Genetic Improvement of Teak in India for Growth and Timber quality

Dr Ashwani Kumar IFS
Director General, Indian Council of Forestry Research and Education, Dehra Dun
Forest in India

- India is the seventh largest country in the world. (Geographical area 328.73 million ha)

- 24.01% Forest/Tree cover. National Policy advocates 33.3%

- India is one of the 12 mega-diversity countries of the world which represent 8% of world’s biodiversity.

- Two global terrestrial biodiversity hot spots
  - the North-eastern States and the Western Ghats.

- About 45,000 Plant species occur in India, of which flowering plants account for 15,000 species.
24.01% of the total geographic area of the country is under forests and Tree cover (SFR 2013)

Against the goal of 33.33% as per national forest policy
India’s Forest

Total forest & Tree cover - 24.01%

- Total forest cover – 21.23%
- Tree cover (Tree patches >1ha & canopy >10%) -2.78%
- VDF - canopy density > 70%
- MDF – canopy density between 40% - 70%
- OF – canopy density between 10% - 40%

Source: FSI, 2013
ICFRE: The Institutional Journey

**Beginning of Scientific Forestry in India**

1. **1864**
   - Forest college with a research lab established in Dehra Dun

2. **1878**
   - New FRI building inaugurated

3. **1906**
   - FRI established with six research disciplines:
     1. Silviculture
     2. Working Plans
     3. Forest geology
     4. Botany
     5. Economics
     6. Chemistry

4. **1929**
   - ICFRE constituted under M o E F

5. **1986**
   - ICFRE has nine institutes and six advance research centers

6. **1991**
   - ICFRE constituted as autonomous organization

7. **2015**
   - Forest Research Institute University established in Dehra Dun
Forest Research Institute, Dehra Dun, India (Established in 1926)
• Teak is one of the most valuable timber yielding tree species in the world, used in ship and boat constructions, furniture and other constructional needs etc.

• Teak usually grows in 800-2500 mm rainfall regime and from sea level to an altitude of about 1200 m.

• It grows well in alluvial soils, fairly moist, warm, tropical climate with soil pH ranges from 6.5 to 7.5

• Teak occurs naturally in South and Central part of India. Rest of India (excluding Himalayas) it was introduced
Status of Teak in India

- India has the richest genetic resources of Teak in the world.
- Natural teak bearing forests: 8.9 m ha
- Plantations: 2.5 m ha
- Clonal seed Orchards: 1255 ha
- Seedling Seed Orchards: 393 ha
- Seed Production Areas: 5541 ha
- Annual planting target varies from: 30,000 to 50,000 ha.
- With Green India Mission (2015) additional 20,000 ha may be planted annually with Teak.
Status of Teak in India

• Distribution of Teak In India
  – Naturally occurring in peninsular and central part of India.
  – Below 24° N latitude (up to Jhansi in the North)
  – Introduced to rest of the country (Except hills)
  – Does not occur above 1200 M height
  – Grows from very dry to very moist conditions

• Teak Plantations
  – Oldest Teak Plantation at Nilambur, Kerala in 1842-46
  – About 44% of the global teak plantations are in India
  – Has emerged as a major agro forestry species
Extent of Teak Plantations In India

Major Teak Growing States

- Maharashtra
- Madhya Pradesh
- Karnataka
- Gujarat
- Andhra Pradesh
- Tripura
- Kerala
- Orissa
- Tamil Nadu

Area in ha
• More than 1 million m³ of Teak wood is imported annually in India at the cost of Rs 13000 million to meet the domestic demand

• Productivity can be increased significantly through clonal Plantation, using improved planting stock and silviculture

• In India Clonal plantation of Teak was not practiced on large scale, but now it is upcoming and has a great scope in increasing the productivity of teak.
Variation of Teak wood in India

- Teak from the Malabar Coast in India is preferred for ship and boat construction.
- Teak from Central Indian region is known for color, texture and grains preferred for furniture and other aesthetic needs.
- Teak timber from Seoni and Bastar are golden yellow in color.
- Teak timber of Chandrapur is well known in Indian market for its color and texture.
- Teak wood of Godavari valley (AP) used for furniture and cabinet making for its ornamental figuring.
- Teak timber from Rajulmadugu of Andhra Pradesh has pink colored heartwood which makes it highly valuable.
How to Improve Productivity in Teak Plantations?

- Using high yielding clones
- Using genetically superior seeds
- Using hybrids
- Selecting good site for Plantation
- Sound silvicultural practices
Clonal Forestry of Teak

Why Clonal Forestry?

• Clonal forestry increases the productivity significantly compared to seedling plantation.

• Significant gains can be achieved in shortest period of time.

• 2 to 4 fold enhancement of productivity has been reported in clonal plantation compared to seedling plantation.

• MAI up to 10 m³/ha/year has been achieved using superior clonal plants and improved silviculture.
Plus Tree Selection

Plus trees is a superior phenotype selected at a specific selection intensity (usually 1 : 500 to 5000) for growth, form and other desired parameters and are further deployed in breeding program or used for collecting improved seeds to meet immediate demand.
PLUS TREE SELECTION FOR CLONAL FORESTRY
The selected plus trees are felled and coppice shoots used for multiplication.
Rooted Coppice shoot cuttings
• A total of 41 plus trees of Teak were selected multiplied clonally and established a Vegetative Multiplication Garden (VMG)
• VMG is used for multiplication of clones for establishing Clonal plantation
Rooted Juvenile cutting of Teak
Multiplication of Teak clones
HARDEened PLANTS FOR FIELD PLANTING
Clonal Testing of Teak (10 month old) at Salem
CLONAL MULTIPLICATION OF TEAK

Clonal plantation
Selection of plus tree
• The average volume of a tree in the Teak plantation was 0.625 m³ / tree
• The average volume of the selected trees of Teak was 2.34 m³ / tree
• Therefore the productivity can be increased through clonal plantation by 2 to 4 fold.
Genetic improvement of Teak in India

- Teak tree improvement activities are going on in many countries in the world. In India it started in 1956
- The strategy and the program is unique to each country.
- Teak has a very high timber value.
- There is huge gap between the demand and supply of the teak wood
- It has been introduced to the other countries also, particularly Africa and Latin America, from where India is importing Teak wood
- Predominantly used for afforestation purposes, hence it is convenient to introduce the genetically improved quality planting material
Genetic improvement of Teak in India

- 4 to 6 percent gain is expected by collecting seed from phenotypically superior plus trees.
- Additional 6-8 percent gain is expected from progeny tested trees.
- Thus 10-14 percent cumulative gain can be achieved by simple improvement methods.
- Advanced breeding programs may yield larger gains but these methods are time taking and much costlier.
- Quality Planting material coupled with improved silvicultural operations and upkeep will result in very high percent gain.
- The strategy followed meet the challenge is two fold
  - Short time Strategy
  - Long term Strategy
Improved quality seed requirement

• On the average 30,000 to 50,000 ha of area has been annually planted with Teak.

• Under Green India Mission (Climate Change program) additional 5 million ha area will be afforested in 5 years staring 2015

• Another 5 million ha of degraded forest areas will be taken up for rehabilitation in next five years.

• It is expected that from this year onwards about 50,000 to 70,000 ha area will put under teak plantation annually.

• It is expected that about 4600 tons of quality seed will be required for raising plants to achieve this target

• How to meet this challenge of huge quantity of quality seed demand?
Teak Improvement program

- Quality seed production
  - To meet the immediate demand
  - Long term strategy

- Quality Planting material
  - Clone multiplication
    - Stump planting
    - Rooting of branch cuttings
    - Budding
    - Grafting
  - Tissue culture
  - Vegetative multiplication of quality seedlings
Establish Breeding populations

Rank families and trees within families

First thinning retaining best trees

Select Plus trees Natural Forests/Plantations

Grafting

Clonal seed orchard

Vegetative Multiplication Garden

Mass vegetative propagation

Seed

Progeny trial

Clonal trial

Commercial Plantation

Clonal evaluation: Productivity, tree form, key pests, diseases, clone matching to site, carbon sequestration potential, physiological parameters (WUE, NUE etc.)

Seeds

Elite Clones
Breeding Program of Teak

Base Populations

Natural / Plantations

Breeding Populations

Propagation Populations

Year 1
Select 400 Plus Trees and Establish Breeding population (Progeny trial)
Seed Production Area (Bulked seeds of plus Trees)

Year 10
Rank families and trees within families
First thinning retaining best trees
50 best families
Mass vegetative propagation
Multiplication Garden

Year 10
Second Thinning (SSO)
Clonal seed orchard 100 clones

Year 15
Collect seed from 300 trees for next generation's breeding population
Bulk seed

Year 16
Seeds from 100 Trees from Nat/Plan
Progeny trial
Commercial Plantation

Year 17
Establish second generation’s breeding population
Cuttings

1st Generation

2nd Generation
Vegetative propagation

- **Tissue culture of elite genotypes**
  - Success after plantation is generally low; cost high

- **Bud grafting**
  - Suitable for raising Clonal Seed Orchards

- **Wedge grafting**
  - Suitable for raising Clonal SEED Orchards

- **Rooting of Branch cutting**
  - Depending upon juvenility can be used for field planting or for raising CSO

- **Rooting of cuttings from juvenile plants**
  - Can be planted in the field

- **Stump planting**
  - Useful for field planting
• **Seed orchards**:
  Phenotypically superior selected teak trees are multiplied and are planted especially for the production of abundant superior seeds. This ensures mating between the selected genotypes.
  – Clonal Seed Orchards (CSO)
  – Seedling Seed Orchards (SSO)
  – Higher generation seed orchards

• **Hybrids**:
  To combine complimentary traits of two parents, to exploit hybrid vigor (heterosis)
CLONAL TEAK SEED ORCHARDS

- Clonal seed orchards (CSO) are established for production of genetically improved seeds
- Clones multiplied through grafting are used in the CSO
- Maximum gains are achieved in the shortest possible time
- Genetic base remains narrow
- Mosaic planting of clones
Bud grafted Teak plants – ready for plantation in the CSO
Clonal Seed Orchard of Teak, Walayar (kerala)
Challenges with Teak in India

- Low seed yield in Clonal Seed Orchard (CSO)
- Poor germination of seeds
- Less availability of quality planting stock for raising seed orchards
- Problem of flowering synchronization
- Low average productivity (2.85 m³ / ha / year)
- Narrowing of the Genetic base
Flowering variation among clones in CSO, Walayar
Compiled flowering records all clones and ramets in three CSOs for the last 8 years and categorized into different groups:

1. Consistently flowering
2. Irregular flowering
3. Regularly alternate flowering
4. Consistently non-flowering

Five Ramets of each clone were treated with paclobutrazol to induce flowering.
Problems in Clonal Seed Orchard (CSO) of Teak

- Low Seed production
- Walayar CSO: 8 to 11 kg / ha

Synchronization of flowering for hybridization

CSO Walayar (Kerala)
- Total No Clones : 20
- Flowering Clones : 14
Seed Filling and Germination in CSO

Poor Germination
4 to 10% Germination

High level of seed emptiness

Seed Filling:
Empty Fruits: 23%
One seeded: 52%
>1 seeded: 25%

CSO is not Meeting the Planting Target

- The reasons for low seed production may be due to Physiological, Environmental or Edaphic factors which is not clearly understood
Seed Production Areas

• Used as interim measure to obtain improved quality seeds, till more intensively material is available from seed orchards.

• Poor phenotypes are rouged from the stand and good trees are left to interbreed.
Teak-Seed Production Area – Lakhimpur kheri (UP)
Teak Tree with prominent knots in Campbell’s plot
Twisted wood of Teak – A highly heritable trait
Seedling Seed Orchard, TFRI Jabalpur
Raised from progenies of Plus Trees
<table>
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<tr>
<th>State</th>
<th>C S O ha</th>
<th>Seed Qty Kg</th>
<th>S S O ha</th>
<th>Seed Qty Kg</th>
<th>S P A ha</th>
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<td>Total</td>
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<td>393</td>
<td>15720</td>
<td>5541</td>
<td>277050</td>
<td>311595</td>
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</table>
Genetic Diversity in 10 teak populations

Mean Genetic Diversity between the 10 populations is as follows
Genetic diversity between population: 0.20

High genetic diversity within the populations compared to average values for long lived perennial woody plants.
Genetic diversity within population: 0.78

Genetic Diversity in 10 teak populations
<table>
<thead>
<tr>
<th>Progeny Trial</th>
<th>Parents</th>
<th>Height</th>
<th>Diameter</th>
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<tbody>
<tr>
<td>Chandrapur (MS)</td>
<td>A-21</td>
<td>0.12</td>
<td>0.67</td>
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<td></td>
<td>A-16</td>
<td>0.93</td>
<td>0.77</td>
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<td></td>
<td>A-35</td>
<td>0.44</td>
<td>0.74</td>
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<td></td>
<td>A-17</td>
<td>0.21</td>
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<td></td>
<td>ORPUB-1</td>
<td>0.68</td>
<td>0.17</td>
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<td></td>
<td>ORPUB-5</td>
<td>0.70</td>
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<td>16 year old</td>
<td>ORPUB-23</td>
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<td>0.15</td>
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<td>ORPUB-26</td>
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<td>0.02</td>
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<td>ORPUB-29</td>
<td>0.28</td>
<td>0.60</td>
</tr>
<tr>
<td>Dhandatopa (Orissa)</td>
<td>ORPUB-23</td>
<td>0.50</td>
<td>0.15</td>
</tr>
<tr>
<td>12 year old</td>
<td>ORPUB-26</td>
<td>0.26</td>
<td>0.02</td>
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<td></td>
<td>ORPUB-29</td>
<td>0.28</td>
<td>0.60</td>
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Progeny Trials of Teak (TFRI, Jabalpur)
## Analysis of Progeny Tests of Teak

<table>
<thead>
<tr>
<th>Progeny Trials</th>
<th>Age of trial</th>
<th>No. of half-sib families</th>
<th>Heritability (NS)</th>
<th>Genetic Gain (%)</th>
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<td></td>
<td>Height</td>
<td>DBH</td>
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<tr>
<td>Chandrapur (MS)</td>
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<td>9</td>
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<tr>
<td>Dhandatopa (Orissa)</td>
<td>12 years</td>
<td>27</td>
<td>58.00</td>
<td>26.00</td>
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</table>

Source

Genetic Diversity in Indian Teak
Population genetics & Genetic diversity studied in populations of *Tectona grandis* through ISSR markers

Populations studied – 29
Markers used – Inter simple Sequence Repeats
Origin of populations – A.P., Kerala, Karnataka, M.P., Maharashtra, Orissa, Rajastahan, Tamilnadu

<table>
<thead>
<tr>
<th>Total gene diversity</th>
<th>Gene diversity within populations</th>
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<tr>
<td>0.32</td>
<td>91 %</td>
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</table>

Agroforestry Models developed by ICFRE

- Agri-silvicultural models (Teak + casuarinas with agricultural crops like maize, cotton, turmeric, tomato and chilly)

- Agri-silvi-horticulture model (Teak+coconut with agricultural crops like turmeric, vegetables, maize and cotton) and Silvi-horticulture model (Teak-Gauva, Annona) (George, 2000).
Teak in Agroforestry System in Tamil Nadu

Teak-black gram Agro-forestry
Rooted Tissue Cultured Teak plant in liquid media, ready for hardening
Conservation of Genetic Resources

- India has a rich repository of Teak genetic resources.
- Within provenance variability is much more than between the provenances.
- Major growth characters have reasonably high heritability and subsequently high genetic gains.
- A National Teak Germplasm bank has been established at Chandrapur in Maharashtra as an attempt to *ex situ* conservation of the genetic diversity of Teak in India.
- Vegetative propagation techniques will have to be further refined to bring down the cost of plantlet production on commercial scale.
National Teak Germplasm Bank Chandrapur Maharashtra
Way Ahead

Establishment of Teak Institute

- At national Level: Chandrapur, Maharashtra
- At International level: ??

The Teak tree improvement program need to be vigorously continued further. So far less than 10% of the quality planting material is available from the improved sources. With the start of Green India Mission the demand for quality planting material is going to double.

Even there is need to establish 2\textsuperscript{nd} and higher generation of seed orchards in order to capture further gains leading to higher economic benefits to the agro-forestry farmers as well as Forest Corporations.

Capturing hybrid vigor through hybridization is an other area of potential genetic gains. So far it has been deployed on limited scale only in India.
THANK YOU
Gains achieved

1. From clones
2. Improved seeds from Clonal Seed Orchards (CSO)
3. Quality Seeds from Seed Production Areas (SPA)
4. Seeds collected from Plus Trees
4. Hybrids
Teak trial with Improved planting stock of Teak at Nilambur (Kerala)
• The first teak plantation in India was established in 1846 at Nilambur

• Teak is also planted in Indonesia, Sri Lanka, Vietnam, Malaysia, East and West Africa, The Caribbean, South America (Brazil) and Central America (Costa Rica).

• The global teak plantations are estimated to be three million ha with major share in India (44%) followed by Indonesia (33%).
Scheme of implementation

- **SELECTION**
- **BASE POPULATION**
- **INFUSE POPULATION**
- **HYBRIDIZATION**
- **BREEDING POPULATION**
  - PROPAGATION POPULATION (seed orchards)
  - PRODUCTION POPULATION (plantation)