

Forest Genetic Resource Management and Tree Improvement



Research on the evaluation, utilization and conservation of forest genetic resources (FGR) is essential for deriving products and services desired by different stakeholders having interest in these resources. Expectedly, FGR and its exploitation through tree improvement is given high priority by all the Institutes. This Chapter describes current status of research work involving selection, testing and breeding of different tree species involving FGR. Tree crops fulfilling various industrial, environmental and livelihood requirements in different parts of the country are being subjected to genetic improvement for increasing the productivity. Genetically improved and high yielding planting material of species like *Acacia*, *Bamboo*, *Casuarina*, *Eucalyptus*, *Melia*, *Neem*, *Sandal*, *Shisam* and *Teak* have already been made available to different stakeholders like farmers, wood-based industries and forest department.



5.1 Conservation of Forest Genetic Resources

Germplasm collection, evaluation and planting of Karanja for improved productivity and higher oil content (FRI)

Pongamia pinnata (Karanja) is a potential bio-fuel species, which could even be used for cooking, lighting of lamps, as a lubricant, water-paint binder, pesticide and for tanning. 312 candidate plus trees in the states of Punjab, Haryana, Uttar Pradesh and Uttarakhand have been selected based on growth and seed production of which, 95 were designated as plus trees, based on high oil content. Pod, seed and oil content characters showed significant differences among the accessions. The heritability were recorded to be higher than 60 per cent for all the traits which indicated that the economically important traits are under fairly strong genetic control making them amenable for selection and breeding. Oil content was the highest in accession 81 (41.4%) and such high yielding genotypes have been planted at various locations to reconfirm their performance in terms of growth as well as seed production and also to evaluate stability. The field evaluation will be continued to select and release genotypes with exceptionally high oil-yielding capacity for commercial cultivation.

Benefits of the research : Superior germplasm of Karanja was identified. Selected genotype of Karanja may be used in establishment of high oil yielding Karanja plantations.

Population genetic analysis of *Dendrocalamus hamiltonii*, a commercially important bamboo species (FRI)

Fifty five bamboo-based SSR primers have been synthesized and screened for their transferability in targeted species. Out of these, 30 primers were positively amplified in *Dendrocalamus hamiltonii* (Bans) and 15 were polymorphic. In total about 450 leaf samples belonging to 19 populations have been collected from the natural range of distribution in Assam, Mizoram, Arunachal Pradesh, Nagaland and Meghalaya for population genetic analysis. Genomic DNA of all the samples has been extracted, quantified and dilutions were prepared. Three polymorphic SSR primers have so far been used to screen 12 of the 19 populations sampled.

Benefits of the research : Genetic analysis of bamboo may be useful in planting stock improvement programmes.

Establishment of second generation seed orchards of *Eucalyptus* (Safeda) and selection of clones for high productivity in *Eucalyptus* (IFGTB)

Growth data has been collected from progeny trials located in Karikudi, Arimalam, Marakkanam, Coimbatore, Pudukottai, Thiyagadurgam and Kandiyur. They were statistically analyzed to identify the best performing families and individuals using block adjusted values. Based on the growth performance, 200 superior trees were selected from Coimbatore, Kuruchi, Kandiyur, Udumalpet and Chennai trials. They have been coppiced and coppice shoots have been used for mass multiplication.

Benefits of the research: About 200 second generation plus trees have been identified. The selected plus trees will be tested and high yielding clones will be released for commercial cultivation by farmers. About 10% higher economic returns are expected.

Genetic diversity assessment for management of *Eucalyptus* seed orchards (IFGTB)

Eucalyptus seed orchards were evaluated for early prediction of genetic gain. SSR markers were deployed to fingerprint parents and progenies over generations to understand gene flow and segregation patterns occurring in the progenies. Field studies were undertaken to understand the flowering and fruiting behaviour of the parents and observations were recorded to correlate with mating system.

Benefits of the research: The results of the study will provide information on the combining ability of clones and will help reduce expenditure incurred in laying out progeny trials in multi locations.

Evaluation of genetic resources of *Melia dubia* in Tamil Nadu and Kerala for productivity enhancement in tree farming (IFGTB)

About 10 ha area of provenance resource stands, progeny trials and seed orchards have



been established. Pest and disease problems of the species in nursery and plantations were recorded and control measures are being developed. A VMG has been established at IFGTB from which clones are being vegetatively propagated for field testing. Three clonal trials were established in Tirupati, Dharwad and Chennai. A Field Gene Bank of *Melia dubia* is being maintained in the Vegetative Propagation Complex.

Benefits of the research: Technology for mass production of *Melia* has been established. *Melia* being a fast growing species is in high demand. The research undertaken in the species aims at identifying superior performers, different clones for different end uses and popularising the same.

Clonal Evaluation of *Ailanthus excelsa* in different agro-climatic zones of Tamil Nadu (IFGTB)

Identification of the Candidate Plus Trees has been done in the Cauvery delta zone, western and southern zone and 30 clones have been assembled in the VMG for mass multiplication. One clonal trial has been established in Tuhavarankurichi field research station.

Benefits of the research: New germplasm with



Coppice shoot production of *Ailanthus excelsa* in VMG

fast growth and straight stems has been selected to increase productivity in plantations. When planted in farmers' field after adequate testing, the new germplasm is likely to increase wood production by 15% worth around Rs.25,000/- per ha per year.

Study of variation in Red sanders (*Pterocarpus santalinus*) for growth and heartwood content according to edaphic and climatic factors in Tamil Nadu (IFGTB)

Two plantations in Palapilly and Kodanad

(Kerala) and Anakapura and Jarakabande (Karnataka) were evaluated for growth and soil and wood samples were collected and analyzed. Two progeny trials were planted at Chennai and Neyveli Research stations during 2013 and they are periodically assessed.

Benefits of the research: Plus trees with fast growth and high heartwood content will be selected for conservation and improvement. The new selections will increase quantity and quality of wood produced in plantations.



Progeny trial of Red sanders at Neyveli Research station

Germplasm assemblage of genetic resources of *Gmelina arborea* Roxb. in Karnataka (IFGTB)

As part of long-term genetic improvement programme, seeds were collected from 40 CPTs of *Gmelina arborea* (shivani) selected in different States and established three progeny trials in Hosakote, Shimoga and Dharwad in Karnataka. Growth data was collected four months after field planting from all the trials.

Benefits of the research: Assessment of the performance of the species across locations in the country would enable selection of accessions which are stable across locations and can be deployed in national programmes.

Exploration, Collection and evaluation of forest genetic resources and development of National Gene Bank (IFGTB)

Extensive survey has been conducted in different parts of Tamil Nadu and Kerala and studied variation on morphological and reproductive characteristics in teak populations, and selected 29 populations which showed distinct and desirable characteristics for *in situ* and *ex situ* conservation. Action has been taken



for establishment of seed bank and field gene banks.

Benefits of the research: Clonal propagation of teak has been standardized. The Teak populations selected for *in situ* conservation based on desirable characteristics will be useful to State Forest Department for effective utilization.

Mapping and monitoring of *Casuarinas* and *Eucalyptus* plantations in Tamil Nadu using RS and GIS (IFGTB)

Spatial extent of *Casuarina* and *Eucalyptus* plantations in selected districts of Tamil Nadu was mapped using remote sensing and GIS. Supervised classification was used to classify the satellite images (LISS IV Resourcesat-2/ L-4FMX 5.8m resolution) and recode technique was used to reclassify the misclassified pixel with the help of Google Earth and field check. Mapping of *Casuarina* and *Eucalyptus* plantations in Ariyalur District has been completed and extent of the plantations based on age/maturity was calculated. Mapping of plantations in Karur District has been completed and accuracy of classification needs to be checked through field survey. The procured satellite images of Cuddalore and Villupuram Districts were geo corrected and processed. Unsupervised and supervised classifications of the images were done. Data on *Casuarina* and *Eucalyptus* plantations in Pudukkottai and Sivaganga Districts were collected with the help of field staff of Tamil Nadu Newsprint and Papers Limited.

Benefits of the research: Techniques for spatial mapping of *Casuarina* and *Eucalyptus* plantations has been developed. This study will help the pulp wood based paper industry to assess the availability of raw materials and also help the policy makers in efficient management of natural resources.

Growth Variability in *Melia dubia* (Malabar Neem) plantations and seed germination (IWST)

Growth data from 25-30 trees in sample plots laid out in different locations (Hiriyur and Kollegal, Yeshwanthapur and Hunsur) have been collected. These plantations had different spacing and are uneven aged. Fruit/seed parameters were recorded and pre-treatment methods for germination were studied.

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.

Growth, assessment and genetic diversity of *Melia dubia* Cav. in Karnataka (IWST)

This study was taken up to assess the growth and genetic diversity of natural and planted populations of *Melia dubia* (Hebbevu) which has a potential of accruing 5 to 7 cm diameter per year under intensively managed conditions. The genetic diversity studies of different natural/plantation grown trees reveal that *M. dubia* has considerable variation which would facilitate in developing further tree improvement strategies.

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.

Seed behavior and effect of differential drying and temperature on viability of *Mesua ferrea* (Nag champa) and *Madhuca insignis* species of wet evergreen forest of Western Ghats (IWST)

Madhuca insignis is a highly threatened species and its distribution is restricted and seed bearing trees are limited. Variability in terms of fruit and seed traits was observed in *Mesua ferrea* (Nag champa) and *M. insignis*. In *M. ferrea*, considerable variation was observed in terms of fruit weight within and among the populations, however there was no effect of seed weight on germination. Seeds from Sagar were bigger and heavier compared to other populations. In *M. insignis*, seeds from Kaup were bigger in size as compared to seeds from Nadoli. *M. ferrea* seeds are intermediate in nature and can be stored for 165 days at 5 °C. *M. insignis* seeds are recalcitrant in nature and cannot be stored for more than 75 days at 15 °C.

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.

Conservation, improvement and bio-resource development of sandalwood (*Santalum album* L.) (IWST)

Core samples from trees of different girth classes of sandalwood populations were



extracted and heartwood and sapwood contents were determined. Oil content was found to be 0.2 to 1 % in age class of 9-12 years and maximum of 4 % oil content in 30 year old trees. Sub-culturing, micropropagation through axillary shoots and somatic embryogenesis is being carried out at frequent intervals. *In vitro* rooting experiments with different combinations of auxins and cytokinins are under progress. New callus culture has been established for somatic embryogenesis. Around 40 ISSR primers have been screened for molecular marker studies involving samples collected from different States. Training programme and demonstration for production of quality planting material was carried out and agro-forestry Multi Locational Trials are maintained in Mudenahally, Bevanahally and Koppa in Karnataka.

Benefits of the research: Sandalwood nursery technology has been standardized and documented. Sandalwood based agroforestry model plots have been established in 3 locations in Karnataka with secondary long term horticultural species like mango, amla and coffee. This has been serving as demonstration plots for farmers during annual training programme on sandalwood cultivation in IWST.

Assessing the performance of *Pongamia pinnata* L. Pierre (Karanj) in Karnataka and establishment of multilocation trial: A step towards varietal release (IWST)

Measurement and oil estimation for collected pods/seeds from all the clones planted in different research ranges of Karnataka Forest Department is in progress. Pod, seed, and oil data are subjected to PCA/D² analysis for selection of best performers. Top 25 best performing genotypes are selected for clonal multiplication, grafting of all the selected clones completed and used for MLT experiment.

Benefits of the research: Outcomes of the research will help selection of best performing varieties.

Development of quasi *in-situ* conservation and restocking of natural areas of *Embelia ribes* Burm.f. (Vidanga) - an important endangered medicinal plant species (IWST)

In vitro propagation through axillary shoot proliferation using nodal segments from mature plants was used for large scale multiplication and restocking of *Embelia ribes* (Vidanga) populations. New cultures have been

established using explants from matured plants from the natural populations from Narasimha parvat, Sringeri and Agumbe, Karnataka. Tissue culture has been developed and plants were raised for field planting.

Benefits of the research: It will help in restocking and conserving the RET species in its natural habitat.

Enhancing seed productivity of Clonal Seed Orchards of *Tectona grandis*, *Tamarindus indica* and *Syzigium cumini* using cultural operations (IWST)

Tectona grandis (Teak, Sagon, Sagwan) at Janganmatti, Dharwad, *Syzigium cuminii* (Jamun, Jumbul, Jambolan) and *Tamrindus indica* (Imli) CSO at Nallal and Gottipura in Hoskote range were selected for carrying out flowering studies. Experiments were laid out to induce flowering and fruit setting viz. girdling, shoot pruning, root pruning and branch girdling on low-flowering and non-flowering clones.

Benefits of the research: The study would lead to increase in productivity of seed in clonal seed orchards established by forest departments.

Establishment of demonstration plots and modern nursery for producing quality planting stock of *Santalum album* (Sandal) and bamboo (IWST)

A model Sandalwood Nursery was established at Bhatoli with a capacity of raising 55,000 seedlings. Demo-plots of sandalwood with red gram (arhar) as primary host and Indian gooseberry as secondary host were established in Mohali, Ropar, Mathewada (Ludhiana) and Bhatoli (Talwara) with 60-90 % survival after one year. Demo plots of one hectare each of 4 bamboo species (*B. balcooa* (Bhaluka/boro bamboo), *B. nutans* (mokal/Jatie makal), *D.asper* (sweet bamboo) and *D. hamiltonii* (Tama bamboo) were established in Talwada and Biodiversity park at Bhatoli, Desua. Training on sandal nursery establishment, bamboo vegetative propagation and plantation management was given to PFD officials in Bhatoli and at IWST.

Benefits of the research: Technology for raising quality planting stock of sandalwood in forest nurseries in Punjab has been developed and demonstrated to Punjab Forest Department. A technical bulletin on sandalwood cultivation prospects in Punjab has been prepared. Demo plantations in sandalwood in 2



ha along with secondary horticultural species have been developed in Bhatoli Biodiversity Park, Hoshiarpur from seedling stock transported from IWST. Demo plantations have also been established in Mohali, Ludhiana and Ropar. This is expected to boost sandalwood cultivation in Punjab and also serve as seed source for sandalwood nurseries of Punjab forest department. Sandalwood based agroforestry practices with horticultural crops are expected to generate additional revenue and an alternative land use option for farmers in drier tracts of Punjab.

Reassessing the population status of Indian Sandalwood (*Santalum album*) in Karnataka (IWST)

Sandalwood (*Srigandha*) plantations were identified in different districts such as Tumkur, Kolar and Chitradurga. Growth parameters like height, clear bole height and girth were recorded from plantations of different ages. In a four year old plantation, average girth was recorded as 16 cm. Information pertaining to growth, heartwood and sapwood has also been recorded in a 14 year old plantation harvested in Nelamangala, Bengaluru district.

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.

Germplasm collection and *ex-situ* conservation of *Pterocarpus marsupium* Roxb (Beeja sal) (TFRI)

Germplasm collection was done in three agro-climatic zones of Chhattisgarh and seedlings raised and seed source trial has been established at Naya Raipur, Chhattisgarh and Chhindwara.

Benefits of the research: Technique for propagating plants through seed has been

optimized. This will result in *ex-situ* conservation of Germplasm.

Induction, evaluation and development of polyploides in *Azadirachta indica* (AFRI)

Reconnaissance surveys were conducted in Jodhpur area of Rajasthan and Palanpur, Gujarat. Nineteen phenotypically superior trees were marked and fruits were collected. Seeds were collected from four seed sources and selected superior trees and provided to FRI for onward supply to IFFCO. Seedlings of neem (*Azadirachta indica*), these seed sources have been raised in the nursery. Survey was conducted to identify the existing production populations. Five populations including three progeny trials have been identified.

Benefits of the research: Genetic improvement of *Azadirachta indica* would lead to better financial gain by planting superior planting material.

Bamboo genetic evaluation, improvement and propagation (RFRI)

Thirteen superior clumps from four bamboo species were selected from the gene bank that was used for propagation through culm and branch cuttings. New rhizomes were collected from the selected clumps and planted in the germplasm bank for establishment. A rhizome bank of selected clumps of bamboo species was established at RFRI, Jorhat.

Benefits of the research: The rhizome bank will help in conservation of high-yielding genotypes. These selections will serve as the base material for mass propagation and supply in the region, and that will boost the productivity of bamboo, which is an important forestry species of the region.

Identification of suitable clones of *Populus* species for Northeast India through genetic evaluation (RFRI)



Establishment of progeny trial of *Pterocarpus marsupium* in Naya Raipur (a) and CFRHRD campus, Chhindwara (b)



Phenotypically superior *Populus gamblei* (Pipelee) were collected from Northeastern states. Genetic evaluation of the selected genotypes along with known clones of other *Populus* species in different agro-climatic region was done.

Benefits of the research: Proposed clones development at the end of this project will provide planting material for agroforestry systems in the region. The selection is still at the preliminary stage.

Collection, conservation and evaluation of *Melia dubia* germplasm from North-Bengal, Odisha hills and other parts of India for identification and release of superior clones (IFP)

Seeds of 42 progenies have been collected from FRI, Dehradun, and established two progeny trials with 21 progenies at two locations in Jharkhand (FRC, Mandar and Nagri) and at one location in Bihar (KVK, Manjhi, Saran). Similarly, a progeny trial with 60 progenies collected from FRI, IWST and North Bengal has been established at FRC Mandar, Ranchi in 2015. The seed characteristics of different seed sources have been recorded. The growth data like plant height, collar diameter and insect pest attack have been recorded in field trials. Surveys have been conducted at various places in Bihar, Jharkhand and districts of North Bengal (Malda, Siliguri, Jalpaiguri, Cooch Behar and Darjeeling) and identified superior genotypes of *Melia dubia*. Standardization of vegetative propagation technique is in progress.

Benefits of the research: Germplasm of the species has been collected from all over the country and a germplasm bank has been established at IFP, Ranchi. The information on genetic diversity present in the collected material will help in planning further breeding

and improvement programmes. Better performing genotypes will be identified under the project which will be recommended for mass multiplication and plantation.

Evaluation of *Dalbergia sissoo* Roxb. clones for large-scale clonal forestry in Gangetic plains and Chotanagpur plateau (IFP)

Forty five CPTs have been selected in Jharkhand and Bihar states based on the criteria for plus tree selection, mainly consisting of traits of timber productivity and disease resistance in *D. sissoo*. The selected CPTs were multiplied through shoot cuttings, brought to Institute, planted in mist chamber employing 2mM IBA treatment for their multiplication. The stock plants in the CMG with 19 clones have also been maintained for consistent supply of propagules for clonal multiplication. Clones of selected CPTs and mortality resistant clones collected from FRI Dehradun have been multiplied. Clonal trials have been established in Jharkhand with 12 clones and at Purniya, Bihar with 16 clones. Biochemical parameters like chlorophyll, proline, phenol, soluble sugar and starch have been studied in promising clones in the clonal trails. Molecular characterization of 21 promising clones has been carried out to assess genetic diversity among the selected clones. Enzyme systems related to tolerance viz., SOD and peroxides have been estimated in different clones.

Benefits of the research: Clonal propagation package for large scale afforestation of *Dalbergia sissoo* has been developed. Identification of 19 promising clones in terms of superior growth and resistance to mortality in resistant Gangetic plains and Chotanagpur plateau and their testing in different ago-climatic zones has provided suitable resistant clones for the region.

5.2 Tree Improvement

All India Co-ordinated Project for genetic improvement of *Melia dubia* Willd.

FRI, Dehradun

The *Melia dubia* (Burma Drak/ Malabar neem) is adaptable to a wide range of climatic conditions like arid, semi-arid and semi-moist areas, where it is widely cultivated for its fast growth and multiple uses. It is emerging as an

alternative to Eucalyptus and *Populus deltoids* (Poplar) for raising agro-forestry plantations. Candidate Plus Trees were selected in natural forests of Assam and Arunachal Pradesh and plantations of Uttarakhand, Punjab and Haryana and shortlisted superior accessions as plus trees based on ranking of economically important traits. Seedlings were raised from individual trees and a series of evaluation trials



were established in different locations to estimate growth performance, G x E interactions and stability. Early growth of certain progenies was found to be highly uniform.

Benefits of the research/work: The study will help to identify better progenies of *Melia dubia* as an alternative species to *Eucalyptus* and *Populus deltoids* (Poplar) for raising agro-forestry plantations.

AFRI, Jodhpur

Multi-location progeny trials of Malabar Neem (*Melia dubia*) established at Ghodiwara (Jhunjhunu), Bassi (Jaipur), Jodhpur, Gandhinagar and Deesa were maintained and evaluated. Data from five progeny trials were collected, compiled and tabulated. Analysis of new trials at Bassi and Ghodiwara was performed. Differences amongst the families were found to be highly significant in both the trials for height as well as collar girth. Heritability in narrow sense in Bassi was 70 and 71 percent for height and 20 and 33 percent for collar girth at individual and family levels respectively. These estimates at individual and family levels for Ghodiwada were 18 & 37 and 28 & 51 respectively.

Benefits of the research: It will help in selection of *Melia dubia* with desirable traits resulting in higher productivity.

RFRI, Jorhat

Ninety one superior trees were selected from Manipur, Nagaland, Meghalaya, Sikkim and Cooch Behar. Fruits were collected to study their physical attributes and extracted seeds were sown in nursery beds. Seeds of 42 accessions were also procured from FRI, Dehradun to establish multi-locational trials.

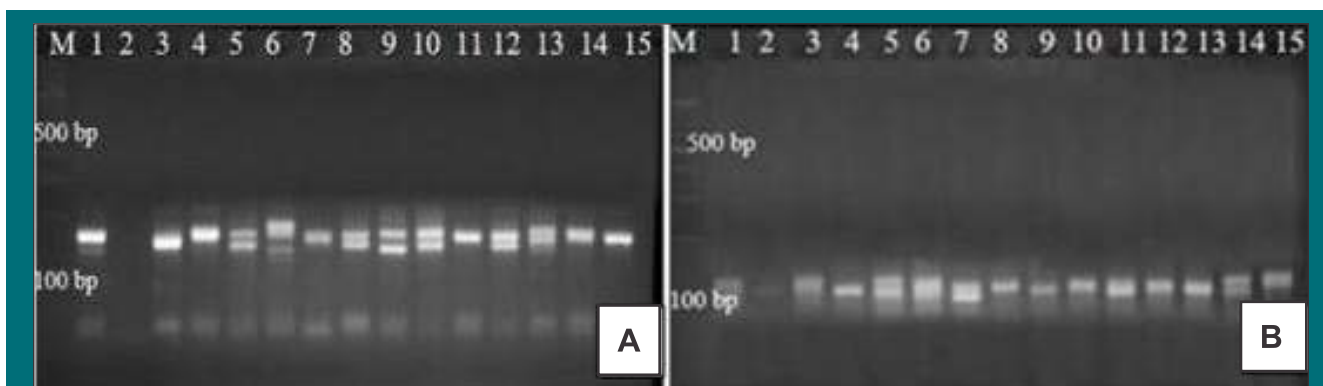
Two trials were established, one each at RFRI, Jorhat and Tizit, Nagaland, with the progenies raised from the seeds provided by FRI. Three trials were established at RFRI with the progenies from the selected trees of North East region. Fruits were collected from 58 selected trees to establish breeding population at Dhubri. Observations were recorded on flowering and fruit setting. DNA samples were extracted from 53 progenies selected from North East region and the methodology was standardized for optimization of PCR reactions.

Benefits of the research: The programme will produce high-yielding clones of *Melia dubia* which would be of great benefit to the plywood industry.

IWST, Bengaluru

Recorded data on survival and growth from progeny trials planted at Agundapalli and Megharwali. Survival was higher in Agundapalli compared to Megharwali. Seed variability and germination studies were carried out for fruits collected from Shimoga and Bhadaravati. Genetic diversity was assessed using 15 ISSR markers showing polymorphism. Screening of ISSR primers by cross transferability from other species was carried out and none of the primers showed amplification in *M. dubia* (Hebbevu). ISSR primers developed through Next Generation Sequencing were screened for amplification and polymorphism. Six ISSR primers showing good polymorphism has been selected for assessing diversity of *M. dubia* populations.

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.



ISSR amplification profile for two ISSR markers using 15 DNA samples in 3.5% agarose gel. Lane M-100bp plus ladder, Lane 1-15, 15 DNA samples (A) MSSR7 and (B) MSSR10



Genetic Improvement of *Casuarina* species through second generation orchards (IFGTB)

This project has been implemented since 2008 to advance the ongoing breeding programme for *Casuarina* to the second generation. The best 5% of female/monoecious trees were selected based on superiority in terms of growth, stem form and wood traits from the first generation breeding populations. Open-pollinated seeds collected from these trees along with an infusion population of about 100 families received from CSIRO, Australia were used to raise second generation breeding populations as large progeny tests with 150 to 200 families in about 16 ha area in Andhra Pradesh, Puducherry and Tamil Nadu. All trials have been periodically assessed for growth, stem form and wood traits and variation among families and seed sources have been estimated. Genetic parameters like heritability, genetic gain and G x E interactions have been assessed using the variance estimates. All trees in progeny tests older than five years have been ranked and inferior families and trees were removed for conversion into seedling seed orchards (SSO) for seed collection and supply.

Benefits of the research: New second generation seed orchards have been established to produce genetically improved seed capable of yielding at least 15% higher wood production than seeds of first generation orchards. Each Kg of seeds from the new orchards is sold at Rs.10,000/- to farmers, forest departments and industries. The 15% additional wood production provided by the seeds is worth Rs.15,000/- per ha per year. The new clone released has been licensed to industries and nursery operators and a license fee of Rs.18,00,000/- has been collected so far. They are also mass multiplied in the state-of-the-art nursery of IFGTB and sold to farmers and a revenue of Rs.5,00,000/- per year is earned.

Two clones of *Casuarina junghuhniana* have been released through ICFRE's guidelines for variety release. One clone CJ-9 has been registered with PPVFR Authority, Govt. Of India for IPR protection.

Development of an inter-specific hybrid, *Corymbia torelliana* X *C. citriodora* through

controlled pollination: A genetic resource for paper industry (IFGTB)

Pulp improvement with emphasis on disease resistance was attempted through full-sib breeding of *Corymbia torelliana* X *C. citriodora*. The progeny were of intermediary in terms of morphological characteristics and traceable in terms of leaf shape, stem straightness, stomatal distribution and lignotuber development. A pilot trial with seven full-sib families was developed at Karamadai, Tamil Nadu, followed by two trials in Walayar, Kerala and Nellore, Andhra Pradesh. No gall infestation has been noted either in the parents or in the inter-specific di-hybrid *C. torelliana* X *C. citriodora* progeny. After eighteen months in field the di-hybrid progeny were coppiced and multiplied vegetatively. Characteristics such as amphi-stomatic and production of lignotubers were found to be inherited from the pollen parents.

Benefits of the research: Developed techniques for inter-specific crossing in *Corymbia* species. The research focused on development of disease resistance and pulp improvement in *Corymbia*. Full-sib breeding of *Corymbia torelliana* X *C. citriodora* resulted in progeny which were intermediary in terms of morphological characteristics and traceable in terms of leaf shape, stem straightness, stomatal distribution and lingo-tuber development.

Evaluation of inter-specific hybrid clones of *Eucalypts* (Safeda) for productivity and wood traits (IFGTB)

Thirty clones short listed from the mapping population based superior productivity traits compared to the commercial clones at the nursery stage have been subjected to multilocation field testing. Three clonal trials were established in Nellore (Andhra Pradesh),



Inter-specific hybrid clonal trial of *Eucalyptus*



Neyveli and Thuvankurichi (Tamil Nadu). Early growth assessment showed a few hybrid clones outperforming the commercial clones.

Benefits of the research: A set of selected clones are under testing for subsequent release for commercial cultivation by farmers. The tested clones are expected to be superior in its yield attributes than the existing Clonal varieties being planted by farmers. It is expected that the yield is improved by 10%.

Genetic improvement of *Eucalyptus* through mapping and tagging of QTLs/genes (IFGTB)

Under the network program on genetic improvement of *Eucalyptus* for developing markers tagging economically important traits, quantitative traits such as improved pulping, greater rooting, lower lignin and higher salt tolerance were targeted. Pedigreed clones of *E. camaldulensis* (Ec-7, Ec-17 and Ec-111) and *E. tereticornis* (Et 217 and Et 86) and an *E. grandis* (13017 Lorne) were deployed for hybridizing the above mentioned traits. Di-hybrid combinations of *E. camaldulensis* X *E. tereticornis*, *E. tereticornis* X *E. camaldulensis*, *E. camaldulensis* X *E. grandis* and *E. tereticornis* were developed. Multi-location clonal trials were developed with commercial clones as benchmark for selecting superior hybrid clones.

Benefits of the research: *Eucalyptus* hybrid clones were developed for future breeding programmes. Methods were developed for hybrid confirmation in Eucalypts using microsatellite markers. A combined NIR spectroscopy model was developed for non-destructive estimation of holocellulose and klason lignin content in *Eucalyptus* wood. A cost effective, high throughput technology of target capture and exome re-sequencing was developed for identification markers for linkage/QTL mapping. Hybrids generated under this programme will lead to hybrid clone release. NIR spectroscopy model developed can be used for documenting wood property traits.

Genetic Improvement of *Gmelina arborea* (Gamhar) Roxb. through selection and clonal evaluation (IFGTB)

90 CPTs based on growth superiority, clear bole and pest and disease resistance were selected in natural forest and farmers plantations of Tamil Nadu, Kerala, Karnataka and Andhra

Pradesh and marked with GPS. The bio-metric, phenology, reproductive characters and wood properties and seed and seedling characteristics of CPTs have been studied. Progeny trials at Salem and Thuvankurichi (Tamil Nadu) have been established and growth performance is periodically assessed.

Benefits of the research: Developed technique for selection of CPTs and clonal multiplication of multiplication of *Gmelina arborea*. Established progeny trail will serve as base material for future breeding programme for developing new clone and hybrids. Quality seeds expected from the field trial will be sold at higher price. The clone developed from the progenies of field trial will be registered under PPVFRA act.

Selection and multi-location testing of *Gmelina arborea* (gamhar) clones for growth, form and wood Traits (IFGTB)

50 candidate plus trees based on superiority in height, clear bole, GBH, tree spread and apical dominance have been selected. The wood samples collected from the CPTs were analyzed for density, moisture, fiber length, fiber diameter, lumen diameter and Runkel ratio. Standardization of vegetative propagation technique is in progress.

Benefits of the research: Standardized clonal multiplication technique deploying large scale commercial multiplication. Clones with higher productivity and wide adaptability will be used for developing hybrid clone. High productive clones will have direct impact on improving standard of living of farming communities. Released *Gmelina* clones will be registered under PPVFRA act.

Germplasm assemblage and Improvement of *Leucaena leucocephala* (Subabul) for industrial biomass productivity (IFGTB)

Thirty four seedlots of *Leucaena* were collected from different agencies including University of Hawaii, USA. Two provenance-progeny trials with 24 seedlots were established at Neyveli and Thuvankurichi in Tamil Nadu. The growth data recorded at 6 and 12 months showed that accessions like Hawaiian giant variety exhibited outstanding growth, straight stem form and low flower/fruit production. Vegetative propagation techniques for large scale mass multiplication of selected trees have been standardized.



Benefits of the research: New germplasm with desirable properties like straight single stem and fast growth has been selected for pulpwood production. When planted in farmers' field after adequate testing, the new germplasm is likely to increase wood production by 20% worth around Rs.20,000/- per ha per year.

Rapid Improvement of *Casuarina* and *Leucaena* to Enhance Pulpwood Production from Farm Forestry Plantations (IFGTB)

40 seedlots of *Casuarina* from CSIRO, Australia have been imported. Seeds of *Casuarina equisetifolia* from the IFGTB clonal trial established at TNPL were collected. A total of 265 CPTs of *Leucaena* were selected in Koppal, Karnataka and 167 CPTs from Prakasham district, Andhra Pradesh. Seedlings and clones have been produced and field trials have been established.

Benefits of the research: 17 field trials were established in collaboration with 5 industries viz. IP-APPM, TNPL, BILT, WCPM and JK Papers.

Selection and Evaluation of High Yielding clones of *Pongamia pinnata* (Pungan) (IFGTB)

Under project, Tree improvement of *Pongamia*, a total of 91 high fruit yielding trees of *P. pinnata* have been selected from different states, multiplied clonally and a clone bank has been established in the Institute campus. Seeds have been collected from 91 selected plus trees, raised seedlings in the nursery and a germplasm bank of *P. pinnata* has been established at Neyveli, Tamil Nadu. A clonal trial of *Pongamia* with selected 56 clones has been established at Neyveli to identify the best performing clones. Generally, the fruit yield in *Pongamia* is around 50 to 60 Kg, whereas clone No 19 from Dharmapuri showed maximum fruit yield of 250 Kg/tree with oil content 30.54% and it is one of the top ranking clones. It was observed that most of the clones from Dharmapuri and Krishnagiri of Tamil Nadu exhibited high oil content (19 to 30.5%), high fruit yield, high fruit weight and high seed weight. Clone No 54 of Pudukottai showed highest oil content of 33% compared to all other clones. Molecular characterization of high yielding clones of *Pongamia* has been done using RAPD markers.

Benefits of the research: Developed Clonal

propagation technique. A total of 19 high fruit yield with high oil content clones have been identified which will be useful for clonal plantation programme to improve oil production. The 91 clones assembled in the clone bank will be used for tree improvement programme.

Selection and Screening of Germplasm of *Thespesia populnea* for Improving Productivity (IFGTB)

139 plus trees of *Thespesia populnea* based on growth and tree form were selected in Tamil Nadu, Kerala and Puducherry. Cuttings from these trees were rooted and a Clonal Multiplication Area with 86 clones was established at Panampally, Kerala. Periodic observations on growth and health status were recorded in CMA. New experiments were initiated with rooting of leafy cuttings and cost-effective water culture technique and succeeded in both the initiatives.

Benefits of the research: 139 plus trees were selected for future improvement. These clones will be tested in multi locations in the newly approved project.

Conservation and improvement of *Calophyllum inophyllum* (Punnai/Sultan Champa)- A potential TBO of Karnataka (IFGTB)

66 CPTs were selected in Karnataka based on the selection criteria of 15 fruits in one-foot length of branch. The mean oil content for 66 CPTs was found to be 55.3%. Shortlisted 25 high oil yielding CPTs based on oil content and those recording 55% and above were assembled in germplasm bank for establishing trials. A clonal trial was established at Kasargod in Honnavar District.

Benefits of the research: Developed techniques for Clonal propagation of *Calophyllum inophyllum* and mother bed chamber facility protocol for the species. Mass multiplication of *C. inophyllum* clones.

Improvement and popularization of *Swietenia mahogany* (Mahogany) for rural livelihood promotion in Tree-Outside-Forests (TOFs) - Potential timber yielding species of Meliaceae (IFGTB)

70 CPTs of *Swietenia mahogany* and *S. macrophylla* were selected in Tamil Nadu, Kerala, Karnataka and Punjab and passport



data were recorded. Stem cuttings collected from the CPTs were subjected to rooting with different hormonal concentrations. Open-pollinated seedlings were also raised. Wood samples of CPTs and soil samples of populations were collected and are being processed for further studies. Standardization of seed handling techniques is being carried out. Based on isozymes studied in *S. macrophylla* and *S. mahagoni*; Formaldehyde dehydrogenase, Iso-citrate dehydrogenase and Glutamate dehydrogenase have been found suitable for species discrimination.

Benefits of the research: Seed handling techniques has been standardized. Valuable germplasm of Mahagoni has been assembled.

Distribution, diversity and productivity of *Dendrocalamus stocksii* (Munro) (Marihal bamboo) in Western Ghats of Karnataka (IWST)

A total of 102 genotypes of *D. stocksii* were evaluated. Variation was found for culm and clump characteristics and also for physiological parameters among the populations. Sindhudurg, Kasargod and Udupi populations showed better photosynthetic capacity and WUE. The similarity co-efficient amongst the 100 accessions ranged from 0.06 to 0.6, indicating genetic diversity. Nearly 95 percent of the clustering was as per the populations demarcated. Linear allometric equation was developed to predict various above-ground biomass components based on culm basal diameter and height which showed that culm biomass equation produced better predictions ($R^2=0.69$). Based on the number of records of occurrence of the species, the ecological niche of the species was developed by using DIVA-GIS niche modeling program using BIOCLIM (Bio-climatic analysis and prediction system).

Benefits of the research: A germplasm bank was assembled consisting of 100 genotypes/ accession from over a 850 km stretch in Central Western ghats extending from Kasargod in Kerala to Ratnagiri in Maharashtra which captures the natural variability in this commercially important multipurpose bamboo species. This is an important step in future improvement programmes of the species.

Studies on variation in reserpine content in some high yielding genotypes of *in-vitro* and Seedling raised *Rauvolfia serpentina*

Benth. (Sarpagandha) (TFRI)

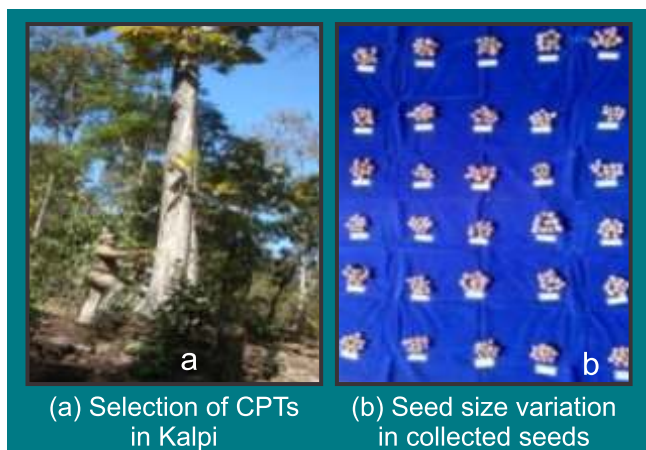
The chemical estimation of reserpine content in five genotypes has been completed. The cultivar OR-AG (Odisha) had the maximum reserpine content followed by MP-CW from Madhya Pradesh. Both cultivars were proposed for release in the meeting of implementation team followed by regional variety testing committee.

Benefits of the research: Technique for propagating plants through seed by scarification treatment has been optimized. *In vitro* technique of plant production has been developed. Release of two varieties with high reserpine content is in final stage.

Improvement of Teak for higher productivity in Central/Peninsular India: A multi-institutional All India Coordinated Project (TFRI)

Teak seeds have been collected from plus trees at Rukhad and Kurai (South Seoni), Pali (Bilaspur), Devpur (Raipur), Kalpi (Mandla). Seeds collected from clonal seed orchard in the TFRI campus and studies on treatment and germination is being carried out.

Seeds of five plus trees were germinated on half strength hormone free MS medium. Three size-grades of seeds in three different positions (embryo in upside position, embryo in downside position and embryo placed horizontally on the medium) were inoculated on this medium. Maximum germination was obtained in fruits of medium size. In the seeds inoculated with embryo in downside position, maximum germination was obtained. Maximum callusing was obtained on MS medium supplemented with 0.1 μM 2, 4-D and 0.01 μM kinetin followed by 0.5 μM 2, 4-D and 0.5 μM 2, 4-d and 0.1 μM kinetin.



(a) Selection of CPTs in Kalpi

(b) Seed size variation in collected seeds



Preliminary statistical analysis of morphometric data of six zones out of 15 teak dominated agro-climatic zones revealed that there is significant differences for all the traits studied i.e. height, clear bole height, DBH, wood fibre length, wood density except fibre breadth. Genomic DNA from collected samples (180 trees) was isolated and quantified. Genotyping of the collected material (first six zones) involving SSR markers is under progress.

Benefits of the research: Development of silviculture and management practices for seed orchards, better management of seed production and improved quality and quantity of seed. Genomic DNA isolation was standardized and wood quality studies are underway.

Collection of germplasm of *Madhuca indica* J. F. Gmel (Mahua) for identification of best sources in Chhattisgarh through phyto-chemical evaluation (TFRI)

Fruits were collected from trees of five girth classes, viz., 61-90 cm, 91-120 cm, 121-150 cm, 151-180 cm and over 181 cm from Surguja and Jashpur. Five trees per girth class were selected and their GPS location was noted. Height, DBH and crown length of the trees were measured and around 1-2 kg fruits per tree were collected and studied for various seed traits. Oil content and saponin content in seeds from Bilaspur, Jashpur, Kanker, Sarguja and Jagdalpur were estimated. The seeds of Jagdalpur had 17.3 to 63.9 % of oil content.

Benefits of the research: Selection of phenotypically superior trees, with high sugar and saponin content in various agro-climatic zones of Chhattisgarh.

Genetic improvement of *Dalbergia latifolia* Roxb. (Rosewood, Kala Shisham) through selection and evaluation of germplasm in central India (TFRI)

Forest areas of Maharashtra, Odisha and Chhattisgarh were surveyed and 27 candidate plus trees (CPT) were selected. The morphological data on total height, clear bole height, diameter at breast height (DBH), crown diameter, number of primary branches, status of flowering and fruiting and GPS data were recorded. Physical parameters of pods viz., pod length and seed weight were assessed and germination studies conducted. *In-vitro* shoot cultures were multiplied and maintained on MS

medium supplemented with 0.5 μ M BA. Somatic embryos were obtained on the margin of cotyledons of seeds collected from the trees 90 days after flowering. Highest somatic embryo formation was obtained on 0.5 mg l⁻¹ 2, 4-D (56 %) which was significantly higher than any other treatment. The somatic embryos were inoculated on MS medium supplemented with different concentrations of BA for maturation. Shoot formation and elongation was achieved.

Benefits of the research: Selection of superior Germplasm and better planting material through micro-propagation technique.

Collection and morpho-molecular characterization of critically endangered *Litsea glutinosa* (Maida chhal) germplasm from Madhya Pradesh and Chhattisgarh (TFRI)

A total of 101 trees of *Litsea glutinosa* have been located in different areas of Madhya Pradesh and Chhattisgarh and recorded morpho-metric and GPS data. Propagating material (seeds and root suckers) have been collected and established in the nursery and an experiment on macro-propagation was laid out to assess the possibility of propagation through branch cuttings. A germplasm bank was established at the Institute and work on the molecular characterization of the germplasm is in progress.

Benefits of the research: Propagation technology through seeds has been developed by enhancing seed germination. Germplasm of this critically endangered species has been assembled as a Germplasm bank. Potential pockets have been identified in natural forests.

Development of commercially viable induction system for *Aquilaria malaccensis* (Agarwood) and management of Agarwood production in humid tropics of Karnataka (IWST)

Soil samples were collected from Karnataka and North-Eastern part of India. A total of 89 colonies of fungus were obtained from the wood and soil samples. Fungal species which have been reported to induce agar wood in north-eastern part of India were selected from the 89 colonies and pure cultures were multiplied. In total 40 fungal isolates were selected based on the colony characteristics and also on the basis of preliminary



identification at the genus level.

Benefits of the research: Induction of commercially exploitable agarwood in early stages can reduce the gestation period and facilitate early returns which would be lucrative to farmers. A comprehensive technology package for agar wood induction would help popularizing the cultivation of this species in Karnataka.

Development of DNA-based identification system for three important timber species of Karnataka (IWST)

Three important timber species, *Dalbergia latifolia* (Rosewood), *Tectona grandis* (Teak, Sagon, Sagwan) and *Lagerstoemia lanceolata* (Nandi) were selected for the study. In order to standardize the protocol, leaf and core samples were collected from Dandeli, Haliyal and Barchi taluk of Dharwad district as well as IWST campus and isolated genomic DNA from leaves. The quantity of DNA was the highest but the purity was less in *L. lanceolata*. In case of *D. latifolia*, DNA quantity as well as purity was high, and in *T. grandis* the purity and quantity was less. In order to improve the purity and quantity of DNA, modifications in the protocol like addition of high quantity of PVP, increasing the concentration of NaCl, proteinase, and RNase were carried out. Standardization of the protocol of wood genomic DNA isolation is in progress.

Benefits of the research: Development of specific molecular marker for three important timber species, *Dalbergia latifolia*, *Tectona grandis* and *Lagerstoemia lanceolata* would help in authentic identification of species by Forest Department and for commercial activities.

Screening of *Gmelina arborea* Roxb. clones for productivity and stability (RFRI)

Twenty one clones were found promising in terms of growth parameters, i.e. height, collar diameter, diameter at breast height, straightness and crown shape, in a clonal trial at Naharoni, Jorhat. Three clonal trials with 25 clones were established among them, two at Manipur and one at Shillong, Meghalaya. Two VMGs, one at RFRI, Jorhat and another one at Luwangsangbam, Imphal East, Imphal were

also established. Based on the observations of pest attack at Naharoni experimental site, 7 clones were identified as less attacked, 8 clones considered as highly attacked and 55 were recorded as moderately attacked. The biology of the pest, *C. leayana* ('gamar' defoliator) was studied in lab conditions and the variation of leaf area damage by the pest on different clones was also recorded.

Benefits of the research: The study will help in developing *C. leayana* tolerant clones of *Gmelina arborea* (gamar). This will increase the productivity of this important tree species which is a source of timber in the region.

Bamboo genetic evaluation, improvement and propagation (Networking Project) (IFP)

Culm and culm branch cuttings collected from nine superior clumps of *Dendrocalamus strictus* and three of *Bambusa tulda* maintained in IFP Germplasm Bank are being multiplied.

Benefits of the research: Refining and scaling up of vegetative propagation procedures for *Dendrocalamus strictus* and *Bambusa tulda* through adventitious rooting of culm and branch cuttings. The research ensures large scale availability of clonal plantlets of superior clones for plantation in diverse areas in eastern India.

Improvement in seed yield of *Jatropha curcas* (Jatropha) through breeding and silvicultural practices (IFP)

Eight parents of *Jatropha curcas* were selected on the basis of yield and growth performance. Diallele crossing without reciprocal was made using eight parents. A total of 28 different crosses were made during April – June, 2015. The seed setting and germination percentage of seeds in different crossing combination has been recorded. A field trial with 36 populations (8 parents + 28 F₁ progenies) has been established in 2015 and growth data has been recorded.

Benefits of the research: Promising accessions of *Jatropha* are being evaluated following diallele mating design for determining the utility as parents in the development of hybrids and/or high yielding composites.



5.3 Vegetative Propagation

Induction, evaluation and development of polyploids in *Azadirachta indica* (Neem) (FRI)

Collected seed from individual plus trees in the States of Gujarat, Haryana, Punjab, Rajasthan, processed, de-pulped, treated and supplied to the following units of IFFCO: CORDET (Phulpur, Allahabad), CORDET (Kalol, Gandhinagar), CPM (Aonla, Bareilly) and CPM, IFFDC (Raebareilly, Lucknow) and also AFRI, Jodhpur for experimentation. Screening of natural polyploids has been initiated with standardizing procedure for counting chromosomes and detecting variation among seeds of 41 progenies germinated in the laboratory. The experimentation on creation of polyploids among different progenies using various combinations of colchicine was initiated as well as LD₅₀ is being worked out. The experimentation on tissue culture was initiated with the successful culturing of nodal cuttings from 3-year old accessions maintained in the green house as well as from 5-15 years old trees using cytokinins and auxins.

Benefits of the research/work: The study will be useful in genetic improvement of *Azadirachta indica* (Neem).

Commercial production of quality planting material of bamboo species (Bans) (FRI)

Strengthening tissue culture lab infrastructure in three ICFRE Institutes, viz. FRI, Dehradun, TFRI, Jabalpur and RFRI, Jorhat and up-gradation of Tissue Culture laboratories at all



Bud break in selected neem accession on MS media supplemented with 1mg/L BAP.

these three Institutes has been completed. The existing tissue culture facilities at these Institutes are being used to test multiplication protocols for the allotted bamboo species for commercial production.

Benefits of the research/work: Mass multiplication technology using quality planting stock (QPM) for Bamboo will increase the productivity of plantations. Interested farmers/SFDs will get QPM of Bamboo.

Development of tissue culture protocol for propagation and conservation of *Ginkgo biloba* L. (Maidenhair tree) (FRI)

One male and two female trees from Nainital and four non-flowering trees in FRI Campus, Dehradun were selected. Standardized media for inducing leaf and stem callus was carried out with MS media supplemented with different



Tissue culture multiplication and hardening of Bamboo species



concentrations of plant growth regulators (PGR). The leaf as well as the stem callus (nodal callus) were maintained through periodic sub-culturing, and shoot induction is in progress. HPTLC analysis of leaves was carried out for estimating ginkgolides and bilobalide contents in one male and three female trees. Ginkgolide A, ginkgolide B and bilobalide were detected in all the samples but ginkgolide C was not detected in any leaf sample, therefore, needs reconfirmation. Ginkgolide A and B levels in leaves of male and female trees did not differ significantly.

Benefits of the research: Conservation and propagation of *Ginkgo biloba* that will have potential use for medicine industry.

Vegetative propagation and silvicultural practices for selected tropical timber species for plywood and panelwood industries (IWST)

Fertilizer and spacing trials were laid out for *Ailanthus excelsa* (Peethari), *Anthocephalus cadamba*, (Kadamba) *Grevillea robusta* (Silver oak) and *Melia dubia* (Hebbevu). Survival was 60 to 80% in case of fertilizer trials, while mortality was high in spacing trials (up to 50%).

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.

Ex-situ conservation through seed storage, propagation and natural regeneration status of medicinally and economically important RET species of wet-evergreen forest of Western Ghats (IWST)

Survey was carried out and seeds of *Kingidendron pinnatum* (Enne mara), *Oroxylum indicum* (Aanemungu; Bunepale) and *Nothapodytes nimmoniana* (Peenari) were collected and sown for germination. *O. indicum* seeds germinated in 15 days while, *K. pinnatum* and *N. nimmoniana* seeds had dormancy. Cutting of seed and removal of seed coat helped in overcoming dormancy and enhanced germination in *K. pinnatum* and *N. nimmoniana* respectively. The seeds of *K. pinnatum*, *O. indicum* and *N. nimmoniana* were

stored at 5°C, 15°C, 25°C, 35°C and at room temperature. Viability was tested at periodic interval to determine ideal storage conditions.

Benefits of the research: The research findings will be useful to State Forest Departments, Plantation managers, Researchers.

Bamboo genetic evaluation, improvement and propagation: Phase II (IWST)

Field trials of four species *B. bambos* (Indian thorny bamboo), *D. stocksii* (marihal bamboo), *D. brandisii* (Burma bamboo) and *D. strictus* (bans) were evaluated in addition to *B. balcooa*, *B. nutans* and *D. asper* established in Koppa, Chickmagalur District and Virajpet, Coorg District in Karnataka. Germplasm banks of *B. bambos*, *D. strictus*, *D. stocksii* and *D. brandisii* with 60 genotypes were maintained in Gottipura field station. To restock this germplasm bank, an additional 26 CPCs of *D. stocksii* from Dapoli were transported to IWST in the form of rhizome offsets and culm cuttings. The existing well established germplasm bank of *B. bambos*, *D. strictus* and *D. stocksii* established in 2005-06 were also evaluated for genetic gain. Collected seeds from flowered CPCs of *D. brandisii* in Chickmagalur and Coorg and raised seedlings in nursery. Preliminary selection based on seedling vigour and growth was carried out for planting of selected seedlings in Germplasm bank at Hoskote.

Benefits of the research: Planting stock raised from superior clumps of the targeted bamboo species will be available for planting by stakeholders. This will enhance the overall productivity of bamboo plantations being raised.

Bamboo (Bans) genetic evaluation, improvement and propagation: Phase II (FRI)

This inter-institutional project supported by National Bamboo Mission - BTSG was executed by FRI, Dehradun as the nodal agency along with four other ICFRE institutes viz., IWST, Bengaluru; TFRI, Jabalpur; RFRI, Jorhat and IFP, Ranchi on ten priority species



viz., *Bambusa bambos*, *B. vulgaris*, *B. tulda*, *B. nutans*, *B. balcooa*, *Dendrocalamus strictus*, *D. hamiltonii*, *Pseudoxytenanthera stocksii* (syn. *Dendrocalamus stocksii*), *D. brandisii* and *D. somdevai*. In the first phase, a total of 357 superior clumps of ten species were identified by the five institutes. In phase II of the project, out of the selected 357 clumps, 177 clumps have been picked up for their multiplication in consultation with NABM based on their previous record of flowering. Propagation technique has been standardized and multiplication of selected clumps is in progress.

Benefits of the research/work: Genetic improvement of Bamboo will lead to productivity enhancement of Bamboos.

Bamboo genetic evaluation, improvement and propagation (TFRI)

The multiplication of planting materials of four species assigned to the institute viz., *Bambusa bamboos* (Katang bans), *B. tulda*, *B. vulgaris* and *Dendrocalamus strictus* (Lathi bans) have been multiplied through rhizomes and being assembled in germplasm bank. The propagated plants are maintained by further process of macro-proliferation.

Benefits of the research: Technique for propagating plants through mini-cutting in *Bambusa vulgaris* developed, with 95% rooting success. In *Bambusa tulda* rooting success has been optimized upto 80% in cuttings. The superior clumps of four bamboo species i.e., (*B.bambos*, *B.vulgaris*, *B.tulda*, *D.strictus*) have been marked in three states and assembled as germplasm bank in the campus of the institute.

Assessment of variability, improvement and refinement of cloning techniques of *Tecomella undulata* (Sm.) Seem. (AFRI)

Tecomella undulata (Sm.) Seem (Bignoniaceae) is an economically important timber yielding tree of arid region which is commonly called as 'Marwar Teak'. Recorded the growth parameters from the progeny trials established at Jodhpur and Jhunjhunu districts of Rajasthan. The average height of 87.4 cm and average collar diameter of 1.01 cm were recorded at Jodhpur. The progeny of CPT No-36 from Pali district gave the best growth of 128 cm height, and maximum collar diameter of 1.72 cm was found in progeny of CPT No-7 from Nagaur. Similarly, at Jhunjhunu, an average height of 32.8 cm and average collar diameter of 0.35 cm was noticed. The genetic diversity studies in *Tecomella undulata* (Rohida) using ISSR markers is in progress.

Benefits of the research: Standardization of ISSR primers and screening of twenty four ISSR primers for mapping genetic diversity of *Tecomella undulata*. It will help in improvement of Rohida and use of plus trees in increasing productivity by use of seeds and vegetative material. Improvement of productivity using seeds & vegetative materials will result in better financial gain to the farmers.

Utilization of biotechnological tools for clonal propagation and supply of genetically superior trees of Neem, Ardu and Bamboo (AFRI)

Micro-propagation protocol developed for Neem (*Azadirachta indica*) and Bamboos (*Dendrocalamus asper* and *D.hamiltonii*) were transferred to State Forest Department,



(a) View of germplasm bank in the TFRI campus, (b) propagation of *Bambusa tulda* in mist chamber and (c) transfer of *B. vulgaris* plants in polythene bags.



Gujarat. Trainings were imparted to SFD staffs for handling tissue culture technology and using the protocol developed to produce tissue culture bamboo plants. Nearly 5000 in vitro shoots were supplied and these were further multiplied at SFD-Gujarat. Macro-propagation of neem was also attempted.

Benefits of the research: Tissue culture technology of neem and bamboo (*Dendrocalamus asper* and *D.hamiltonii*) were demonstrated and transferred to SFD, Gujarat, which will be utilized for multiplication of superior trees of neem and bamboos. Adaption of macro and micro propagation technology will lead to production of quality clonal planting material there by ensuring better financial gain.

Development of technologies for multiplication of economically important desert plant - *Capparis decidua* (AFRI)

Tissue culture protocol for *Capparis decidua* (Kair) developed starting from axillary bud culture, *in-vitro* shoot multiplication and *in-vitro* rooting of shoots. Tissue culture raised plants were hardened in mist chamber and kept in shade house for acclimatization.

Benefits of the research: Developed micro propagation protocol for higher fruit yielding trees of *Capparis decidua*. High fruit yielding trees of *Capparis decidua* can be multiplied through tissue culture.

5.4 Biotechnology

Development of methods for functional analysis of genes involved in salt tolerance in *Eucalyptus tereticornis* (IFGTB)

A composite transgenic system with a transformation efficiency as high as 61% was developed in *Eucalyptus* for functional analysis of genes in transgenic roots that develop on non-transgenic shoots. This technique has been adapted by another research group in France for functional analysis of lignin genes in *Eucalyptus*. For the first time, it is found that the composite transgenic system is suitable for rapid screening of genes conferring salt tolerance in *Eucalyptus*. Using this strategy, it was determined that transgenic silencing of a sodium transporter gene in roots significantly increases salt tolerance of *Eucalyptus*.

Benefits of the research: A composite transgenic system for rapid functional analysis of genes in *Eucalyptus* has been developed. Composite transgenic strategy was used to silence a sodium transporter gene in the roots, which resulted in enhancing salt tolerance of the plantlets by >75 mM NaCl.

Incorporating resistance in *Eucalyptus* to *Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae) through expression of insect-specific dsRNA

(IFGTB)

NGS derived sequence data of *L. invasa* was analysed and lin-mir-3p-6273 was identified as a potential miR that regulates 262 genes in *L. invasa*. Furthermore, synthesized a unique 794 bp multigene silencing construct for developing RNAi based control of *L. invasa*.

Benefits of the research: A 794 bp multigene targeting hpRNAi construct has been designed, synthesised and confirmed by sequencing, restriction digestion. *Eucalyptus* RNAi transgenics for insect resistance.

Patents generated:

- a. An accessory for gene delivery into live plants.
- b. *Leptocybe* specific multigene targeting silencing construct.

DNA barcoding of *Pterocarpus* species (Red sanders) (IFGTB)

A barcoding primer Ribulose-1,5-bisphosphate carboxylase oxygenase (rbcL) with a product size of 650bp was optimized in *P. santalinus*.

Benefits of the research: Genomic DNA was isolated from leaves of *Pterocarpus santalinus* plantation population. Specific DNA fragment size (650bp) was sequenced. The new



sequences of the population is useful for development of barcode of this species.

Cytogenetic analysis of selected native tree species (IFGTB)

Basic methodologies were standardized to visualize the chromosome preparations of *Ailanthus excelsa* (Maharukh/ Mahaneem) and *A. triphysa* (halmaddi). Procedures for genome size estimation in *A. excelsa* were standardized.

Benefits of the research: Chromosome numbers and genome size estimation will benefit the ongoing tree improvement activities.

Development of descriptors and DUS testing guidelines for indigenous forest tree species [*Tectona grandis* (Teak) and *Melia dubia* (Malabar Neem/ Malai Vembu)] and establishment of Field Gene Bank (IFGTB)

Morphological descriptors were observed in different locations for developing DUS characters in natural populations and plantations established by the forest department and farmers. Variability within a plantation was found to be low in teak with respect to leaf, bark, flower and fruit characters. Some amount of variability was observed in the natural populations. The tree stem form, leaf, branching habits and reproductive characters were found to be the most effective discriminating characters. A draft DUS guideline is under preparation.

Benefits of the research: DUS test guidelines have been developed in Teak and *Melia*. These guidelines are required for the PPV&FRA for notification of these species for conducting the DUS tests and registration of varieties in these species for IP protection.

Development of descriptors and evaluation of artificial inoculation in *Aquilaria malaccensis* (RFRI)

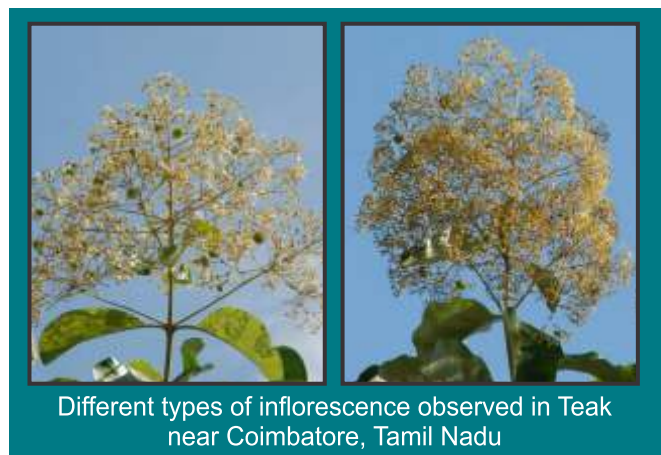
Three variants based on leaf morphology have been identified. Artificial inoculation of fungi was found successful to induce agar wood formation in two of the variants. The study will identify the morphological descriptors for

A. malaccensis (Sanchi, Agar, Agarwood) with special reference to the traditionally known subtypes namely Bholi and Jati. These descriptors would be useful while registering any clone developed, for the purpose of IPR protection. The study will also document the differences in response to artificial inoculation of fungi for agarwood formation, and help in identifying the variants that are prone to infection.

Benefits of the research: The germplasm being collected under the study will aid in conservation of this threatened species. The economic benefit from the study will be of immense use for the large number of farmers planting agarwood and the industries that are engaged in agarwood oil extraction and export.

Development of gene markers for high seed oil content and dissecting molecular basis of female flower development in *Jatropha curcas* towards its genetic improvement for high seed yield (HFRI)

Under the project, the institute has maintained the field trials of *Jatropha curcas* (Ratanjot, Jablota) established earlier at Majauli, Bhojnagar and Samloe and recorded various parameters in the field jointly with researchers of collaborative partner, Jaypee University of Information Technology (JUIT). Collected



seeds from various sites and provided to Network partner for further studies. Established 500 plants from selected *Jatropha curcas* cuttings in Bir Plassi nursery Nalagarh, Solan.



Plantations (0.1ha each) have been established at two locations namely Thakurdwara, Nalagarh and Jawalaji, Kangra during January 2016 with the selected material raised at Nalagarh for future studies.

Benefits of the research: Development and establishment of demonstration plantation of *Jatropha curcus* for future use.

Assessment of genetic structure, linkage disequilibrium and marker-wood trait association in CPTs of teak (*Tectona grandis* L.f.) maintained at National Teak Germplasm Bank, Chandrapur (M.S.), using molecular markers (IFP)

Genomic DNA of plus trees of teak maintained at Chandrapur are being extracted. Meanwhile, PCR assay for amplification of SSRs markers and candidate genes are being standardized.

Benefits of the research: The research would help assist teak tree improvement programme that would lead to enhancement of productivity and quality of timber wood. The technique would be expected to facilitate selection of superior planting stock at an early seedling age, thereby increasing financial gain per unit area. A patent or intellectual property right (IPR) may be feasible for DNA marker probe for identification of superior teak seedlings.