

Genetic Improvement of Teak in India for Growth and Timber quality



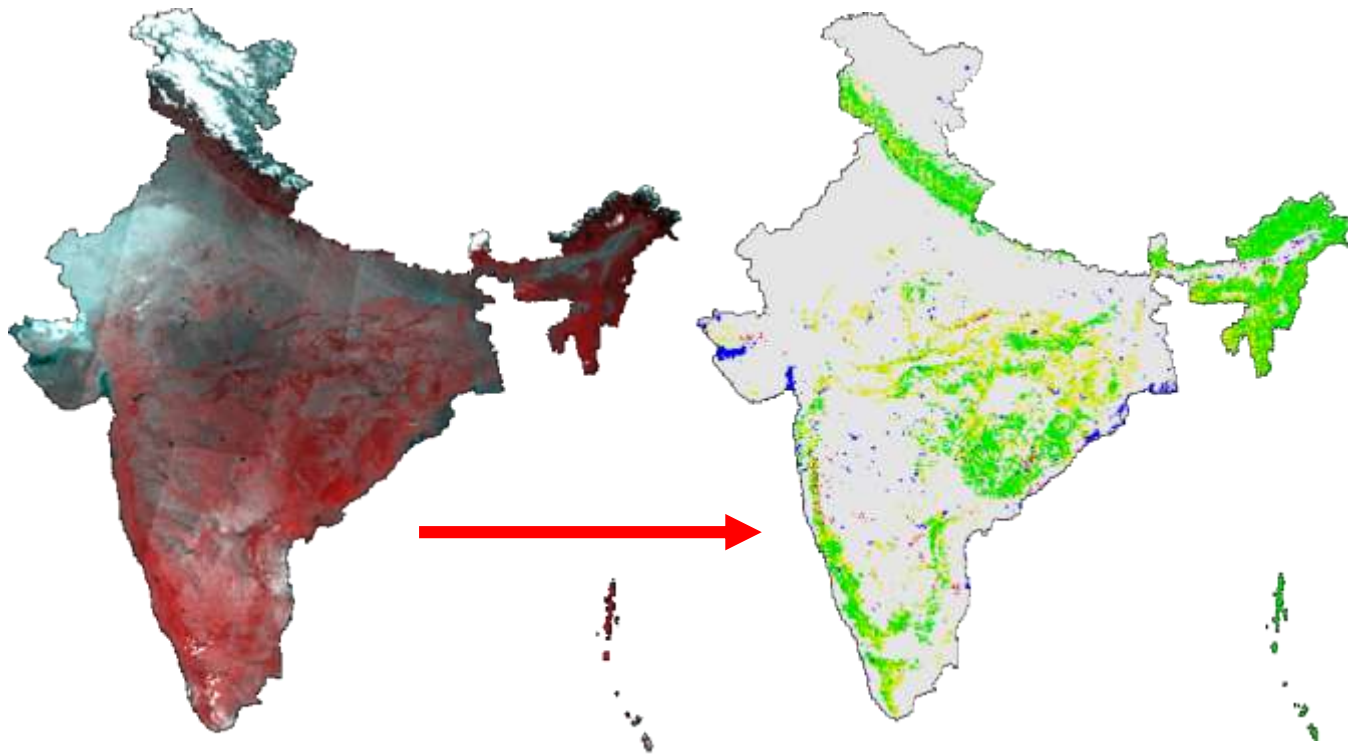
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Forest in India

- **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.**

Forest / Tree Cover in India



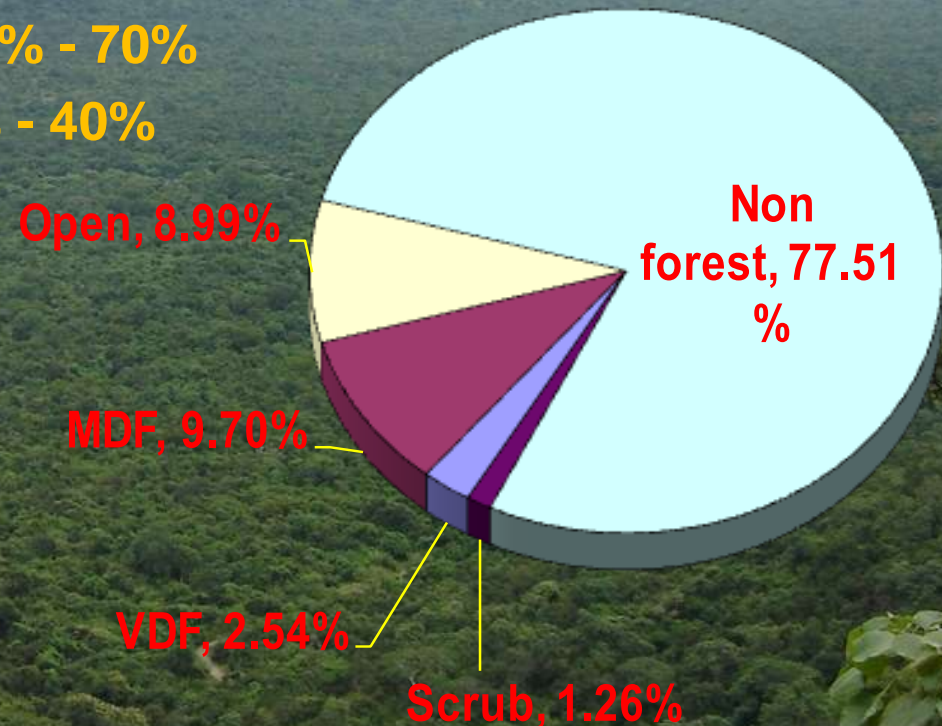
**24.01% of the total geographic area of the country is
under forests and Tree cover (SFR 2013)**

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

1864

1878

1906

New FRI building inaugurated

1929

ICFRE constituted under M o E F

1986

ICFRE has Nine Institute and 6 Advance Research Centers

1991

2015

Forest college With a research lab established in Dehra dun

FRI established with six research disciplines –

- 1. Silviculture**
- 2. Working Plans**
- 3. Forest geology**
- 4. Botany**
- 5. Economics**
- 6. Chemistry**

- 1. ICFRE constituted as autonomous organization**
- 2. Forest Research Institute University established Dehra dun**

Indian Council of Forestry Research and Education





Forest Research Institute, Dehra Dun, India (Established in 1926)

Teak

- 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**

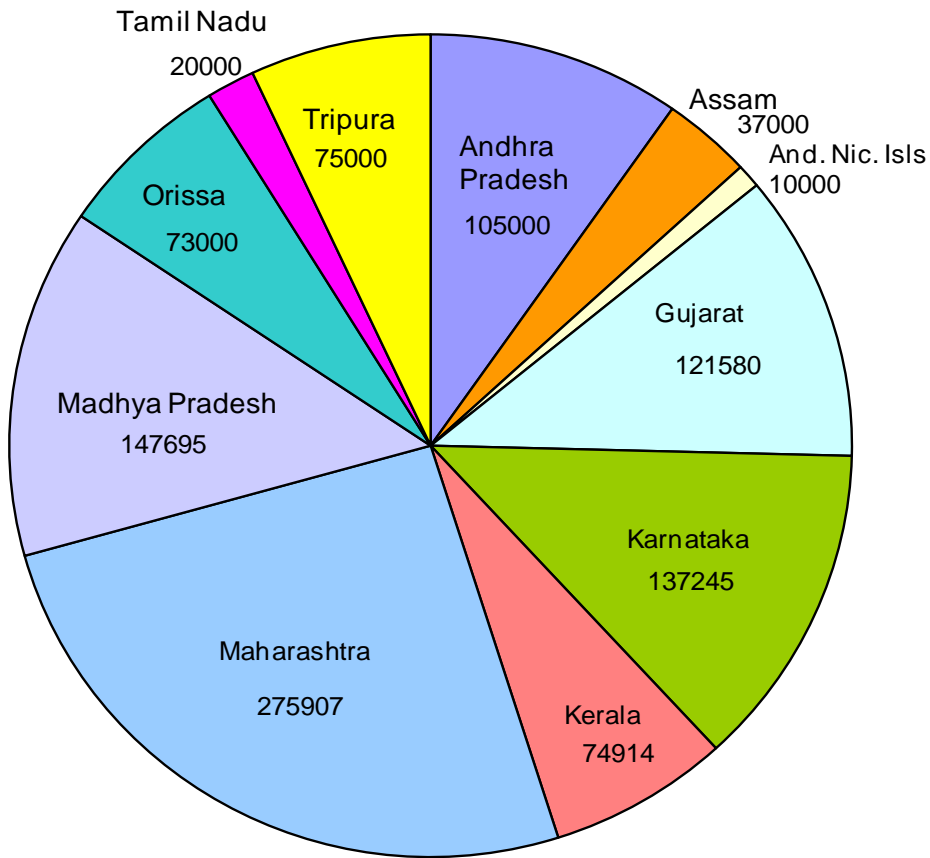
Status of Teak in India

- **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

Distribution of Teak in India



Extent of Teak Plantations In India



Area in ha

Major Teak Growing States

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

- **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



Coppice shoots



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





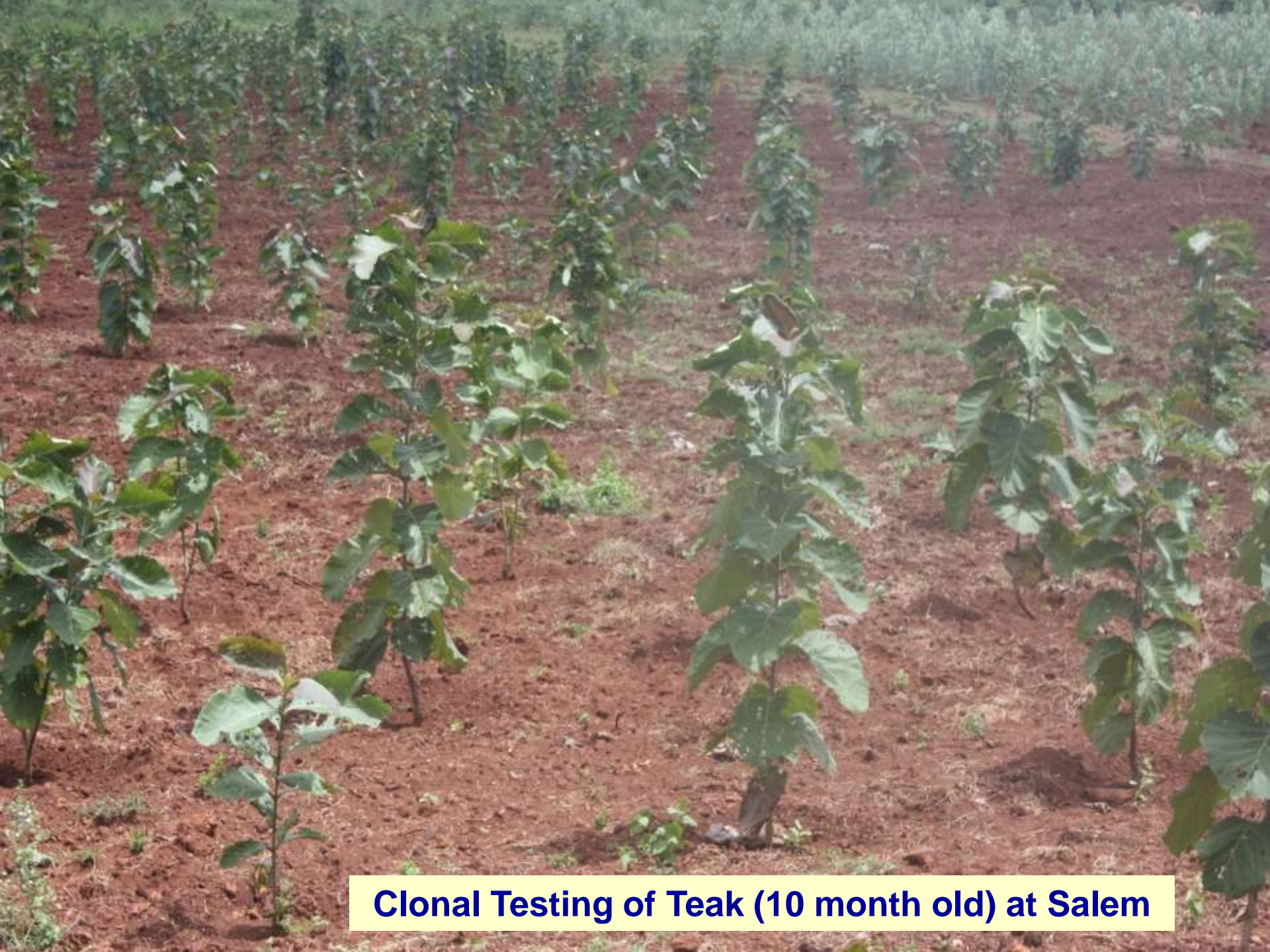
Rooted Juvenile cutting of Teak

Multiplication of Teak clones



HARDENED PLANTS FOR FIELD PLANTING





Clonal Testing of Teak (10 month old) at Salem

CLONAL MULTIPLICATION OF TEAK





Expected Gain Through Clonal Plantation

- The average volume of a tree in the Teak plantation was $0.625 \text{ m}^3 / \text{tree}$
- The average volume of the selected trees of Teak was $2.34 \text{ m}^3 / \text{tree}$
- 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 starting 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 be 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

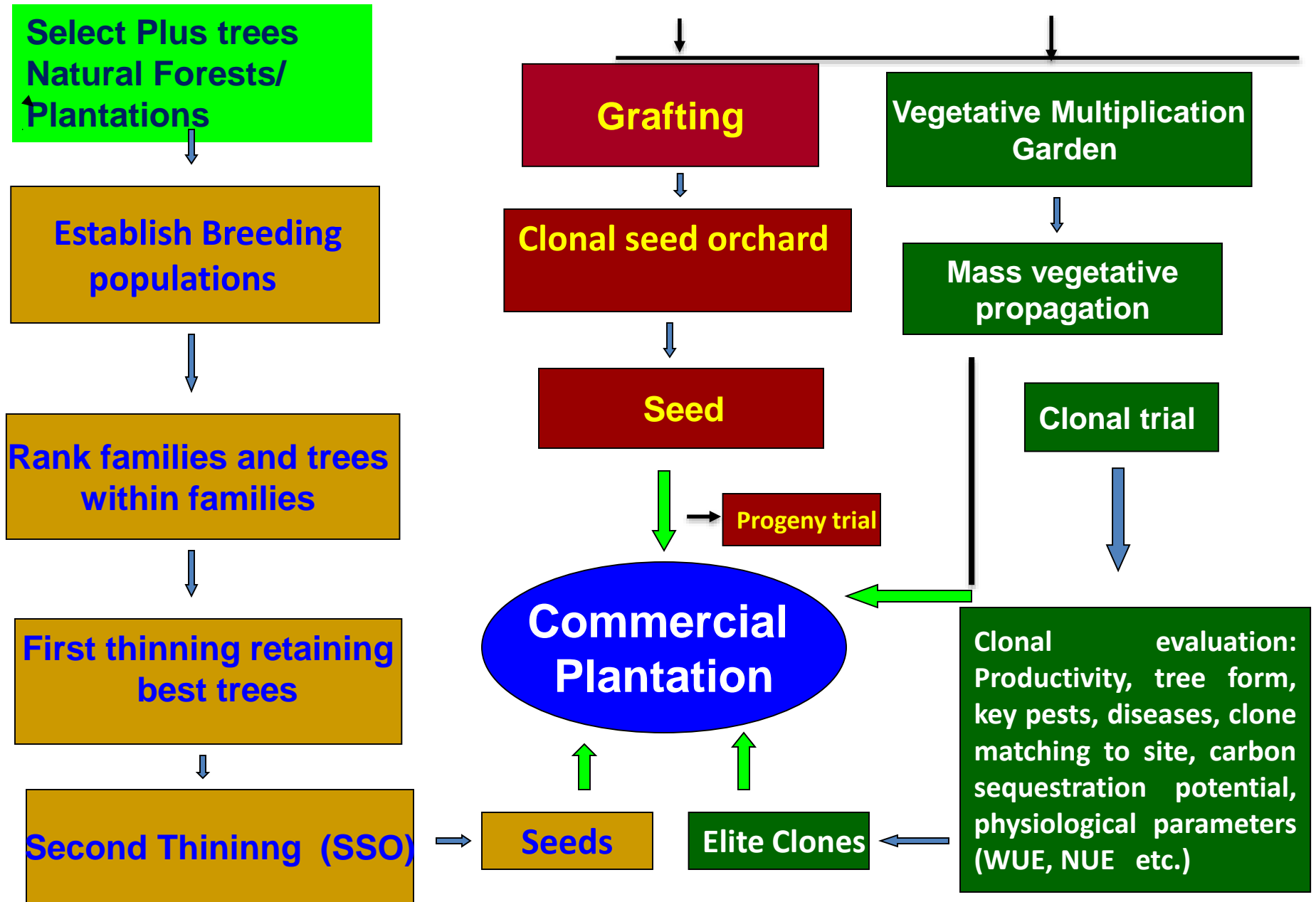
–Quality seed production

- 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

Tree improvement Program for Teak



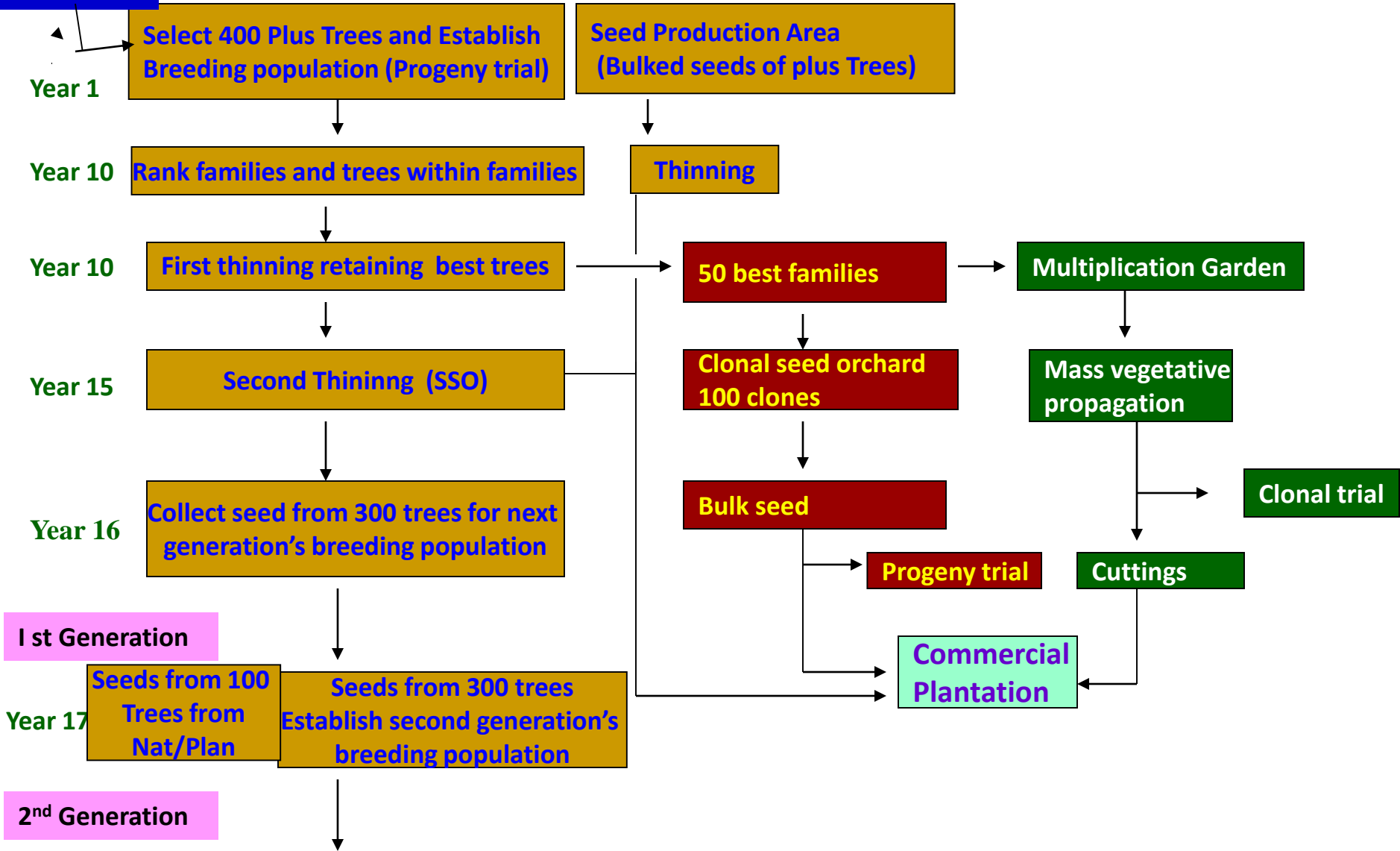
Breeding Program of Teak

Base Populations

Breeding Populations

Propagation Populations

Natural / Plantations



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**



MVC-287F.JPG

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



Flowering clone

Non-flowering clone

Assessment of Clones for Imposing Treatments to Induce Flowering

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



A 17 year old teak CSO



Non-flowering clone



Flowering clone

Problems in Clonal Seed Orchard (CSO) of Teak



CSO Walayar (Kerala)

- Total No Clones : 20
- Flowering Clones : 14

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

**Synchronization of flowering
for hybridization**

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)



MVC-295F.JPG

**Clonal Seed Orchard Wedge grafting (Teak) Campierganj, Uttar Pradesh
(YOE 1965)**



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

State	C S O ha	Seed Qty Kg	S S O ha	Seed Qty Kg	S P A ha	Seed Qty Kg	Total seed Kg
Tamil Nadu	187	2805	36	1440	53	2650	6895
Andhra Pradesh	85	1275	34	1360	689	34450	37085
Karnataka	120	1800	42	1680	464	23200	26680
Madhya Pradesh	240	3600	45	1800	1360	68000	73400
Maharashtra	450	6750	62	2480	749	37450	46680
Kerala	35	525	28	1120	1337	66850	68495
Oddisha	30	450	36	1440	217	10850	12740
Uttar Pradesh	10	150	18	720	125	6250	7120
Uttrakhand	6	90	12	480	25	1250	1820
N E states	35	525	—	—	—	—	525
ICFRE Institutes	38	570	70	2800	358	17900	21270
Assam	3	45	—	—	64	3200	3245
Gujrat	16	240	10	400	100	5000	5640
Total	1255	18825	393	15720	5541	277050	311595

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**

Source: Kumar A, M.G. Gogate, Rajesh Sharma and A.K. Mandal, 1997. Genetic evaluation of teak clones of Allapalli region, Maharashtra. The Indian Forester. Vol. 123(3): 187-189.

Genetic Diversity in 10 teak populations



General combining ability of parents for different characters

Progeny Trial	Parents	Height	Diameter
Chandrapur (MS) 16 year old	A-21	0.12	0.67
	A-16	0.93	0.77
	A-35	0.44	0.74
	A-17	0.21	0.80
Dhandatopa (Orissa) 12 year old	ORPUB-1	0.68	0.17
	ORPUB-5	0.70	0.88
	ORPUB-7	0.92	0.50
	ORPUB-8	0.35	0.09
	ORPUB-9	0.32	0.91
	ORPUB-18	0.48	0.24
	ORPUB-19	0.99	0.72
	ORPUB-20	0.76	0.38
	ORPUB-23	0.50	0.15
	ORPUB-26	0.26	0.02
ORPUB-29	0.28	0.60	



Progeny Trials of Teak (TFRI, Jabalpur)

Analysis of Progeny Tests of Teak

Progeny Trials	Age of trial	No. of half-sib families	Heritability (NS)			Genetic Gain (%)		
			Height	DBH	Basal Area	Height	DBH	Basal Area
Chandrapur (MS)	16 years	9	84.00	35.00	37.00	23.35	3.52	7.45
Dhandatopa (Orissa)	12 years	27	58.00	26.00	26.00	34.46	20.97	4.19

Source

D. Swain, S.C. Mohanty, Rajesh Sharma, A.K. Mandal and B.N. Gupta, 1996. Preliminary analysis of quantitative characters in teak. Proc. Indian Natn. Sci. Acad. B62: 169-172

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, Rajasthan, Tamilnadu



Total gene diversity	Gene diversity within populations
0.32	91 %

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).

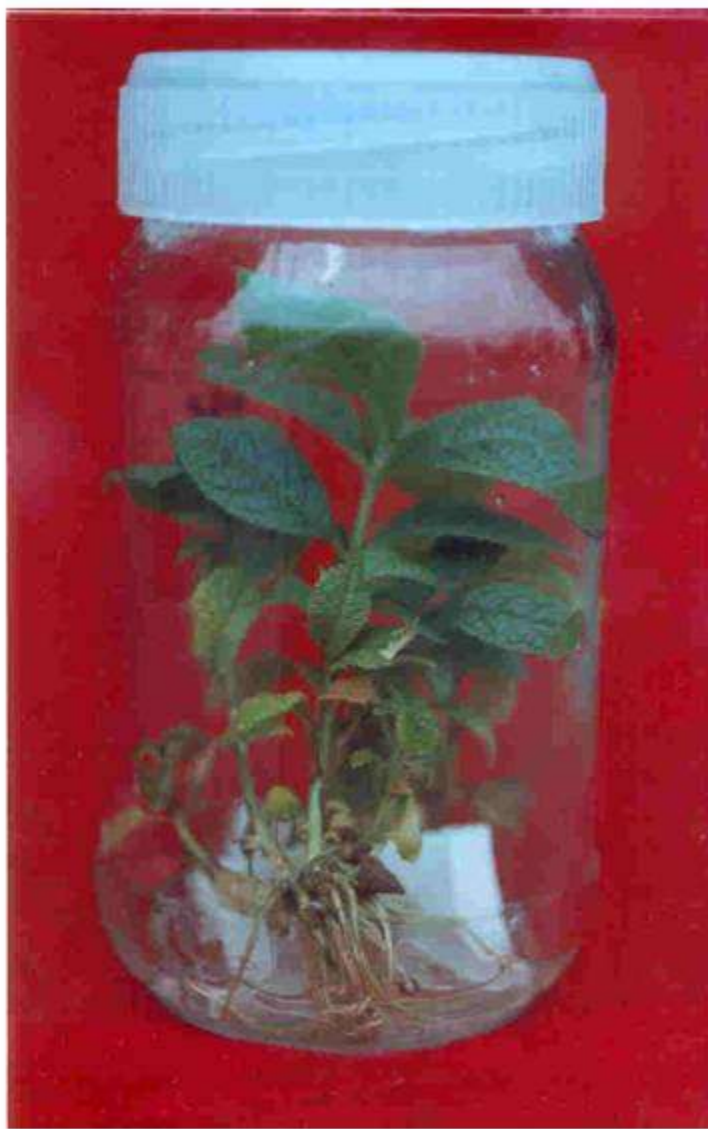
Teak in Agroforestry System in Tamil Nadu



Teak-black gram Agro-forestry

MICROPROPAGATION OF TEAK





**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 2nd 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

