acrocarpus fraxinifolius* can be promoted in farmlands for fetching highest wood productivity under drip irrigation.

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Growth Dynamics of *Acrocarpus Fraxinifolius* Under Irrigated Condition

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Abstract

Acrocarpus fraxinifolius seeds were collected from twenty mother trees growing in natural settings. The progenies were evaluated for their growth and development under irrigated conditions. FCRIAF2 exhibited superiority in growth by attaining 9.1 m height and 13.54 cm diameter and 0.67 m^3 in three years after planting. The fast growth rate of this species could be harnessed and introduced in marginal lands and small holdings to increase industrial wood supply from farmlands.

Introduction

The role of trees within landscapes has been given much attention recently, in contexts ranging from local watersheds to regional impacts and global cycles. As an example, trees, forests and reforestation are specifically identified as viable climate change mitigation measures by the Kyoto Protocol (IPCC 2000), but have also been identified both as carbon sinks and sources. It is evident that widespread and continuing deforestation has significantly reduced the extent of forests globally, in general, and across the tropics, in particular (FAO 2006). Increasing population pressure, and demand for both food and wood have led to the conversion of large areas of forest to agriculture, industrial, urban, and other uses reducing not only terrestrial carbon stocks, but also the supply of easily available wood. The resulting scarcity of fuelwood, timber for construction and wood for a huge array of industrial and commercial uses has imposed significant constraints on the rapidly growing rural societies and the national economies of many developing countries.

In developing countries like India, people's dependence on forests for their basic needs is inevitable (Ramachandran *et al*., 2005). The demand for wood is increasing every day, because of inadequate supply and ban on felling in the natural forests. The National Forest Policy (1988) suggested that the wood based industries have to make their own arrangements for the supply of raw materials. Concerted efforts were not taken to popularize the indigenous fast growing tree species having industrial utility, which will satisfy the raw material for wood based industries from farmlands. Hence, the importance of industrial plantations gained momentum across the country to meet the industrial needs.

Acrocarpus fraxinifolius is one of the fast growing native tree species, attaining a height of 30 m and a girth over 3 m. The wood is suitable for furniture, packing cases, pulp and plywood. Introduction of fast growing indigenous species in farm lands will improve the wood production outside the forests and could bring better returns to farmers. A conservative forest policy coupled with promotion of farmers/ industries linked plantation activities on under-utilized cultivable and marginal agricultural lands will help to mitigate the crisis (Pandey,2007).

Materials and Methods

Acrocarpus fraxinifolius seeds were collected from twenty mother trees growing in natural habitat of Nilgris and lower Palani hills based on their growth traits. Progenies of twenty mother trees were raised in nursery and six months old seedling progenies were planted in field at an espacement of 3 x 3 m in randomised block design. The experiment was conducted at Forest College and Research Institute, Mettupalayam (11°19' N, 77°56' E) with a mean annual rainfall of 920 mm, temperature range of 20 - 35 ^{0}C in an altitude of 300 M above mean sea level. The seedlings were irrigated one or two times a week based on weather conditions. Biometric observations Viz., tree height (m) and diameter at breast height (cm) were recorded in 12, 24 and 36 months after planting.

Results and Discussion

In one year of growth, *Acrocarpus fraxinifolius* expressed a mean height of 2.93 m and diameter at breast height of 4.27 cm. However, the progeny FCRIAF

15 recorded the highest growth in height with 3.49 m and the progeny FCRIAF 13 registered the diameter increment 5.35 cm at the highest side. In second year, FCRIAF 2 progeny exhibited a height and diameter growth of 6.41 m and 9.16 cm respectively, which is significantly higher than the mean values of 4.84 m for height and 6.00 cm for diameter growth.

The mean values for growth traits at three years of age in *Acrocarpus fraxinifolius* were 8.29 m, 8.34cm and 0.052 m^3 for height growth, diameter growth and volume respectively. The progeny FCRIAF 2 recorded the highest growth of 9.61 m height, 13.54 cm diameter at breast height and tree volume of 0.167 m^3, which proved significant superiority in growth behaviour consistently and consecutively in growth stages than other progenies as well as general mean. The furrow irrigation improved both the stem girth and plant height of trees in mango (Mattar, 2007), that root system tended to expand with the increase of amount of irrigation applied (Oliveira, 2001).

The increased availability of fuel and fodder and other benefits depend on the quantity of biomass a tree species can produce (James et al., 2008). In fact, when wood production is the major objective of the landowner, fast-growing tree species must use less water per m^3 of wood produced. Irrigation water needs are generally low during the initial growth stages, but increases exponentially during the vegetative phases.

Conclusion

The fast growth rate of indigenous species could be effectively harnessed for increased productivity. The fast growing trees when grown in farm settings under irrigated conditions could fetch higher returns to farming community and may address the raw material requirement of wood based industries to a certain extent.

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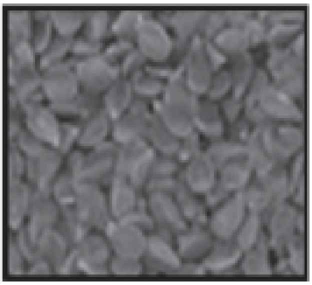
Table 1. Growth of *Acrocarpus fraxinifoliu*s progenies three years after planting

Name of the progeny	12 MAP		24 MAP		36 MAP		
	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Volume (m^3)
FCRIAF 1	2.46	3.66	4.70	7.72	8.18	9.35	0.103
FCRIAF 2	3.18	4.48	6.41	9.16*	9.61*	13.54*	0.167*
FCRIAF 3	2.64	4.16	4.06	4.51	6.98	6.19	0.023
FCRIAF 4	2.39	3.75	4.35	4.75	7.14	7.08	0.036
FCRIAF 5	3.30	4.88	5.44	6.80	7.69	9.26	0.053
FCRI AF 6	3.36	4.28	5.34	6.26	9.41	8.56	0.060
FCRIAF 7	2.75	3.93	5.04	5.37	8.14	6.86	0.040
FCRIAF 8	2.63	4.06	5.75	7.36	9.23	9.08	0.066
FCRIAF 9	3.13	4.70	4.29	7.35	9.39	10.06	0.105
FCRIAF 10	2.70	3.74	4.49	5.95	8.34	9.54	0.082
FCRIAF 11	2.81	4.39	4.16	3.85	5.54	5.67	0.021
FCRIAF 12	3.05	4.58	4.61	6.81	8.11	7.98	0.043
FCRIAF 13	3.43	5.35	4.50	5.47	9.40	10.33	0.087
FCRIAF 14	3.15	4.27	4.79	5.13	8.00	7.83	0.046
FCRIAF 15	3.49	4.77	4.90	6.31	6.73	9.02	0.059
FCRIAF 16	2.70	3.59	4.18	4.10	6.35	6.13	0.022
FCRIAF 17	3.06	4.38	5.06	6.99	8.95	8.93	0.069
FCRIAF 18	3.08	4.30	4.62	6.96	7.28	7.26	0.043
FCRIAF 19	2.79	5.29	4.43	5.15	8.43	7.31	0.039
FCRIAF 20	2.50	2.76	5.72	4.08	6.40	4.72	0.011
Mean	2.93	4.27	4.84	6.00	8.29	8.34	0.052
SEd	0.63	1.04	0.91	1.38	1.65	1.80	0.032
CD (0.05)	1.26	2.07	1.82	2.76	3.30	3.59	0.064
CD (0.01)	1.68	2.76	2.42	3.67	4.39	4.79	0.085

Growth of *Acrocarpus fraxinifolius*

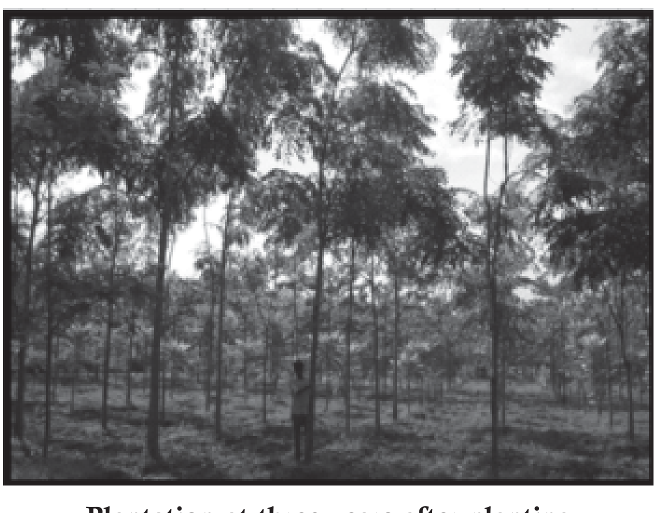


Seeds

Seedlings in nursery bed

Seedlings in nursery

Plantation at six months after planting



Plantation at three years after planting

Cultivation Technology For Sandalwood (*Santalum album L.*)

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Abstract

Sandal is a commercially and culturally important plant species belonging the family santalaceae. Sandal is considered is as one of the most valuable tree in the world. The sandal is known for its oil which is pronounced as the most famous East Indian sandal wood oil which is produced from the heartwood of sandal on distillation. The sandal wood oil has been known in the perfume industries for several century. The dwindling sandal genetic resources on one hand and the increasing demand on the other hand escalated the gap between demand and supply. Due to wider gap between the actual availability and the growing demand, the prices of sandal wood and the associated value added product have gone out steeply. This necessitated development of sandalwood plantation throughout agro and farm forestry but for want of suitable varieties and the associated management technology the achievement in the sandalwood promotion is dismally modest. Hence organized plantation development coupled with efficient supply chain is very essential and hence the current paper has been designed and presented for promotional activities.

Introduction

East Indian Sandalwood is a tree indigenous to India. Sandalwoods are also indigenous to India, Nepal, Bangladesh, Sri Lanka, Australia, Indonesia, Hawaii, and other Indo-pacific Islands. Sandal is considered is as one of the most valuable tree in the world. Sandalwoods have essential oils in the wood and roots that produce a distinctive fragrance that is highly valued (Kamondo, 2014).

The sandal is known for its oil which is pronounced as the most famous East Indian sandal wood oil which is produced from the heartwood of sandal on distillation. The sandal wood oil has been known in the perfume industries for several century (Srinivasan *et al*. 1992).

Besides perfume industry the sandal oil and powder obtained from sandal wood found multifarious utility in cultural and religious festivals coupled with the utility in wide range of medicinal use. Particularly in Asian Countries (Subasinghe 2013) such multifarious utility and the associated escalating demand in the global market both in perfumery industry and other utility. The demand for sandal is increasing but at the same time the supply from forests has almost been stopped which resulting in wider gap between demand and supply.

Due to this wider gap between the actual availability and the growing demand, the prices of sandal wood and the associated value added product have gone out steeply. This necessitated development of sandalwood plantation throughout agro and farm forestry but for want of suitable varieties and the associated management technology the achievement in the sandalwood promotion is dismally modest. This paper reviews the existing status and suggests the possibility of sandalwood promotion in the country.

There are 18 species of sandalwood distributed all over the world, out of which *Santalum album, S.yasi, S.spicatum* and *S.lanceolatum* yield fragrant oil of commercial importance. All the sandalwood species are identified as obligate wood hemi-parasites which means they absorb certain nutrients such as phosphates and nitrates from the host trees via root connections called haustoria (Subasinghe 2013). *S.album* produces the best fragrant material, and is one of the oldest perfumery materials and the powdered heartwood, upon distillation, yields East Indian Sandalwood Oil. The oil is highly rated for its fixative properties and for its persistent, heavy, sweet and woody odour (Arun Kumar et al 2012).

Ecology and Distribution of sandalwood in India

Hence among all species *Santalum album* is widely preferred by the growers and the dependent industries. India is housed with wide range of sandal trees naturally in deccan plateau and the western ghats. The total extend of sandal distribution in the country in around 9000 sq km and out of which nearly 8200 sq km is present only in two states viz., Karnataka and Tamil Nadu (Venkatesan et al 1995). These two states contribute over 85% of world production of sandal wood. In general, sandal is regenerated naturally in these two states but its commercial significance made this species introduced in other parts of the country. Sandal thrives best under rainfall ranged between 500 and 2000 mm and distributed between 650 and 1200 MSL altitude. The distribution in India state wise is furnished in table 1; fig1.

Sandal grows best with a rainfall ranges between 500-2000 mm and it is reported that good heart wood formation occurred in the rainfall ranges between 800 and 1000mm. the temperature requirement for the species range between 15° - 17° (Minimal) and 37° - 40° (Maximum). Sandal does not tolerate water logging and is a light demanding species but in early stage it seems to be shade bearer. Sandal grows very well in sandy clayey red lateritic loamy even in black cotton soil. But sandal very well grown in red ferruginous (iron) loam over laying on metamorphic rocks. The sandal also grows in rocky ground and stony or gravelly soils. But not suitable for calcareous conditions (Luna 1989).

Table 1. Distribution of sandal wood in India

Sl. No	State	Area
1.	Karnataka	5245 sq.km
2.	Tamil Nadu	3040 sq.km
3.	Andhra Pradesh	175 sq.km
4.	Kerala	63 sq.km
5.	Maharashtra	8 sq.km
6.	Orissa	25 sq.km
7.	Madhya Pradesh	33 sq.km
8.	Other States	8962 ha

Source: Srimathi et al 1995

Fig. 1. Distribution of sandalwood in India

Source: Srimathi et al 1995

Botanical Description

Sandal wood is botanically described as *Santalum album* L. and is a small evergreen tree distributed in dry deciduous forests. The tree attains the height of 12-13 meters under the girth of 100-240 centimeter. The tree has slender, Drooping and erect branching; Leaves or opposite and decussate with whirled arrangement. They are thin, ovate-lanceolate and glabrous. Bark is reddish or dark gray or nearly black, rough with deep vertical cracks. Flowers are purplish-brown, unscented and are axillary paniculate cymes. Flowers are tetra or pentamerous.the tree starts flowering even at the stage of 2-3 years and flowering occurs biannually from March to May and September to December. Fruit is the drupe, purple at maturity and the fruits are predominantly single seeded. The seeds are naked lack testa (Luna 1989).

Cultivation Technology

Seed source and seed trees selection

Seed source selection involves surveying areas with Sandalwood plants to identify potential populations for seed collection. Sandalwood in India is associated with other plant species such as; *Harrisonia abbysinica, Euclea divinorum, Lantana camara, Maytenus acuminata, Grewia similis* and *Dondonea viscosa* whose presence can be used as an indicator of occurrence of Sandalwood. A good seed source should have as many individual Sandalwood plants as possible from which to collect seeds. Sandalwood occurs in groups and therefore adjacent groups in one locality should be considered as one source.

In the selected seed source(s), select seed trees from which to collect seeds. In selecting seed trees, choose healthy and vigorously growing individuals. Avoid deformed, unhealthy, infected and young or over-mature trees.

Seed collection, extraction, processing and storage

Ripe fruits are hand-picked and dropped into a cloth or khaki bag. Where the tree is tall, a ladder should be used to reach the fruits. Never attempt to lower the high branches by pulling as Sandalwood stems and branches are brittle and break easily. Collected fruits should be handled with care, as the seed coat of freshly collected seeds is fragile and easily crushed.

Collected Sandalwood fruits should be extracted within 48 hours after harvesting. Seed extraction and processing involves: cleaning and sorting of fruits; depulping, floatation and drying; treatment to prevent fungal infection; and packaging and storage of the seeds.

Sandalwood seeds are rinsed in clean water and then immersed in water (floatation) to isolate empty seeds from filled seeds. Most empty fruits float and should be discarded while fruits with good seeds sink. The fruits that sink should be subjected to further extraction process that involves depulping, floatation and drying.

Without delay, extract Sandalwood seed by removing pulp surrounding the seed by gently squeezing or rubbing the fruits with hands to separate the seeds from the fleshy pulp while avoiding crushing the tender seed coat. Any pulp remaining on the seeds should be removed by spreading the seeds on a wire mesh (4 mm) and rinsing with water. The clean seeds are then immersed in water. The seeds that sink give the best grade while any floating seeds can be retained as lower grade seed. The floating seeds are scooped out and the water drained to retain the sinkers. The seeds are subsequently handled as different seedlots although subjected to similar treatment.

The seedlots are spread on wire mesh layered with wire gauze for airdrying for a period of about 24 hours. The seeds should be dried under shade. If drying is done in the open, ensure the seeds are not rained on.

Dried seed are dusted with fungicide such as carbendazim at 0.02% to control fungal infection during seed storage or after seed sowing. Appropriate packaging and storage maintains the quality and protects Sandalwood seeds until the time of sowing. Seed is packed in moisture tight polythene envelopes or in closed plastic containers. Packed seeds should be stored in cool dry cabinets or cupboards at room temperature. Sandalwood seeds can be stored in airtight containers in a cool dry place for up to a year without significant loss of viability.

Seed collection and treatment

Sandal is propagated predominantly through seeds. The seeds are to be collected from the identified plus trees preferably at the age of 20 years and above. The seeds are collected and soaked in water and are rubbed to remove the soft pulp. The depulped seeds are then dried and 1 kg seeds contain about 6000 seeds. The seeds exhibits initial dormancy for 3-4 weeks and after 4 weeks it starts germination which is about 80% under laboratory condition and 60% under field condition. The seed retain viability upto 9 months. The uniform and very good germination can be obtained soaking seeds with 0.05% gibberlic acid over night.

Seed germination

For germinating seeds, raised beds are prepared with 10 x 1 m size. The mother beds are raised with sand and red soil at 3: 1 and are thoroughly mixed with thimet at 500 g per bed. The treated seeds are soaked with carbendazim at 0.02% and around 2.5 kg seeds spread uniform over the bed. The seeds are covered with paddy straw and the mother bed to be watered two times daily for a period of 10 – 15 days. The germination starts from 4 weeks onwards and continue up to 7 – 8 weeks. The germinated seeds are at 4 – 6 leaf stage are picked out transplanted to the polybag containers of 15 x 25 cm size. The poly bags are filled with soil, sand and farmyard manure at 3:1:1 ratio. The sandal seedlings are transplanted along with host plant. Wide range of host plants viz., Casuarina, *Cajanus cajan*, Albizia, Amaranthus etc. are better suited for association. Necessary initial shade to be provided for 15 – 30 days and then the seedlings are placed in open nursery condition. Shifting is very essential for

Fig 2. Sandalwood Cultivation Technology Cycle

the plant to avoid root penetration. Pruning of host plant is also very essential and this pruning of host plant has to be done frequently which will ensure growth of sandal. All these nursery operation to be continued for about 9 – 12 months till the seedling attain 45-65 cm. Two feet old seedlings are amenable for planting in the field and ensure higher survival in the field.

Transplanting Sandalwood in the field

Selection of suitable sites

Sandalwood tolerates a wide range of soils so long as they are well drained but does not tolerate areas prone to water logging. Sandalwood should not be planted in areas prone to frost.

Land preparation

Complete ploughing or 1 m strip ploughing should be done before the onset of the rainy season. In case of bushy areas, complete slashing should be done before ploughing. Slashed material can be used as fuelwood and the remaining brush spread uniformly along the rows.

Staking

When Sandalwood is established as a plantation crop, stakes should be prepared in advance, at least a week before the onset of the rainy season. The stakes are used to mark the planting spots for pitting. During staking, The spacing recommended for sandalwood plantation 3 X 3 m. But several farmers are practicing wider planting of 4 X 4 m and 5 X 5 m in Tamil Nadu.

Pitting and planting

The pits of 30 x 30 x 30 cm (or) 40 x 40 x 40 cm (or) 60 x 60 x 60 cm are dug out depending of nature of soil. The pits are partially filled with soil mixture with neem cake 25-50 g / pits, Chlorpyrifos 2 g powder / pit and the 2 ft height seedlings are planted along with the host. The host in the polythene container can be maintained along with secondary host species. Sandal attracts or it has association with over 150 species (Luna 1989). Best association are found wide range of host viz., *Albizia*, *Terminalia, Lagerstroemia, Dalbergia, Anogneissus, Casuarina, Acacia nilotica, Pongamia pinnata, Wrightia tinctoria* and *Cassia siamea*.

Sandal is a hemi root parasite and hence planting host is very essential to meet the nutritutional requirement. Sandal establishes association with host haustorial connection which facilities drawing of nutrients.

Tending Operation

Soil working has to be done once in every six months around the trees radius of 50 cm during soil working periods application of farmyard manure particularly in farm land is preferred at 5 kg per plant per annum is preferred. The host plant needs to be pruned periodically otherwise they suppressed the growth. Sandal also needs to be pruned in order get clean bole and ensure maximum development of heartwood. Care should be taken while pruning sandal wood branches and it should not damage the plant which otherwise will attract pest and diseases.

Summary and Conclusion

Sandalwood is valued for its aromatic heartwood since time immemorial which resulted in ruthless felling of sandalwood population across the country. This has resulted in dwindling of elite genetic resources and the existing population is highly emaciated population. Hence several improvements programme have been made but for want of suitable technologies the achievement in this front is very low. The dwindling sandal genetic resources on one hand and the increasing demand on the other hand escalated the gap between demand and supply. Hence organized plantation development coupled with efficient supply chain is very essential and hence the current paper has been designed and presented for promotional activities.

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Survival and Initial Growth Response of Dhaman (*Grewia Tiliaefolia*) Under Controlled Irrigation System

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Abstract

A field experiment was conducted to study the growth of Dhaman (*Grewia tiliaefolia*) under drip irrigation system with the objective to promote precision farming. The biometric attributes *viz.*, height, basal diameter and no. of branches were estimated during time of planting and 3 months after planting. The preliminary growth information revealed that *Grewia tiliaefolia* exhibited highest growth with maximum height of 1.05 m, basal diameter of 2.02 cm and number of branches of 5 numbers in 3 months under drip irrigation. The field study is in progress and the growth performance will be evaluated with the objective to reduce the rotation and increase the yield.

Keywords: Biometric attributes, Drip Irrigation, *Grewia tiliaefolia*

Introduction

Water supply is a major constraint to crop production in world. Water demand for rapid industrialization and high population growth reduces water share for agriculture and plantation crops. The further scarcity of irrigation water for crop and trees production should be addressed for sustaining the food and wood supply through efficient water conservation and management practices even in high rainfall areas (Panda *et al.*, 2004). Moreover, the harvest per every drop of irrigation water should be enhanced while considering the best water use efficiency (WUE) associated with any crop. Optimum moisture level in the soil near the root zone of the crop is critical to agriculture and plantation crops. Drip irrigation is frequent application of water directly on or below the soil surface near the root zone of plants. Drip irrigation is one of the irrigation methods which can help to increase irrigation water potential and crop yield. Drip irrigation can be helpful if water is scarce or expensive because evaporation, runoff, and deep percolation are reduced and irrigation application efficiency is improved. Strategically deficit water supply through drip irrigation can save water and energy input. In general, water management assumes paramount importance to reduce the wastage of water (Almeida *et al.*, 2011). It is also necessary to increase the Water Use Efficiency (WUE) and ensure equitable water distribution.

Wood from forest is the world's major renewable commodity and the demand for *wood and* other forest products are in an increasing trend. The increasing growth rate of human population would likely to keep the demand for forest produce at a higher order. In order to bridge the widening gap, forest productivity has to be maximized to meet the increasing demand by adopting new area for plantations outside conventional forest area coupled with techniques to increase productivity. In this research paper an attempt is made to study the survival and growth response of trees species under the effect of drip irrigation.

Materials and Methods

The field experiment was carried out to investigate the effect on growth of Dhaman (*Grewia tiliaefolia*) under drip irrigation during the year 2016-17. The study was conducted at Forest College and Research Institute, Mettupalayam (11° 19' N and 77°56' E) with an altitude of 300 m above MSL and mean annual rainfall of 920.5 mm. The soil was loamy sand in texture, well drained, slightly alkaline in reaction (pH-7.87) and non saline (EC-0.20 dSm^{-1}).

Grewia tiliaefolia was planted with the spacing of 3m x 2m in potential scale and irrigated with drip irrigation system. The discharge rate of drippers was 2.0 liters/hour for one hour/day. The quantity of water irrigated is 12 liters/plant/week. The following biometric observations *viz.*, height, basal diameter and number of branches were recorded at the time of planting and 3 months after planting. The height and diameter increment was measured for the growth period of 3 months after planting.

Result and Discussion

Wood production from the forest plays an important role in economy development of a country. The population increase and the improved living standards of the people forcing the producers to produce maximum wood and NTFP based products for the next decades. The enhancement of production of the products from limited water availability can only be assured by using micro irrigation that to drip irrigation (Panigrahi *et al*., 2012). Drip irrigation has proved its worth resulting in higher yield with better quality produces in different wood and wood based products, besides saving substantial amount of irrigation water over surface irrigation (Panigrahi *et al*., 2008).

In *Grewia tiliaefolia* seedling height observed were 0.63 m and 1.05 m at the time of planting and 3 months after planting respectively (Table 1). Growth and production of peach trees were monitored with different forms of irrigation and result observed was higher water use efficiency, yield and larger trees growth under drip irrigation was compare than micro jet irrigation systems and furrow irrigation (Myres, 1988). On supporting the present result, maximum height increment in Casuarina was attained in drip irrigation at short interval (Wood *et al*., 1975). The basal diameter in *Grewia tiliaefolia* was 1.17 cm and 2.02 cm at the time of planting and 3 months after planting respectively (Figure 1). The increases in rate of irrigation have a significant increase in tree collar diameter and vigour (Narayanamoorthy, 2003). With 100 % irrigation water supply through drip system the yield of plantation trees was estimated to be 30 % more than the conventional ring basin irrigation. This may be due to better soil water environment in root zone because of reduction in bulk density and greater porosity due to drip irrigation (Gunduz *et al*., 2011). Drip irrigation registered superior performance in terms of growth indices (Plant height, tiller density, root biomass and total dry matter accumulation), physiological parameters (WUE, total chlorophyll, catalase activity and leaf malondialdehyde value), yield and its components along with increased water potential values (Kato *et al*., 2008).

Conclusion

Grewia tiliaefolia was performed well under drip irrigation system in farm lands and was proven with the increment in height and basal diameter. Drip irrigation was helpful in enhancing the water use efficiency and improved the growth in their early stages, which may reflect considerably in subsequent growth and development in tree crops at later stages.

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Table 1. Growth of Dhaman (*Grewia tiliaefolia*) under drip irrigation

Sl.No.	Parameters	At the time of planting	3 MAP
1	Height (m)	0.63	1.05
2	Basal Diameter (cm)	1.17	2.02
3	Number of Branches (Nos.)	2	6
4	Height Increment (%)	-	46.15
5	Basal Diameter Increment (%)	-	42.07

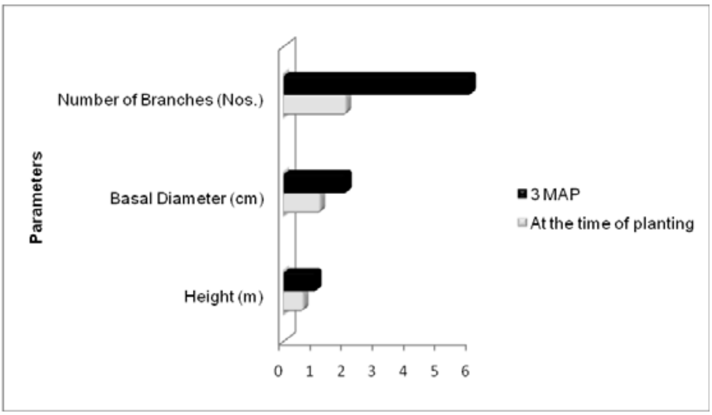

Figure 1. Effect of drip irrigation on *Grewia tiliaefolia* at early growth stage

Clonal Evaluation of Eucalyptus Genetic Resources for Pulping Quality

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Abstract

The tree farming is ecologically as well as economically more viable than traditional agriculture. Investment in tree plantations always remained relatively low in India, inspite of the fact that the existing forests cannot continue to meet our wood requirements. However, realizing the existing problem, the expenditure on afforestation has increased enormously from fifth five year plan onwards but still the results on the land are not encouraging and we have not been able to increase area as well as the forest productivity to the desired level. The misery caused to the entire nation due to unprecedented eco-degradation is enormous and warrants immediate remedial measures. To counteract the impending crisis, use of fast growing tree species managed with intensive cultural operations especially in tree farming have opened up new vistas in wood biomass production. Against this backdrop, the current study was planned to screen and identify superior genetic resources of *Eucalyptus* for higher pulp yield and wood volume.

Twenty seven clones in three Eucalyptus species viz., *Eucalyptus camaldulensis*, *Eucalyptus tereticornis* and *E. urophylla* were subjected for pulp quality analysis. The clone EC 48 has been characterized for wood quality towards its amenability for paper and biomass based power generation industries and the results are very encouraging. The clone expressed the Pulp yield of 48%, Kappa number 19.3 and Lignin content of 23.20% which expressed superiority over the local seed sources. Similarly, this clone expressed acceptable strength properties *viz.,* Burst index (5.0 K Pa m^2 g^{-1}), Tear (8.20 m Nm^2 g^{-1}) and Tensile index (80.0 Nm g^{-1}) which are again proved superior.

The wood characterization for energy properties indicated that the clone EC MTP 48 had higher Calorific value of 4314 kcal/kg, Fuel value index of 142.58 and Heating value of 30.27 $MJkg^{-1}$ and extend scope for its amenability towards biomass based energy utility. For biomass based energy utility, the clone can be harvested at the rotation age of 3 years and hence extend greater scope for High Density Short Rotation (HDSR) Energy Plantations.

The productivity studies revealed that three clones *viz.*, EC MTP 48, EC MTP 47 and EC MTP 41 recorded superiority in terms of growth characteristics viz., diameter at breast height, height and volume. The phenotypic and genotypic coefficient of variance estimates were low to high in range and volume recorded the highest PCV and GCV. The heritability values were high for all the traits investigated. Considering the pulp quality and productivity conjointly, the clone EC MTP 48 proved superior and this study recommends the suitability of EC MTP 48 for pulpwood plantation programme.

Key words: Eucalyptus, clonal evaluation, EC MTP 48, superior SRC.

Introduction

The Indian forests are in a grim situation today with total productivity of only 15 million m^3 of industrial timber and 195 million m^3 of firewood. The requirement of various woods in India by 2020 AD was projected to 437 million tons of fuel wood and charcoal, 37 million m^3 of industrial wood, 33 million m^3 sawn timbers, 5.7 million m^3 pulp and paper wood and 1.3 million tones of wood based panels (Parveen *et al.*, 2010).

In India, the pulp and paper industry is considered as one of the largest consumers of forest based raw material. The pulpwood is primarily consumed for paper and paperboard production followed by newsprint and rayon making. Application of paper is varied and one cannot think of a life without paper. The paper industry in India comprises of more than 813 mills producing nearly 14.99 million ton of paper, paper board and news print per annum and provides 0.5 million people directly and indirectly employment to 1.5 million people. For the past ten years from 2000 - 2010 paper consumption in India has grown at a compound annual growth rate of 9.93 percent (WWF, 2012). During 2011-

2012, the domestic production of paper and paperboard was 11 million tonnes against the consumption of 11.23 million tonnes (mt), a deficit of 0.23 mt. The total production accounts for 1.6 per cent of the world's production. The estimated turnover of the industry was approximately 30,000 to 35,000 crore. The production of paper industry is expected to cross 20 million tons by 2020 and 40 million tons by 2030 with an annual growth rate of 7 - 8 per cent (CRISIL, 2012). Per capita consumption of paper has increased from 5 kg to 13.2 kg per annum between 2003 and 2015 against the world average of 40 kg to 57 kg (MCI, 2015). An increase in consumption by one kilogram of per capita paper would lead to an increase in demand of one million tons.

There are limited options to meet the ever-growing wood demand either by increasing the total forest covers or increasing productivity of man-made forests substantially. The former happens to be an unachievable target and therefore, the reforestation to be carried out only with genetically improved planting material, which could easily be done either by developing artificial hybrids or clones with substantially higher productivity.

The genus *Eucalyptus* belongs to the family Myrtaceae and comprises about 700 species (Eldridge *et al.*,1993). In fact, it is one of the most valuable tree species, which is widely planted across the world due to its wide adaptability, faster growth and short rotation. Eucalypts many wood based industries particularly for pulp, paper, furniture, cellulose and poles as scaffoldings. It finds suitability as a feedstock for the production of cellulosic bio-fuels and production of energy from charcoal, which reduces emission of greenhouse gases. In fact, it sequesters about 10-14 tone of carbon ha per yr from planting to harvesting in fast growing tropical plantations. Furthermore, eucalypts have a positive net carbon balance when computing production of CO_2 used for energy from charcoal or as pulp and paper. Eucalypts remove CO_2 from the atmosphere at a rate of about 1.8 tone for every tone of dry wood and also generate O_2 at a rate of 1.3 tone for every tone of dry wood (Myburg *et al.*, 2006).

Millions of seedlings of *Eucalyptus* are being planted in India every year but the productivity has not been consummating with the expected yield basically due to poor quality of planting stock. On the other hand, significant improvement in yields has been achieved in many countries through application of breeding and genetic tools coupled with clonal forestry.

Hence, there is a need to identify and screen superior short rotation clone for pulpwood, which has the potential for high pulp recovery coupled with high productivity.

Material and Methods

Eucalyptus tree improvement programme was initiated during 2000 by introducing 135 seed lots from CSIRO Australia and the first generation evaluation was completed during 2005. The first generation evaluation identified 20 potential seed lots (Table 1) and from these base populations 20 plus trees (Clones) have been screened and characterized for pulp and energy quality coupled with their evaluation through clonal means. The clonal evaluation trial was established at Forest College and Research Institute, Mettupalayam using first generation screened 20 clones of three Eucalyptus species viz., *Eucalyptus camaldulensis*, *E. tereticornis* and *E. urophylla* and for comparision 7 local clones and 1 seed sources have been used. From each species, a billet of each 1 m length and 50-60 cm girth were collected, debarked and chipped separately and screened. The screened chips were used for pulping experiments. Some chips were converted into dust for proximate chemical analysis. Based on the initial screening study in the laboratory, the wood samples were subjected to analysis of physical and chemical properties. The pulping experiments were also carried out to find out its suitability for papermaking.

The physical characteristics such as bulk density, basic density and moisture content of wood chips are estimated. For the chemical properties analysis, the billets of individual tree species were chipped in pilot chipper; air-dried and converted into wood meal. The wood dust passing through 40 mesh but retained over 60 mesh was subjected to analysis for moisture, ash, hot water soluble, one per cent NaoH soluble, AB extractive, acid insoluble lignin, pentosans, hollocellulose as per TAPPI methods (TAPPI, 1980). The strength properties such as pulping, identification of kappa number, pulp brightness, paper sheet preparation, paper strength measurement, tensile strength, tearing strength, bursting strength measurement, black liquor analysis were analyzed as per standard method (TAPPI, 1980).

Twenty seven Eucalyptus clones were multiplied at the clonal complex using a coppice shoot cuttings obtained from selected clones. The existing seed source of Eucalyptus hybrid was raised through seeds and used for comparison. The clones and seed source were established in the field in a randomized block design with three replications. In each replication nine ramets/seedlings were used for the experiments. The data on height, diameter and volume index were periodically measured and analysed and the analysis of variance, ANOVA table alone with associated t test were conducted following the methods of Panse and Sukhatme (1978).

Pulp Wood Characterization of Eucalyptus Clones

Physical properties of wood chips

The results of the study indicated that the moisture contents of wood sample of all the clones were found to be ranged between 9.76 (EC MTP 47) and 10.90 (EU MTP 8). The bulk density (284 kg m-3) and basic density (542 kg m-3) were found highest in clone EC MTP 48 and lowest in clone EC MTP 41 (Table 2). It showed that increased density to be strongly linked to favourable strength, stiffness, hardness and working properties of sawn timbers, as well as pulp yield and paper making quality. The wood density of Eucalyptus pulp wood is possibly one of the most influential factors controlling the strength and several other physical characteristics of the paper sheet. It is relatively simple and inexpensive property to determine, even in unsophisticated environments. The bulk density exhibited wide variation and the maximum density was recorded by the clone EC MTP 48. This variation among tested clones and seed source may be due to the differences between early and late wood, which could have created variation between and within trees. Similarly significant difference was observed among Eucalyptus species in basic density, which ranged between 446 kg m^{-}3 (EC MTP 41) and 542 kg m-3 (EC MTP 48).The wood density properties are of major importance for the production of quality pulp and paper. The amount of wood needed to produce one tone of air dried pulp is calculated from the density and pulp yield (Storebraten, 1990). Persson (1975) found that differences in diameter growth have major impact on basic density of wood. Basic density is again highly correlated with late wood content (Bergstedt and Olsen, 2000). Similarly, the variability exhibited in most physical properties studied among different Eucalyptus clones in the current study also attests the results of earlier findings. But it is important to understand the exact relationship between wood density and other fibre characteristics of the test clones that have an effect on pulp and paper quality.

Chemical properties of wood chips

The proximate chemical analyses give an idea of potentiality of raw material for paper making. The chemical analysis in terms of ash content ranged between 0.32 (EC MTP 48) and 0.71 (EU MTP 1) (Table 3). The chemical investigation carried out in wood pulp of Acacia mangium recorded high ash content (Saepuloh, 1999). However, all the selected clones in the current study exhibited lower ash content, which thus lend a scope for utilization as improved pulp wood. The alcohol-benzene solubilities of wood constitute the waxes, fats and resinous matter. In the current study, the extractives were in the range between 1.1 (EU MTP 1, EU MTP 2 and ET MTP 29) and 1.4 (ET MTP 14, EC MTP 47 and EC MTP 48) and potential differences were recorded among the selected clones. Similar variation in alcohol benzene extractives were observed among various clones of *Eucalyptus tereticornis*, wherein the extractives ranged between 1.06 and 1.35 (Rao et al., 1999). Among the chemical properties, holocellulose is very important because it is a measure of total carbohydrate content of the wood (Tappi, 2001). The holocellulose constituting cellulose and hemicellulose is the major portion of fibrous raw material. The holocellulose content in the study ranged between 71.6 (S.O) and 75.2 (EC MTP 48) and other Eucalyptus species recorded in between these. The result indicated the superiority of EC MTP 48 over the existing seed source and other clones. The content of pentosans ranged between 13.0 per cent (EC MTP 47) and 18.5 per cent (S.O) and acid soluble lignin was found to be in the range of 23.0 per cent (EC MTP 47) to 25.7 per cent (S.O). The overall chemical analysis revealed that the clone EC MTP 48 is most superior among twenty seven clones, which could be preferred for commercial deployment for pulpwood plantation establishment.

Strength properties of wood chips

The strength properties of paper are directly associated with cellulose and inter fibre bonding. The clone EC MTP 48 recorded high holocellulose and low lignin content due to increased pulp yield and is good for interfibre bonding and pulp strength. Similar variations among tree species for various strength properties were also recorded in *Eucalyptus tereticornis* and *Eucalyptus grandis* (Patil et al., 1997). Within the species, the strength properties varied due to age but in the current study variation occurred among clones of same age which indicated the variation might be due to genetic differences. In the current study, satisfactory levels of strength properties was achieved even in five years of growth, which indicated that the clones tested in the current study could be harvested even in five years as against seven years of current practice by the state forest department.

The comparison of pulping results for yield and strength properties of clones of all the species revealed that EC MTP 48 is most superior compared to Control (S.O). Among the three species under test, *Eucalyptus camaldulensis* recorded higher strength properties compared to other two species. The strength properties viz., tensile index, tear index, burst index and specific coefficient were recorded superior values in EC MTP 48, EC MTP 47 and EC MTP 41. This might be due to superior fibre characteristic of these genotypes. This besides, the chemical requirement to achieve 20 kappa number in this species is only 17 per cent with normal chemical requirement and good bleaching response might also contributed for improved strength properties.

Among the strength properties, tearing strength depends upon fibre length, width etc. Hence, the maximum tearing strength, burst index and tear index in EC MTP 48, EC MTP 47 and EC MTP 41 must be due to superior fibre characteristics. Strength properties are best obtained with EC MTP 48, EC MTP 47 and EC MTP 41, which might be due to higher freeness and optimized kappa number (<20) recorded by the clones. The wood and wood properties are very important not only for production of paper but also the properties of paper (Storebraten, 1990). The pulp and paper property are highly dependent on fibre morphology and sheet forming processes. Wood with different properties give different pulp and paper qualities (Kibblewhite, 1989). However, in the current study, only dominated trees were selected which expressed wide variability. This indicated the genetic differences among clones of different Eucalyptus species.

Considering all physical, chemical and strength properties, all the trees subjected for analysis were found suitable as a source of pulpwood. However, considering the pulp yield and kappa number coupled with strength properties (Table 4), the superiority of the EC MTP 48, EC MTP 47 and EC MTP 41 as a source of pulpwood was evident and hence the above three clones are recommended for clonal deployment towards establishment of industrial wood pulpwood plantations.

However, the variation in physical, chemical and strength properties observed among the clones of three Eucalyptus species suggest that further improvement could be made via selection, breeding and further clonal deployment of outstanding individuals.

Productivity Studies

Genetically improved and fast growing clonal planting stock has revolutionized productivity and profitability of plantation of many species amenable to vegetative propagation (Lal, 2005). Clonal planting stock is true to type uniform and with all the superior desirable properties of the elite mother tree (Parthiban *et al*., 2004). It is absolutely necessary to ensure a wide genetic base of clones to safeguard against possible epidemics and to provide continuous superior genetic resources to meet the demands of wood based industries. The existing genetic superiority of elite trees should be evaluated through comparative trial in order to screen site specific clones with superior wood traits. Genetic improvement of the planting stock through clonal evaluation can play a very significant role in improving productivity, yields, quality of produce and profitability. Against this backdrop, clonal evaluation trial was carried out using twenty seven clones and one seed source as control. The clones differed significantly under field conditions during 12, 24, 36, 48 and 60 MAP for various growth parameters such as plant height, diameter at breast height and volume (Table 6).

The clonal evaluation trial indicated that one clone viz., EC MTP 48 expressed superiority in all four characters investigated followed by EC MTP 47 and EC MTP 41.Similarly, in *Eucalyptus tereticornis* four clones viz., ET12, ET9, ET1 and ET6 expressed superiority out of sixteen clones tested (Sasikumar, 2003). Similar results were also reported in the clonal evaluation trials of *Eucalyptus grandis* (Lambeth *et al*.,1994). Their study involving sixteen clones and seedling checks indicated that the clones had better yield, straightness and all other growth parameters compared to check lots of seed origin and also significant differences between clones. Vegetative propagation is excellent approach for development of clonal forestry programme (Vivekanandhan et al., 1997) and it helps to exploit non additive characteristics (Zobel and Ikemori, 1983). Similar genetic gain by exploiting clonal forestry approaches was also done in the hybrids clones of *Eucalyptus grandis* and *Eucalyptus urophylla*. The hybrid vigour was exploited through clonal forestry (Chopra, 2004), which thus lend support to the current investigation. The superiority of few clones in the current study might be due to the genetic that inherited from the selected mother trees. Hence, the three clones viz., EC MTP 48, EC MTP 47 and EC MTP 41, which expressed early superiority could be incorporated in the industrial wood plantation programme.

Considering the wood quality traits coupled with growth attributes the current study recommends clone viz., EC MTP 48 for incorporation in the ongoing plantation programme and also in the future breeding programme.

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Table 1. Biometric attributes of Eucalyptus seed source evaluation trial at 48 MAP

Species	Seed lot	12 MAP			24 MAP			48 MAP		
		Height (cm)	DBH (cm)	Volume (cm^3)	Height (cm)	DBH (cm)	Volume (cm^3)	Height (cm)	DBH (cm)	Volume (cm^3)
Eucalyptus urophylla										
EU MTP 1	17567/23	132.40	1.16	139.85	230.40	2.50	1130.40	504.40	4.35	7492.44
EU MTP 2	17567/20	107.80	1.07	96.88	215.60	3.45	2014.45	409.20	4.49	6475.87
EU MTP 5	17567/10	142.40	0.91	92.57	261.40	2.90	1725.72	519.80	4.59	8596.69
EU MTP 8	17567/4	93.80	1.01	75.11	183.00	2.07	615.55	433.00	3.29	3679.17
EU MTP 9	17567/19	102.80	0.91	66.83	205.80	2.36	899.79	382.00	3.12	2919.06
Eucalyptus tereticornis										
ET MTP 13	13399/JD954	135.39	1.18	147.99	392.60	2.23	1532.60	619.20	2.85	3948.12
ET MTP 14	16647	106.00	0.93	71.97	208.80	1.32	285.59	458.20	1.98	1410.12
ET MTP 24	13398JD930	110.00	0.66	37.61	262.80	1.78	653.64	488.40	2.44	2282.58
ET MTP 29	19960/K1320	148.00	1.03	123.26	333.60	2.25	1325.75	650.60	2.66	3613.66
ET MTP 31	19960/K1323	142.60	1.07	128.16	263.00	2.26	1054.49	558.40	2.74	3290.91
Eucalyptus camaldulensis										
EC MTP 41	18275/1387	119.40	0.60	33.74	360.80	1.39	547.23	436.60	2.35	1892.73
EC MTP 44	16551/JD1596	167.60	0.81	86.32	239.20	1.00	187.77	301.20	1.47	510.93

Species	Seed lot	12 MAP			24 MAP			48 MAP		
		Height (cm)	DBH (cm)	Volume (cm^3)	Height (cm)	DBH (cm)	Volume (cm^3)	Height (cm)	DBH (cm)	Volume (cm^3)
EC MTP 45	19965/24	131.80	0.49	24.84	245.80	0.71	97.27	341.00	1.22	398.42
EC MTP 47	16551/JD1595	135.60	1.12	133.53	281.40	1.39	426.80	325.80	1.33	452.40
EC MTP 48	16551/JD1597	163.00	0.88	99.09	424.60	2.93	2861.44	472.20	3.15	3678.04
EC MTP 50	19566/DL1843	129.60	1.07	116.48	325.40	1.19	361.73	258.80	1.51	463.22
EC MTP 53	19615/5090	188.00	1.48	323.26	333.80	1.87	916.30	384.00	2.43	1779.97
EC MTP 56	19566/DL1840	126.80	0.60	35.83	335.00	1.26	417.50	419.40	1.99	1303.78
EC MTP 57	19566/DL1841	141.00	0.63	43.93	316.80	1.30	420.28	454.40	2.10	1573.07
EC MTP 58	19615/5091	135.20	1.20	152.83	248.00	1.27	313.99	311.80	1.70	707.37

Table 2. Physical characteristics of different *Eucalyptus* clones

S. No.	Clones	Moisture content (%)	Bulk density (OD basis) (kg m^{-3})	Basic density (OD basis) (kg m^{-3})	Chips classification (%)				
					+ 45 mm	+ 8 mm (over thick)	+7 mm (accept)	+ 3 mm (pin chips)	-3 mm (dust)
1	EU MTP 1	10.49	260	499	Nil	6.1	80.1	13.2	0.6
2	EU MTP 2	10.76	270	510	Nil	5.9	78.5	14.8	0.8
3	EU MTP 5	10.02	224	461	Nil	7.1	81.2	11.3	0.4
4	EU MTP 8	10.90	230	455	Nil	5.7	80.4	13.5	0.4
5	EU MTP 9	10.10	235	473	Nil	6.4	75.3	17.6	0.7
6	ET MTP 13	11.20	230	455	Nil	5.5	76.8	17.2	0.5
7	ET MTP 14	10.61	249	469	Nil	6.2	77.8	15.4	0.6
8	ET MTP 24	10.34	210	477	Nil	8.3	79.6	11.8	0.3
9	ET MTP 29	10.47	236	452	Nil	5.2	80.9	13.5	0.4
10	ET MTP 31	10.91	238	484	Nil	4.6	81.5	13.4	0.5
11	EC MTP 41	10.22	234	446	Nil	6.5	82.6	10.1	0.8
12	EC MTP 44	9.93	224	480	Nil	5.1	78.6	15.7	0.6
13	EC MTP 45	10.12	246	460	Nil	4.9	79.2	15.2	0.7
14	EC MTP 47	9.76	270	510	Nil	4.4	82.8	12.4	0.4
15	EC MTP 48	9.98	284	542	Nil	6.5	81.8	11.3	0.4

S. No.	Clones	Moisture content (%)	Bulk density (OD basis) (kg m^{-3})	Basic density (OD basis) (kg m^{-3})	Chips classification (%)				
					+ 45 mm	+ 8 mm (over thick)	+7 mm (accept)	+ 3 mm (pin chips)	-3 mm (dust)
16	EC MTP 50	10.97	245	540	Nil	7.2	79.9	12.1	0.8
17	EC MTP 53	10.49	240	540	Nil	5.8	81.5	12.3	0.4
18	EC MTP 56	10.61	212	468	Nil	5.1	82.7	11.6	0.6
19	EC MTP 57	9.73	210	484	Nil	6.7	72.6	20.2	0.5
20	EC MTP 58	10.64	214	456	Nil	4.6	72.6	22.3	0.5
21	FC RI 3	10.53	238	475	Nil	6.8	78.9	13.5	0.8
22	FC RI 53	10.09	217	470	Nil	9.7	76.8	12.9	0.6
23	FC RI 56	10.88	242	455	Nil	8.9	78.4	11.9	0.8
24	FCRI 103	10.03	210	454	Nil	5.8	82.7	11.0	0.5
25	C 106	11.78	240	484	Nil	8.6	79.0	12.1	0.3
26	C 413	10.82	220	510	Nil	9.4	71.1	19.0	0.5
27	C 283	9.89	206	425	Nil	6.7	75.3	17.5	0.5
28	S.O (Control)	10.29	220	455	Nil	8.3	78.6	12.8	0.3

Table 3. Proximate chemical composition of different *Eucalyptus* clones

Sl. No.	Clones	Ash content (%)	Solubility in Hot water (%)	Solubility in 1 % NaOH (%)	Alcohol benzene extractive (%)	Acid insoluble lignin (%)	Pentosans (ash corrected)(%)	Holocellulose (%)
1	EU MTP 1	0.54	3.0	12.9	1.1	24.3	13.4	73.1
2	EU MTP 2	0.45	2.9	12.2	1.1	24.9	13.7	73.1
3	EU MTP 5	0.63	3.3	11.9	1.8	26.0	15.8	68.5
4	EU MTP 8	0.53	2.8	12.5	1.2	24.6	13.2	73.3
5	EU MTP 9	0.50	3.9	12.2	2.7	25.5	15.2	69.8
6	ET MTP 13	0.68	3.5	13.1	2.0	27.8	16.5	68.9
7	ET MTP 14	0.43	2.8	12.8	1.4	24.2	13.8	73.7
8	ET MTP 24	0.55	3.5	14.7	1.8	26.7	14.1	71.4
9	ET MTP 29	0.34	2.7	14.3	1.1	24.3	13.9	73.4
10	ET MTP 31	0.36	3.2	13.9	2.0	25.3	15.1	70.3
11	EC MTP 41	0.43	2.9	13.5	1.2	24.5	13.3	74.6
12	EC MTP 44	0.71	4.1	13.7	1.3	25.4	16.7	71.1
13	EC MTP 45	0.63	3.5	13.6	2.7	27.1	14.8	69.7
14	EC MTP 47	0.46	3.4	12.2	1.4	23.0	13.0	74.8
15	EC MTP 48	0.32	2.7	12.9	1.4	23.2	14.4	75.2

Sl. No.	Clones	Ash content (%)	Solubility in Hot water (%)	Solubility in 1 % NaOH (%)	Alcohol benzene extractive (%)	Acid insoluble lignin (%)	Pentosans (ash corrected)(%)	Holocellulose (%)
16	EC MTP 50	0.53	3.7	13.8	1.3	24.4	14.8	73.2
17	EC MTP 53	0.48	2.7	12.7	1.3	24.3	14.6	73.2
18	EC MTP 56	0.37	3.3	13.1	1.6	27.6	16.8	72.9
19	EC MTP 57	0.37	3.6	14.2	1.5	26.7	16.2	73.7
20	EC MTP 58	0.48	3.4	12.8	2.4	26.8	15.8	72.3
21	FC RI 3	0.36	3.2	12.5	1.6	27.7	15.2	71.1
22	FC RI 53	0.36	3.6	13.7	2.2	27.8	17.2	70.6
23	FC RI 56	0.63	3.7	14.7	2.1	26.4	17.5	72.8
24	FCRI 103	0.34	3.8	12.2	1.9	26.9	17.2	72.8
25	C 106	0.35	3.4	13.2	1.8	27.3	17.4	72.4
26	C 413	0.31	3.8	12.3	1.6	27.7	14.1	73.3
27	C 283	0.46	3.9	14.5	2.2	27.2	14.2	72.9
28	S.O (Control)	0.38	3.6	14.0	1.2	25.7	18.5	71.6

Table 4. Comparison of different Eucalyptus clones with respect yield and strength

Species	Chemical charge for 20 kappa	Unbleached pulp yield (%)	Strength properties at 300 ml CSF		
			Tear index (m Nm^2 g^{-1})	Tensile index (Nm g^{-1})	Burst index (K Pa m^2 g^{-1})
EU MTP 1	17	45.06	7.5	74.0	4.3
EU MTP 2	17	46.84	7.7	61.0	3.4
EU MTP 8	17	44.65	7.5	70.0	4.1
ET MTP 14	17	44.28	7.6	77.0	4.6
ET MTP 29	17	46.51	7.7	67.0	4.3
EC MTP 41	17	47.35	8.0	78.0	4.7
EC MTP 47	17	47.38	8.0	78.0	4.4
EC MTP 48	17	48.38	8.2	80.0	5.0
EC MTP 50	17	47.02	7.9	71.0	4.1
EC MTP 53	17	46.91	7.8	78.0	4.2
S.O (Control)	17	44.00	7.8	72.0	4.5

Table 5. Energy properties of EC MTP 48

S.No	Properties	Eucalyptus	*Prosopis juliflora*
1.	Calorific value (kcal/kg)	4314	4860
2.	Moisture content (%)	7.67	6.67
3.	Volatile matter (%)	69.25	68.17
4.	Ash content (%)	2.48	2.83
5.	Fixed carbon (%)	20.60	22.50
6.	Ash Fusion Temperature (%)	1267	1370
7.	Ash Deformation Temperature (%)	1143	1220
8.	Fuel value index	142.58	207.59
9.	Heating Value ($MJkg^{-1}$)	30.27	30.56

Table 6. EC MTP 48 Growth Parameters at different growth periods

Clones	12 MAP		24 MAP		36 MAP		48 MAP		60 MAP			
	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Volume (m^3)	Volume (ton/ha)
EU MTP 1	1.87	1.18**	4.25	3.16	6.43	6.50	9.14	9.37	9.44	10.38	0.0800	80.00
EU MTP 2	1.96	1.27**	5.48	3.21	8.46	7.85	10.33	10.33	11.46	11.43	0.1169	116.94
EU MTP 5	1.77	0.97	4.49	3.01	6.50	6.84	7.80	9.53	9.13	11.10	0.0864	86.42
EU MTP 8	1.79	0.86	4.27	2.51	5.93	5.57	7.97	8.63	9.10	10.00	0.0723	72.33
EU MTP 9	1.80	0.82	4.99	3.85*	7.37	8.92**	8.70	9.98	9.73	10.83	0.0868	86.80
ET MTP 13	1.73	0.81	4.70	4.07**	7.67	7.30	9.43	9.20	10.57	10.52	0.0893	89.31
ET MTP 14	1.87	0.95	5.73	5.37**	9.20**	8.14	9.31	9.88	10.39	10.71	0.0899	89.88
ET MTP 24	1.73	0.83	5.10	3.67	8.59	6.90	11.60**	9.17	12.56	10.50	0.1059	105.95
ET MTP 29	1.80	0.91	6.50**	4.03**	10.37	7.44	11.65**	10.29	12.73**	11.21	0.1210	121.00
ET MTP 31	1.73	0.73	4.10	3.86*	6.30	6.23	9.01	8.71	10.29	9.70	0.0747	74.74
EC MTP 41	2.03*	1.36**	5.23	3.51	8.13	7.11	10.60	9.77	11.68	12.01	0.1297	129.72
EC MTP 44	1.67	1.07**	5.33	2.38	10.37**	5.61	13.57**	8.39	14.60**	9.43	0.0996	99.58
EC MTP 45	1.70	0.94	4.63	4.18**	7.93	9.16**	9.67	11.08	10.61	12.06	0.1164	116.43
EC MTP 47	2.07**	1.19**	4.97	4.55**	9.77**	9.08**	12.05**	10.72	13.22**	11.84	0.1426	142.62
EC MTP 48	2.43**	1.34**	7.53**	4.12**	11.43**	8.57**	14.97**	11.59	15.69**	12.67*	0.1920**	192.03
EC MTP 50	1.93	0.94	6.43**	4.19**	9.87**	8.70**	12.84**	10.40	13.79**	11.25	0.1341	134.08

Clones	12 MAP		24 MAP		36 MAP		48 MAP		60 MAP			
	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Volume (m^3)	Volume (ton/ha)
EC MTP 53	1.80	0.96	6.70**	5.07**	9.17**	8.53**	11.43*	10.31	12.14	11.57	0.1229	122.95
EC MTP 56	1.77	0.77	4.83	3.61	9.27**	8.95**	12.57**	11.13	13.50**	12.18	0.1523*	152.34
EC MTP 57	1.73	0.81	4.50	3.84*	5.97	8.63**	8.57	11.20	9.60	12.63*	0.1168	116.81
EC MTP 58	1.70	0.90	4.05	2.92	6.02	8.80**	8.67	10.81	9.73	11.68	0.0999	99.90
FCRI 3	1.73	0.93	6.31**	2.80	9.34**	8.23	12.29**	10.59	13.33**	11.44	0.1359	135.92
FCRI 53	1.67	0.96	5.05	3.03	8.55	8.67**	11.30	11.17	12.40*	12.32	0.1461*	146.13
FCRI 56	1.87	0.91	5.42	3.13	9.48**	7.79	12.83**	10.53	13.73**	11.64	0.1420	142.04
FCRI 103	1.83	0.81	6.37**	3.04	9.40**	8.65**	11.84**	10.53	12.83**	11.67	0.1330	133.00
C 106	1.77	0.80	6.68**	2.94	9.31**	6.17	12.38**	9.47	13.43**	10.38	0.1087	108.76
C 413	1.73	0.83	5.41	3.19	9.80**	8.68**	12.18**	11.42	13.36**	12.33	0.1540	153.99
C 283	1.83	0.90	5.17	3.25	9.70**	8.27*	13.38**	10.32	14.64**	11.27	0.1420	142.00
S.O (Control)	1.57	0.71	4.01	2.58	6.64	6.05	8.69	8.81	9.72	10.08	0.0745	74.55
Mean	1.82	0.94	5.29	3.54	8.46	7.72	10.88	10.12	11.91	11.24	0.1166	116.65
SEd	0.08	0.02	0.24	0.14	0.24	0.27	0.23	0.87	0.25	0.68	0.0138	
CD (0.05)	0.17	0.04	0.48	0.29	0.48	0.54	0.47	1.75	0.50	1.36	0.0276	
CD (0.01)	0.22	0.06	0.65	0.38	0.63	0.73	0.63	2.33	0.67	1.82	0.1534	

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