PHYSICAL PROGRESS REPORT OF THE SCHEME

"STRENGTHENING FORESTRY RESEARCH FOR ECOLOGICAL SUSTAINABILITY AND PRODUCTIVITY ENHANCEMENT"

Submitted by

Indian Council of Forestry Research and Education, Dehradun

(Progress Report as on 31-5-2023 of the scheme "Strengthening Forestry Research for Ecological sustainability and Productivity Enhancement" funded by National Authority CAMPA)

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Contents

Abbreviations

ACZ	Agro-Climatic Zones
AFRI	Arid Forest Research Institute
AICRPs	All India Coordinated Research Projects
ARI	Agharkar Research Institute
ATREE	Ashoka Trust for Research in Ecology and the Environment
BBA	Borax-Boric Acid
BU	Bharthidasan University
Cdh	Choline dehydrogenase
CDZ	Cauvery delta zone
CFPR	Centre for Forest Policy Research
CoA	College of Agriculture
CPCs	Candidate Plus Clumps
CPMB	Center for Plant Molecular Biology
CPPRI	Central Pulp & Paper Research Institute
CPT	Candidate Plus Trees
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Central Statistics Office
DLS	Dynamic Light Scattering
DLS	Dynamic Light Scattering
DNA	Deoxyribonucleic acid
DWR	Directorate of Weed Research
ERT	Electric Resistance Tomograph
FA	Furfuryl alcohol
FCRI	Forest College and Research Institute
FDC	Forest Development Corporation
FID	Forest Identification
FGR	Forest Genetic Resources
FRCER	Forest Research Centre for Eco-Rehabilitation
FRI	Forest Research Institute
GBH	Girth at Breast height
GC-MS	Gas chromatography–mass spectrometry
GCP	Ground Control Point
GDP	Gross Domestic Product
GFM	Gass Forest Museum
GPR	Ground-penetrating radar
HFRI	Himalayan Forest Research Institute
HRM	Heat Ratio Method

Abbreviations

IAPS	Invasive Alien Plant Species
ICAR-KVK	Indian Council of Agricultural Research- Krishi Vigyan Kendra
ICAR-NBPGR	Indian Council of Agricultural Research -National Bureau of Plant Genetic Resources
ICFRE	Indian Council of Forestry Research and Education
IFB	Institute of Forest Biodiversity
IFGTB	Institute of Forest Genetics and Tree Breeding
IFP	Institute of Forest Productivity
IIFM	Indian Institute of Forest Management
IISc	Indian Institute of Science
ITS	Internal Transcribed Spacer
IWST	Institute of Wood Science and Technology
JFMCs	Joint Forest Management Committees
KFRI	Kerala Forest Research Institute
LULC	Land Use / Land Cover
MLT	Multi locational trial
MOUs	Memorandum of Understanding
NBRI	National Botanical Research Institute
NCCF	Network for Certification and Conservation of Forests
NIH	National Institute of Hydrology
NPC	National Project Coordinator
NTFP	Non Timber Forest Products
PAU	Punjab Agriculture University
PCA	Principal Component Analysis
PCCF	Principal Chief Conservator of Forest
PDO	Panchayat Development Officer
PEG	Project Expert Group
PPVFRA	Protection of Plant Varieties and Farmers' Rights Authority
QPM	Quality Planting Material
RFRI	Rain Forest Research Institute
SAMEER	Society for Applied Microwave Electronics, Engineering and Research
SAW	Simple Additive Weighting
SDAU	Sardar KrushinagarDantiwada, Agricultural University
SDM	Species distribution modeling
SDS	Sand Dune Stabilisation
SEM	scanning electron microscopy
SFDs	State Forest Departments
SFRI	State Forest Research Institute

Abbreviations

SSD	Single Shot Detector
SSNCE	Sri Sivasubramaniya Nadar College of Engineering
SVU	Sri Venkatrswara University
SWAT	Soil and Water Assessment Tool
TAFCORN	Tamil Nadu Forest Plantation Corporation Limited
TCC	Total Cyanogenic Content
TDC	Technology Demonstration Centre
TFRI	Tropical Forest Research Institute
TGA	Thermogravimetric analysis
TNAU	Tamil Nadu Agricultural University
ToFs	Trees Outside Forests
ToP	Terms of Payment
UoH	University of Hyderabad
UV	Ultraviolet
VVK	Van Vigyan Kendra
WPG	Weight per Gallon

"Strengthening Forestry Research for Ecological Sustainability and Productivity Enhancement"

Introduction of the scheme: To fulfill national commitments, ICFREwas funded scheme entitled "Strengthening Forestry Research for Ecological sustainability and Productivity Enhancement" by National Authority, CAMPA. The scheme works towards addressing the requirements of conserving the Forest Genetic Resources, enhancing forest productivity, strengthening of ecosystem services, sustainable use of resources, strengthening the extension of Forestry research through various scientific and technological interventions and capacity building of ICFRE personnel. The scheme is for 5 years was approved in 2020. The total outlay of scheme with 6 components is Rs. 313.67 crores.

Objectives of the Scheme are as under:

a) To undertake research aimed at enhancing the health and productivity of natural forests and plantations for augmenting ecosystem goods and services.

b) To undertake research aimed at efficient and sustainable resource use through value addition and development of appropriate technologies.

c) To establish a comprehensive national programme for conservation and development of Forest Genetic Resources.

d) To undertake policy research in forestry sector to analyze the policy gaps and determine concordant policies.

e) To undertake capacity building programmes for stakeholders, including forestry personnel, communities, tree growers and forest-based industries

f) To undertake an exclusive outreach programme taking research and technology to users through a comprehensive extension strategy

Components of the Scheme

i. All India Coordinated Research Projects (31 AICRPs) in collaboration with ICFRE and Non-ICFRE Institutes

ii. Programme for Conservation and Development of Forest Genetic Resources (FGR)

iii. Policy studies under Centre for Forest Policy Research

iv. Capacity Building of State Forest Departments for developing "State REDD+ Action Plans" under National REDD+ strategy

v. Operationalization of Forestry Extension Strategy and Action Plan of ICFRE

vi. Operationalization of Human Resource Development Plan of ICFRE

Component I:

All India Coordinated Research Projects
(31 AICRPs)

Component- I AICRPs

1. All India coordinated Research project on "Testing and deployment of clones and seed sources of Casuarina for different planting environments and end-use applications"

1.1 Objectives:

- To evaluate clonal / family accessions for suitability to coastal, inland, waterlogged, salt-affected areas and other potential environments.
- To screen accessions for suitability to grow as nurse plants in Sandal plantations and as an alternative crop for Eucalyptus.
- To assess water and nutrient use efficiency of accessions and develop a package of cultivation practices for most productive of them.
- To evaluate the wood properties of new accessions for matching with different end uses.
- To develop and field test new hybrid combinations to select advance generation planting material for future deployment.

1.2 Progress:

The main aim of this project is to increase the productivity of *Casuarina* plantations through selection of site- and end use-specific planting material and thereby benefit farmers and wood-based industries. Two sets of field trials are taken up in the project:

(i) clonal trials with the accessions already released by ICFRE in new areas and for new end uses

(ii) family trials with a broad genetic base which will function as a source of next generation clones and also as a seed orchard.

The total number of clonal trails established in different states is 20 (Andhra Pradesh, Karnataka, Gujarat, Haryana, Jharkhand, Madhya Pradesh, Tamil Nadu, Telangana and Uttar Pradesh). The planting material required for establishing the trials were produced in IFGTB, Coimbatore and supplied to different Institutes. Survival and growth data have been recorded from the trials periodically. Current status of establishment of clonal trials by the participating Institutes is given below in Table -1.

Table 1: Details of total number of clonal trials established: 20

Institute	No. of trials	Location of clonal trials
Multilocation clonal tests		
IFGTB	3	Ariyalur and Palapattu, Tamil Nadu; Navsari AU, Gujarat
FRI	3	Shajanpur, UP; Gillakhera and Seonthi, Haryana
AFRI	1	Mahuva, Gujarat
TFRI	3	TFRI Campus, CoA, Balaghat, and KVK, Umaria, MP

IFP	2	Arid and Chandwa, Jharkhand
IFB	3	Kondapuram, Nellore, AP; Dulapally, Telangana, Thimmapatnam, Kadappa, AP
Total	15	
		Sandal-Casuarina Trial
IWST	1	Hosekote, Karnataka
		Clonal trial in Eucalyptus area
IWST	2	Shimoga and Bellary, Karnataka
		Clone-proving trials with new hybrid selections
IFGTB	2	Katrambakkam, Mondipatti, Tamil Nadu

Progeny trails established: 12 progeny trails have been established in different states for *Casuarina junghuhniana* (CJ) and *C. equisetifolia* (CE). The details of the progeny trails are given in table -2

Table -2: Details of progeny trails established

Institute	No. of trials	Location of areas identified for planting	Month & year of planting	Remarks
IFGTB	3	Chettinadu, TN Kagithapuram, TN Mondipatti, TN	September 2021 October 2022 December 2022	112 families (CJ) 30 families (CE) 126 families (CE)
FRI	4	Shajanpur, UP; Kalanaur, Gillakhera and Hisaar, Haryana	July 2021 October 2021	96 families (CJ)
TFRI	1	Umaria, MP	September 2021	80 families (CJ)
IFB	2	Mulugu, Telangana Kavali, Nellore, AP	September 2021 October 2022	80 families (CJ) 98 families (CE)
IWST	2	Nallal, Gotipura, Karnataka	January 2023	45 families (CJ) 70 families (CE)
Total	**12**			

Open-pollinated seeds were collected from 120 CPTs selected from the existing first / second generation breeding populations of *Casuarina junghuhniana*. Nursery raised with the family seedlots at IFGTB and FRI to produce planting stock for establishing progeny trials. So far eight progeny trials established in the States of Haryana, Karnataka, Madhya Pradesh, Tamil Nadu, Telangana and Uttar Pradesh with 45 to 112 families each. Similarly, 126 open-pollinated families of *C. equisetifolia* have been assembled from breeding orchards within India and abroad. Procured seeds from

Fig. 1 Clonal variation in growth and stem form (age: 18 months) in clonal trial at Arid, Jharkhand (IFP)

Kenya Forestry Research Institute, Nairobi, Research Institute for Tropical Forestry, Guangzhou, China and YSG Bioscape, Malaysia. China, Kenya and Malaysia through Import permits obtained from ICAR-NBPGR. Raised 10,000 seedlings and planted four progeny trials during 2022-23 with 70 to 126 families each. **Two hybrid clonal screening trials and two clone-proving trials were established to select new high-yielding clones for future deployment in plantations. Promising clones shortlisted based on early growth have been assembled in a VMG for continuous production of planting stock for further testing.**

Highlights

- 20 clonal trials raised in 09 states across the country (survival rate 80%). Clone CH5 showed consistent superior growth and recommended for cultivation in test locations.
- 12 progeny trials raisedin 07 states across the country with a broad genetic base (130 families) which include germplasm imported from China, Kenya and Malaysia (survival rate 87%).
- Two hybrid clonal screening trials and two clone-proving trials were established (TN, AP) to select new high-yielding clones for future deployment in plantations.
- Promising clones (H3, H8, PV26 and PV27) showing early growth on-par or better than benchmark clone (CH5) have been assembled in a VMG for continuous production of planting stock for further testing.
- The clonal trials in Andhra Pradesh and Tamil Nadu were established in farmers' land as on-farm trials and also in collaboration with Andhra Paper Limited and Tamil Nadu Newsprint and Papers Limited through their farm forestry programmes.

2. All India coordinated Research project on"Bamboo"

2.1 Objectives:

- Genetic improvement through identification of superior clumps, mass multiplication and ex-situ conservation
- Development of package and practices for better clump management, harvesting, development of bamboo seed storage protocols, strategies for management of pre and post flowering resources, analysis of bamboo phylogeny
- Development of processing and preservation techniques for bamboo, bamboo composites and evaluation of bamboo germplasm for structural, strength and pulp properties.
- Development of strategies for management of pests and diseases, extension and technology transfer

2.2 Progress:

- Extensive field surveys were carried out in various forest areas of Uttarakhand, Himachal Pradesh, Rajasthan, Gujarat, Odisha, Jharkhand, Bihar, West Bengal, and the North-East states to find potential genotypes of various bamboo species.
- More than 325 new CPCs of several bamboo species were selected across the country and the superior clumps were mass propagated for their dissemination to the users. Macro- propagation of superior germplasm of selected bamboo species has been carried out and Rhizome bank of different bamboo species have been established at FRI, IFGTB, HFRI, and IFP Ranchi. A Multi Location Trial (MLT) of superior germplasm of *Dendrocalamus strictus* was established at Kotiya (Raebareli), Uttar Pradesh by FRI Dehradun. RFRI enumerated 43 accessions of *Bambusa balcoo*a, 65 accessions of *B.tulda,* 8 accessions of *B. nutans* and 07 accessions of *B. pallida.*

Fig. 2 Activities of MLTs and rhizome bank establishment

- For mass propagation, experiments for micro-propagation have been conducted in selected clumps of *B. cacherensi*s at RFRI, Jorhat *B. nutans*, *D. brandisii* and *D. stocksii* at IWST, *B.tulda, B. balcoa, B. nutans* and *B. polymorpha* and *D. strictus* at IFP Ranchi respectively. Micro-propagated plants of 6 selected bamboo species were hardened at IWST Bangalore and for two species viz. D. *strictus* and *D.hamiltonii* in-vitro root culturing and hardening carried out at IFP Ranchi. RFRI Jorhat produced and hardened 500 in vitro propagated plantlets of *B.tulda* (CPC-AP/BT/06) for planting. All of the cuttings and plant stocks are being maintained and regular tending operations are carried out. Standardization of propagation through culm cutting and macro- propagation in *Schizostachyum dullooa* with talc media (Talc+ IBA) at 1000 ppm formulation and obtained 91% rooting in *S. dullooa*. Macropropagation of *B cacharensis* were done with 200, 400, 800, 1000, 1200, 2000 ppm of talc formulation (Talc + IBA) and B. tulda were done at 400 and 800 ppm of IBA solution and recorded 55.5% of rooting in *B. cacharensis* at 1200 ppm of IBA. *S. dullooa* culm cuttings are macropropagated at 1000 ppm and talc paste were used as a treatment and sprouting started within 2 weeks. Culm cuttings of *B. balcooa* are macropropagated at 2000 and 200 ppm IBA talc formulation respectively.
- Different experiment viz. root initiation, shoot initiation and hardening related to In vitro propagation for mass multiplication of several elite genotypes of Bamboo were conducted IWST, RFRI, IFP and AFRI.
- In order to develop silvicultural practices for increased productivity stand /clump management and harvesting, existing mature clumps of different bamboo species have been identified for silvicultural treatments at all the participating institutes. For establishment of model plantations for demonstration and scientific cultivation, five demonstration plots have been established, one by FRI Dehradun at KVK Kashipur, three by RFRI Jorhat at Messamora gram panchyat office campus;

Namsai (Arunachal Pradesh), Deroi, Sibsagar district, Assam and one by TRFI Jabalpur.One more site selected for plantation of *Bambusa vulgaris* in Kotiya, Raebareli, UP. Thinning operation and soil loosening work in selected matured clumps in demonstration plots carried out. Data was recorded on different growth parameters, casualty replacement, soil working and application of fertilizer was done in the demonstration plantation established.

- For eco-distribution mapping, SENTINEL satellite data was utilized for the North Eastern hill states, detailed methodology was designed for LULC map generation of the states, namely Arunachal Pradesh, Assam, Manipur, Meghalaya, and Nagaland with 87.33% accuracy. The LULC map was completed for Ariyalur, Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kanniyakumari, Kallakurichi, Karur, Krishnagiri, Madurai, Namakkal, Nagapattinam, Nilgiris, Perambalur, Pudukottai, Ramanathapuram, Salem, Sivaganga, Tenkasi, Theni, Thoothukkudi, Thiruvarur, Trichirappalli, Tirunelveli, Triuppur, Virudhunagar district with 88.22% accuracy.
- For evaluation of Bamboo species for reclamation of salt affected lands, two Species trial (5 species each) established in salt affected areas of Prayagraj and Banda District of U.P. and one more field trial established with 10 bamboo species at Prayagraj. For evaluation of Bamboo species for reclamation of coal mined affected area, two species trials having 13 bamboo species in each site established at Tirap colliery of NE Coal fields and Makum coalfields. Similarly, a third site for plantation has been identified at Ledo, OCP of North Eastern Coal Field Ledo, Tinsukia, Assam. For development of Bamboo based multipurpose windbreak models, three windbreak model plantation have been established in wind affected areas each at Champaknagar, West Tripura; Gaburcherra, South Tripura district and Lembucherra, Tripura using *Thyrsostachys oliveri* and *Bambusa polymorpha.* Selection of cover crops for plantation/cultivation were done and MPTs namely; *Parkia timoriana, Emblica* officinalis etc. were planted at Lembucherra Site. Second year data pertaining to height of leading shoot, No. of nodes and internodal length etc collected from established trials.
- Disease survey methods were standardised. Insect and Disease surveys conducted in bamboo nurseries and plantations across various regions in northern, central and North-eastern India and collected damage causing insects/diseased samples of different bamboo species and isolated pathogen and cultured. Pathogenicity tests conducted. Life cycles of bamboo borers, defoliators and grasshoppers were recorded. The species *Murraya koenigii* and *Ageratinaa denophora* were tested for antifungal potential against fungal isolates from diseased bamboo samples. It was found that 1.5% extract of *Murraya koenigii* was most inhibiting against Pestalotiopsis followed by Alternaria and Fusarium. Whereas, 1.5% extract of *Ageratinaa denophora* was most effective against Alternaria followed by Fusarium and Pestalotiopsis. Survey was conducted in social forestry bamboo nursery and plantation at Bhanupratappur, Rajnandgaon, Chilpi, Taregaon and Rengakhar (C.G.) and observed termites and borers damage on bamboo species *D. strictus, B. tulda* and *B. arundinacea* and recorded incidence of insect pests and collected various types of damage symptoms. A field tour was conducted in the district of Rudraprayag at Maikoti Nurasary, Chamoli at Gopeshwer, Mandal, chopta, Ukhimath and Terhi district. The diseased samples of Hill bamboo i.e. *Drepanostachyum falcatum* and *Thamnocalamus spathiflorous* showing leaf spot, culm spot and culm stain were collected. The pathogens were isolated, sub-cultured and purified

for future work. Regular surveys were carried out in Haryana and Uttarakhand in different bamboo nurseries, plantations and storage to check for the infestation levels of different insects. Rearing of *Lyctus africanus, Stromatium barbatum* and *Plagiorhynaus crassicollis* in wooden, chimney and in outdoor cages is being continued. Life cycle of for *Crypsiptya coclesalis, Hieroglyphus banian* and *Pionea flavofimbriata* are completed and data is compiled. Chemical control trials were laid out in bamboo nurseries for the control of the defoliators using three contact insecticides namely Cypermethrin+Chlorpyriphos, Spinosad and Cypermethrin at different concentrations. The results showed that Cypermethrin+Chlorpyriphos was found to be most effective at 0.04 per cent concentration with 71.63% control for C. coclesalis and 71.03% control of *H. banian.* Cypermethrin+Chlorpyriphos was found to be most effective at 0.08 per cent concentration with 76.20% control for *P. flavofimbriata.*

- Protocol for determination of total cyanogenic glycosides content of edible bamboo shoots by picrate paper method standardized. TCC and antioxidant assay carried out for species *B. tulda, B. balcooa, B. nutans, B. bamboos, D.hamiltonii, Melocanna beciferra* collected from various sites.
- Prepared list of morphological traits to be used for taxonomic and anatomical studies. Morphological data recorded depicting different characters of total 62 (16+46) species viz. *M. baccifera, D. falcatum, B. polymorpha, B. vulgaris var. striata, B. vulgaris, B. tulda, B. bambos, B. multiplex, S. pergracile, D. giganteous, D. longispathus, D. membranaceus, D. strictus, D. somdevai, T. oliveri* and *B.vulgaris cv. Wamin.* Anatomical data (Total 10 species) such as types of vascular bundles and epidermal peel characters (stomata, long cells, short cells, macro hairs, prickles and silica bodies) of *Dendrocalamus giganteus, Dendrocalamus membranaceus, Dendrocalamus longispathus, Bambusa multiplex, Bambusa tulda, Bambusa vulgaris* var. *wamin, Bambusa vulgaris* var. *striata, Bambusa vulgaris, Bambusa bambos,* and *Bambusa nutans,* were analysed.
- For molecular characterization and population genetic studies, leaf samples of selected bamboo species were collected and standardization of DNA isolation protocols has been completed in several bamboo species viz. *Ochlandra travancorica, B. balcooa, Dendrocalamus longispathus, B. vulgaris, B.tulda, B.bambos.* Development of polymorphic SSRs is in progress in various ICFRE institutes for genotyping works. A total of 21596 SSRs were successfully developed in the de novo assembled genome of *D. longispathus*. A subset of 50 primer pairs was synthesized for validation through PCR amplification and polymorphism survey, 36 were successfully validated and 16 showed polymorphism across the samples. All the polymorphic primers were also tested for their cross-transferability in 29 other bamboo taxa. Genomic DNA was extracted from all the populations of *Phyllostachys mannii* and *Chimonobambusa callosa*, and work is under progress for the rest. Qualitative and quantitative analysis of gDNA was carried out using agarose gel electrophoresis and spectrophotometer, respectively. A total of six populations of *Dendrocalamus longispathus* have been received out of which 4 populations have been genotyped with 13 polymorphic SSRs and work is under progress for remaining populations. Developed EST-SSR markers through denovo transcriptome assembly. Based on transcriptome sequencing 176215 mono, di, tri, tetra, penta and hexa SSR were predicted. Estimation of genetic diversity of B. balcooa using EST-SSR marker in

Northeast India completed and identified 3 distinct populations. Completed genetic diversity of *B. balcooa* in Northeast India. Tested transferability of 27 EST-SSR in *S. dullooa* and *M. baccifera.* The species of *Bambusa bambos* from Western ghats and Eastern ghats populations were profiled for ten polymorphic SSR primers for population genetic analysis. The populations of *Ochlandra travancorica, Dendrocalamus stocksii, Dendrocalamus brandisii* from Kerala Forest Research Institute germplasm bank DNA was extracted for SSR profiling. The species *Ochlandra travancorica* was genotyped with ten polymorphic SSRs for the KFRI accessions.

- DNA bar coding work, which has been initiated for 21 bamboo species (*P. aurea, Drepanostachyum falcatum, B. polymorpha, B. vulgaris* var. *wamin, D. longispathus, D. membranaceus, D. somdevai, D. strictus, Gigantochloa atroviolacea, G. albociliata, Guadua angustifolia, Melocalamus maclellandii, Melocanna baccifera, Thyrsostachys oliveri, B. tulda, B. multiplex, B. bambos, B. nutans, Schizostachyum pergracile and B. vulgaris* var. *striata*). DNA barcoding markers (rpoC1, rpoB, trnH–psbA, TrnL-F, TrnK-psbA, trnC-rpoB, trnD-trnT, trnT-trnL, atpF- H, PsbK-psbI, ycf1 and NdhF) synthesized. 80 samples (purified PCR products) of ten bamboo species i.e. *Bambusa bambos, Bambusa multiplex, Bambusa nutans, Bambusa polymorpha, Bambusa tulda, Bambusa vulgaris* cv. *wamin, Bambusa vulgaris* var. *striata, Dendrocalamus longispathus, Dendrocalamus membranaceus,* and *Dendrocalamus somdevai,* which were amplified initially, with primers i.e. ndhJ F1R1, ndhJ F2R2, ndhF, and psbK-I have been sent for the DNA sequencing in both directions with forward and reverse primer. The chromatograms (DNA sequence files) were examined manually for peak quality, and poor-quality sequence data (mixed or overlapping peaks). The sequence reads obtained from the forward and reverse primers were assembled into a single continuous sequence using the BioEdit Sequence Alignment Editor, and ambiguous sites were checked and corrected manually by using original chromatograms for further analysis.
- Seed storage protocols at various temperature and moisture/desiccation levels are being standardized. Viability of seeds of *B. bambos* and *D. strictus* under storage at different temperature (ambient room temperature and 50C) and two moisture contents (7 % and 10 %) evaluated. The seeds of *B. bambos* stored at 50C with 7 and 10% moisture maintained 85% viability after 22 months in storage conditions and the ones stored at ambient room temperature, completely lost viability . Seed storage trials of *Bambusa bambos* continued; seeds stored at 5°C temperature at 10% and 7% seed moisture content recorded above 85% germination after 22 months in storage conditions, which appeared to be suitable for short-term storage of the seeds of the species
- *Bambusa bambos* two year- two month's and one year-ten month's old seeds collected from the Eastern and Western Ghats respectively exhibited maximum germination efficiency of about 70%–80% when stored at 10°C in Zip lock covers, followed by Western Ghats seeds stored at 3°C and -20°C that showed high germination. Cell membrane electrolyte leakage was greater in Eastern Ghats Bamboo seeds compared to Western Ghats seeds, measured via an electrical conductivity meter. Moisture content obtained by dry heat method, reveals that Western Ghats *Bambusa bambos* seeds hold less moisture than Eastern Ghats bamboo seeds. The seeds of *Dendrocalamus longispathus* and *Bambusa tulda* were received from Tripura Bamboo Nursery and bamboo society

of India respectively. The seed morphological parameters such as seed length, seed width, seed Index had been recorded using vernier calliper, optical microscope and electronic weighing balance. Moisture content of fresh sample also has been determined using traditional oven method and moisture analyser. TZ test were done to check the viability of different bamboo seeds.

- 170 accessions belonging to 58 bamboo species have been assembled for establishing field gene bank and are being maintained.
- All India Bamboo Flowering Database is under development. Information on the flowering records across the country is being collected. Flowering in *B. nutans* was recorded at two different times, and two different locations, at FRI Campus. Herbarium specimen in the flowering stage of *B. nutans* was prepared and submitted to DD Herbarium for authentic identification and record. Photo plates depicting different parts have been prepared and a flowering report of *B. nutans* was added to the bamboo flowering database. Flowering reports of total 48 bamboo species from different parts of the country were incorporated in the flowering database. Recent flowering data collected from different locations of northeast India. In 2023, sporadic flowering was observed in *D. longispathus* (Manipur and Mizoram), *S. dullooa* (Mizoram), *S. pergracile* (Assam), *B. bamboos* (Assam), *B. balcooa* (Assam), and *D. hookeri* (Meghalaya). Secondary data collected from literature and updated flowering database. Recorded flowering database on following bamboo species. (*Bambusa bamboos, Schizostachyum dullooa, Dendrocalamus longispathus Dendrocalamus hamiltonii, Bambusa tulda, Bambusa balcooa, Bamusa nutans, Bambusa vulgaris, Bambusa pallida, Dendrocalamus giganteus, Melocanna baccifera, Gigantochloa andamanica, Schizostachyum pergracile, Arundinaria racemose, Melocalamus compactiflorus, Dendrocalamus sikkimensis, Dendrocalmus latiflorus, Dendrocalmus hookeri, Chimonobambusa callosa, Bambusa mizorameana, Bambusa arundinacea, Bambusa multiplex, Arundinarea manii, Sinarundinarea falcate, Dendrocalamus patellaris, Schizostachyum polymorphum, Thamnocalamus aristatus, Sinarundinaria maling, Sinarundinaria hookeri, Schizostachyum fuschiianum,* and *Sinarundinaria griffithiana*).
- Newly Developed and installed bamboo bending testing machine has been optimized with loading belt. Testing with *Dendrocalmus strictus* initiated. A new four-point bamboo bending testing machine designed, developed, installed and commissioned for testing large size bamboo pole (length-30 times of diameter) as per new Indian standard IS:6874(2008) and International standards ISO:22157 (2004/2019).
- De-structured bamboo boards of *Dendrocaamus somdevii, Dendrocalamus membranaceus* and *B. tulda* were prepared with various pressure levels viz; 21.0 24.5, 28.0, 31.5 kg/cm2 and physical and mechanical testing carried out. Physical (Water absorption, General swelling, Moisture content, and Density) and mechanical tests (Modulus of rupture, Modulus of elasticity, Compression parallel to the grain, Screw withdrawal, and Hardness) of prepared boards of *Bambusa tulda* were carried out as per IS 1734 and 1708.
- For the protection of in-service bamboos through fumigation of eco-friendly preservatives, fungi static and fungicidal property of Neem and Pongamia pinnata seeds oil against identified fugal

strains were tested. Fumigation of *B. balcooa, D strictus* and *B. tulda* with 5%, 10% and 15% of Neem seed oil (NSO) and Pongamia seed oil (PSO). Determination of retention after fumigation/ treatment. Soil block bioassay of *B. balcooa B. tulda* and *D. strictus* fumigated with Neem seed oil with the fungus Poria monticola. Result shows upto 70% protection with 15% concentration of NSO. Soil block bioassay of *B. balcooa, B. tulda* and *D. strictus* fumigated with Pongamia seed oil with the fungus Pycnoporus sanguineous. Result shows upto 75% protection with 15% concentration of PSO. Efficacy evaluation of fumigated bamboo species with NSO against sap stain fungus is under progress.

- Total 24 CPCs of *D. strictus* are being studied for pulping characteristics. Proximate chemical analysis of the 28CPCs has been carried out. Among all the culms assessed so far, maximum Kraft pulp yield was recorded for CPC- 6-16 (54.85% at 16% alkali charge; 53.15% at 18% alkali charge; 50.58% at 20% alkali charge) followed by CPC-10-4 (54.43% at 16% alkali charge; 50.89% at 18% alkali charge; 48.06% at 20% alkali charge) and CPC-6-20 (53.78% at 16% alkali charge; 50.40% at 18% alkali charge; 50.30% at 20% alkali charge). Eight CPCs of *D. strictus* have been collected from the field, converted into chips and processed for further analysis. In eight processed CPCs of *D. strictus*, moisture content, ash content, silica content, cold water solubility, hot water solubility, alcohol- benzene solubility, 1% NaOH solubility, acid insoluble lignin, holocellulose content**,**

  cellulose content was determined TAPPI standard methods. Kraft pulping of seven CPCs of *D. strictus* at 16%, 18% and 20% chemical charge has been completed. Total pulp yield, rejects, screened pulp yield of all six collected samples were estimated. Kappa number of seven pulped samples (5-16, 8-18, 5-2, 4-4, 8-18, 17-17, 17-9) obtained from different pulping conditions at 16%, 18% and 20% chemical charge has been determined.

- Established five Bambusetum/ Germplasm bank/bambusetum, one each at IFP Ranchi campus and its Mander Research station, two bambusetums established by FRI Dehradun each at PAU Research Farm, Ladowal (Punjab) with 18 species and at Mansa in Research Farm of ICAR-IISWC (Indian Institute of Soil and Water Conservation), Chandigarh with 21 species, one at TFRI Jabalpur campus with 37species and one at Assam (RFRi Jorhat) with 27 bamboo species, A bambusetum was established by IFGTB with 44 species at Iduvai Village, Tirupur District, Tamil Nadu. Training on "Cultivation, Seasoning, Preservation and Utilization of Bamboo" was conducted jointly with BEEM Rural Development Organization, Korategere on 10 March 2023 at, Open Jail, Devanhalli. Bangalore Rural District. About 80 Prisoners (farmers) and jail staff participated in the program.

Highlights

- 325 new CPCs of 12 bamboo species selected and were mass propagated for their dissemination to the users. Established Rhizome banks of selected clumps at FRI, IFGTB, HFRI & IFP.
- Protocol for micro-propagation of 9 different bamboo species and their CPCs standardised. In vitro starter cultures for 4 species (*B. tulda, D. asper, D. stocksii* and *D. brandisii*) produced and sold. Produced 10,000 hardened plants for dissemination. 15 bamboo species tested for reclamation of salt affected lands at Prayagraj and Banda District of U.P. 13 Bamboo species tested for reclamation of coal mined areas of Makum Coalfield, Tirap colliery NE Coal Fields ,Ledo, OCP, NE Coal Fields Tinsukia, Assam.
- Bamboo based wind break models developed for the high wind affected areas of Tripura. Three windbreak model plantation established in wind affected areas each at Champaknagar, West Tripura; Gaburcherra, South Tripura district and Lembucherra, Tripura using *Thyrsostachys oliveri* and *Bambusa polymorpha*.
- De-structured bamboo boards of *Dendrocaamus somdevii, Dendrocalamus membranaceus* and *Bambusa tulda* were prepared and their physical and mechanical properties tested as per Indian Standard 1708 and found suitable for structural purposes.
- Total 24 CPCs of *D. strictuss* studied for pulping characteristics. Maximum Kraft pulp yield was recorded for CPC-6-16, CPC-10-4 and CPC-6-20.
- Seed storage protocols developed for *Bambusa bambos* and *Dendrocalamus strictus*.
- For establishment of model plantations for demonstration and scientific cultivation, five demonstration plantations have been established. The LULC map for north-east states with 87.33% accuracy & Tamil Nadu with 88.22 % accuracy completed.
- Design & developed a bending testing machine capable of testing bamboo up to 40 feet length as per new Indian standard IS:6874(2008) and International standards ISO:22157 (2004/2019).
- For biological control of bamboo diseases, 1.5% extract of *Murraya koenigiiwas* found most inhibiting against *Pestalotiopsis* followed by *Alternaria* and *Fusarium* (the most prevalent nursery disease causing leaf spot and blight in bamboo). Established six bambusetums at different locations for demonstration and their ex-situ conservation.

3. All India coordinated Research projecton "Conservation, improvement, management and promotion of Sandalwood (*Santalum album* Linn.) cultivation in India"

3.1 Objectives:

Establishment and evaluation of base population in sandalwood for breeding and conservation programs. Development of sandalwood based agroforestry system and its promotion in selected agroclimatic zones of India. Evaluation of heartwood formation, yield and chemical profiling of oil in sandalwood population

3.2 Progress:

- Developed guidelines for collection and evaluation of sandal germplasm; establishment of sandal-based agroforestry system and collection of wood core sample for estimation of oil and chemical profiling.
- Populations were identified from Rajasthan (5); Tamil Nadu (11) and Karnataka (26) 460 (Tamil Nadu) and 281 (Karnataka) trees were marked and nursery with single seed selections was raised with 105 seed lots (ICFRE-IFGTB), 103 seed lots (ICFRE-IWST) and 10 bulked seedlots (ICFRE-AFRI).
- The first Methylated cytosine map of *S. album* wood and leaf was generated.
- Integrated RNA-miRNA analysis conducted in leaf and wood tissues and post-transcriptionally regulated genes involved in sesquiterpene pathway and climate adaptation was identified and validated using stem loop quantitative reverse transcriptase–PCR.
- The first set of genome-wide SSR markers were short-listed and thirty 6-FAM labelled polymorphic SSR primers were genotyped in diverse sandalwood populations from Kerala, Tamil Nadu, Madhya Pradesh, Karnataka and Odisha.
- Aseptic in vitro cultures were established from nodal explants and axillary shoot induction was achieved from 12 genotypes with 47 to 97% success while adventitious shoots were induced from 8 genotypes with genotype-wise success ranging from 13 to 100%. Somatic embryo induction from callus and embryo maturation was achieved for 3 genotypes with 100% success.
- Established 12 sandalwood based agroforestry trials in Rajasthan (2), Gujarat (1), Madhya Pradesh (2), Tamil Nadu (3), Punjab (2) and Karnataka (2) with known seed sources. The net economic return from the intercrops in Sandalwood–Shisham-Guava agroforestry trial at Punjab was estimated at Rs. 62,724.00/ha from groundnut and Rs. 29,583.00/ha from cowpea. The economic return of finger millet from the trial established at H.D. Kote, Karnataka was Rs. 80,000.00/ ha while it was Rs. 36,350/ ha from maize/ mustard from trial raised at TFRI, Jabalpur.
- Information on existing agronomic and silvicultural practices and its effect on sandal growth were documented from 150 farmer's fields in 20 districts of Karnataka spanning 8 agroclimatic zones.
- Light traps were found to be an eco-friendly method for control and management of infestation by red stem borer (*Zeuzera coffeae*) on sandalwood.
- Survey was conducted in three states and incidence of sandal spike disease was assessed. Molecular diagnostic assay for SSD detection ascertained the transmission of the phytoplasma through seeds.

- Collected ERT data from 62 plantations and optimized the linear regression model using actual and ERT heartwood data and documented 90% similarity with R2 = 0.95.
- Carbon isotope composition (13C/12C) analysis of 169 wood samples using IRMS completed.
- Estimation of oil content and alpha and beta santalol content was completed in 159 and 100 samples respectively. The oil content by solvent method ranged from 0.25% to 8.25% while alpha santalol ranged from 8.36% to 54.8%. Beta santalol ranged from 3.71% to 23.4%.
- Estimation of oil content using spectrophotometer was completed in 176 samples and ranged from 0.37% to 6.62%.
- Estimation of essential oil extracted from the wood core using the conventional solvent method and an alternate spectrophotometric method revealed 85% correlation across both methods.

Fig. 3 Sandalwood nursery with single tree

Highlights

- Developed guidelines for collection and evaluation of sandal germplasm.
- 783 populations of sandal were identified. 03 Nurseries with single seed selections have been raised at ICFRE-IFGTB), ICFRE-IWST & ICFRE-AFRI.
- The study was done in two tissues (wood and leaf) and candidate miRNA-target transcripts were validated in 3 genotypes.
- Somatic embryo induction from callus and embryo maturation was achieved for 3 genotypes with 100% success.
- Established 12 agroforestry trials in Rajasthan (2), Gujarat (1), Madhya Pradesh (2), Tamil Nadu (3), Punjab (2) and Karnataka (2).
- Light traps were found to be an eco-friendly method for control and management of infestation by red stem borer (*Zeuzera coffeae*) on sandalwood.
- Collected ERT data from 62 plantations and optimized the linear regression model using actual and ERT heartwood data and documented 90% similarity with R2 = 0.95.
- The most suitable and rapid method for estimation of oil content in samples < 600 – 700mg is the UV-Vis spectrophotometric method.
- The agroforestry trials in Tamil Nadu (3), Karnataka (1) and Madhya Pradesh (1) were established in farmer's field. Additionally, survey in farmer's field is being conducted by all participating Institutes to document the sandalwood-based agroforestry models.
- The first set of genome-wide SSR markers were validated in diverse sandalwood populations and the first genome-scale map of DNA methylation in wood and leaf tissues was generated.

4. All India coordinated Research project on "Eucalyptus improvement"

4.1 Objectives:

- To identify the superior Eucalyptus clones across different regions
- To improve the growth vigour and adaptability of genotypes through Inter-specific hybridization.
- To identify and introduce new germplasm /species to suit various climatic conditions and end uses.
- To establish Progeny tested Clonal Seed Orchard for production of quality seeds
- To generate *Eucalyptus* transgenics/ transgrafts with enhanced salt and insect tolerance for confined field trials.
- Identification of secondary development specific miRNAs and polymorphism in their target sites for cataloging new molecular markers for wood formation in Eucalyptus tereticornis.
- To understand the water and nutrient requirement of Eucalyptus.
- To popularize new clonal varieties and assess the impact of the introduced clonal varieties.

4.2 Progress:

Established 14 Multi locational trails at different locations by ICFRE and other collaborating institutes (IFGTB, IFB, FRI, TFRI, AFRI, IFP, ERC). Based on progeny growth parents were selected and 12 hybrid combinations were made. Total 12 hybrid crosses generated and 3 field trials established with about 4000 hybrid plants. The selected 20 plus trees of *E. tereticornis* were multiplied and collected with pollen for hybridization from Panampally. Seedlings of 25 seedlots of 6 species were grown and one field trial for *E. pellita* and *E. urophylla* established in Thalamalai. *E. cloeziana* could not survive and three other specie s viz., *E. longirostrata, E. moluccana* and *E. sideroxylon* have been raised for planting.

Sl.No.	Place of trial	# clones	Area (ha)	Planting	Institute
1	TFRI Campus, MP	152	0.82	Aug, 2020	TFRI
2	Mulugu, Telangana	152	0.70	Sep, 2020	IFB
3	Chandwa, Latehar, Jharkhand	141	0.75	July, 2021	IFP
4	Bargi range, Jabalpur	200	1.00	July, 2021	TFRI
5	KVK, Pratapgarh, UP	159	0.65	Sep 2021	CSFER
6	Mulakalapally, Telangana	162	0.87	Sep, 2021	IFB
7	Thyagadurgam	225	1.00	Oct, 2021	IFGTB
8	Andimadam	232	1.00	Jan, 2022	IFGTB
9	Jaisalmer, Rajasthan	150	0.75	Aug 2022	AFRI
10	Soraon, Prayagraj, UP	86	0.35	Sep 2022	CSFER/FRI
11	Parsapalle, Telangana	152	0.70	Sep, 2022	IFB
12	Thimmalai	225	0.85	Nov, 2022	IFGTB
13	ARS, Mahua, Gujarat	180	0.80	Nov, 2022	AFRI
14	Linch, Mesana, Gujarat	180	0.80	Nov, 2022	AFRI

Selected 25 clones of *Eucalyptus camaldulensis* based on the progeny growth performance for raising the seed orchard. Collected seeds from CSO, Karunya and raised stock for grafting. Collected stem cuttings from selected 25 clones of Eucalyptus from CSO Karunya and CSO Kurumbapatty carried out grafting with a success of 41%. Established one CSO at Gudalur research station (1.0 ha).

Agrobacterium-mediated transformation experiments were initiated using CaMV promoter-driven EcHKT1;1hpRNA construct. Four Eucalyptus transgenic events B5, B6, B9 and B10 were PCR confirmed. RT-qPCR analysis of B9 events showed 87.6 % down regulation of the EcHKT1;1 gene relative to the non-transgenic controls. MsPRP2 promoter and Hsp terminator sequence of *Medicago sativa* and *Arabidopsis thaliana* were used for designing salt inducible root specific construct. MsPRP2 promoter-driven GFP expression in callus and MsPRP2 promoter-driven GUS expression in salt treated and untreated roots of Eucalyptus composite plants showed that the synthetic promoter designed based on truncated promoter sequence of PRP2 gene from *Medicago sativa* is able to drive gene expression in callus tissues of Eucalyptus and is salt inducible. Micro propagated Ec4 and Ec53 clones were multiplied and elongated in MS media. Twenty micrografted plants established with a graft success of 56 % under tissue culture conditions. A total of 1166 polymorphic SNPs were predicted in the miRNA cleavage sites of the target genes. Association analysis was conducted with the 120 SNPs and wood phenotypes of 10 individuals. A total of 84 SNPs were associated with holocellulose and 36 SNPs were associated with lignin.

Baseline data collection on the spread of Eucalyptus clones of IFGTB along with other varieties has been completed in the districts of Ariyalur, Cuddalur & Pudukottai. IFGTB-EC-4 is largely planted by paper mills and farmers in these districts.

Highlights

- Established 14 Multi locational trials at different locations by ICFRE and other collaborating institutes (IFGTB, IFB, FRI, TFRI, AFRI, IFP, ERC) in collaboration with KVK-Pratapgarh, Forest plantation Corporation of Tamil Nadu, Birsa Agricultural University, Aarav Farm, Linch Mehsana, Gujarat, MP forest department, Telangana Forest department.
- Established a CSO at Gudalur research station (1.0 ha).
- Agrobacterium-mediated transformation experiments completed and 8 putative transgenic events generated.
- MsPRP2 promoter and Hsp terminator sequence of *Medicago sativa* and *Arabidopsis thaliana* were used for designing salt inducible root specific construct using which five transformation constructs were developed.
- Association analysis was conducted with the 120 SNPs and wood phenotypes of 10 individuals. A total of 84 SNPs were associated with holocellulose and 36 SNPs were associated with lignin have been identified which can be used as molecular markers for trait-based improvement of Eucalyptus.

5. All India coordinated Research project on "Development of dielectric heating-based processing technologies for solid-wood, bamboo, and their composites"

5.1 Objectives:

- To develop dielectric heating (radio frequency and microwave) based wood/bamboo processing technologies.
- Developing protocols for application of dielectric heating in wood and bamboo based composite preparation for improved efficiency and product quality.
- Evaluating the value addition and cost benefits /commercial aspects of the DH based processes.

5.2 Progress:

- Designing, fabrication and installation of a "pilot scale microwave vacuum dryer" completed. Two bamboo species *Bambusa tulda* and *Dendrocalamus asper* and three wood species *Poplar, Eucalyptus* and *Melia dubia* microwave vacuum drying characteristics evaluated and number of products developed
- Fabrication, testing and integration of "Microwave based moisture meter system" for wood is completed. The calibration of developed Microwave based moisture meter system is being carried out.
- In the green wood Turning, *Melia dubia* and eucalyptus green wood were turned to expose the end grain all along around the wood in order to increase drying rate from end grain surface during conventional drying. Results of these studies showed that within the short period moisture content are reached to below FSP (fiber saturation point) as compare to unturned green wood, the same process was applied for the Provisional patent on "End grain drying of green turned timber" and got patent registration No. 62188 dated 16-06-2022
- Microwave Pretreatment of difficult to treat wood species i.e. *M. dubia* and *E. hybrid* resulted in improvement in preservative penetration and retention. *M. dubia* exhibited through and through impregnation of preservatives i.e. 100% after the microwave pre-treatment followed by preservative treatment as compared to partial impregnation in control samples. *E. hybrid* exhibited 60-70 % Impregnation of preservatives after the microwave pre-treatment followed by preservative treatment as compared to 5-10% impregnation in control samples.

Highlights

- "Pilot scale microwave vacuum dryer" and "Microwave based moisture meter system" for wood drying designed, fabricated and installed.
- A patent on 'End grain drying of green turned timber' was filed (patent No. 62188 dated 16-06-2022).

6. All India coordinated Research project on "Value addition of wood and wood-based composites using nano-material"

6.1 Objectives:

- To develop nano-material embedded ecofriendly wood preservatives/coatings
- Improvement of quality of low density woods by impregnating with nano-filler blended resins
- Improving properties of wood composites using nano materials
- To develop nano cellulose based composite material

6.2 Progress:

- In order to develop nano-material embedded ecofriendly wood preservatives/coatings, stable and homogenous linseed oil nano-emulsions were formed with Zinc oxide (ZnO), Cerium oxide (CeO2) and Copper oxide (CuO) nanoparticles and the efficacy of the nano-emulsions was assessed for UV resistance and decay resistance of wood. Addition of ZnO and CeO2 nanoparticles into the nano-emulsion significantly improved UV resistance of coated wood. Rubberwood impregnated with linseed oil nano-emulsions loaded with ZnO and CuO nanoparticles exhibited improved resistance against both brown rot and white rot fungi. The nano-emulsion was able to protect the integrity of internal structure of wood on exposure to fungi as revealed by SEM studies

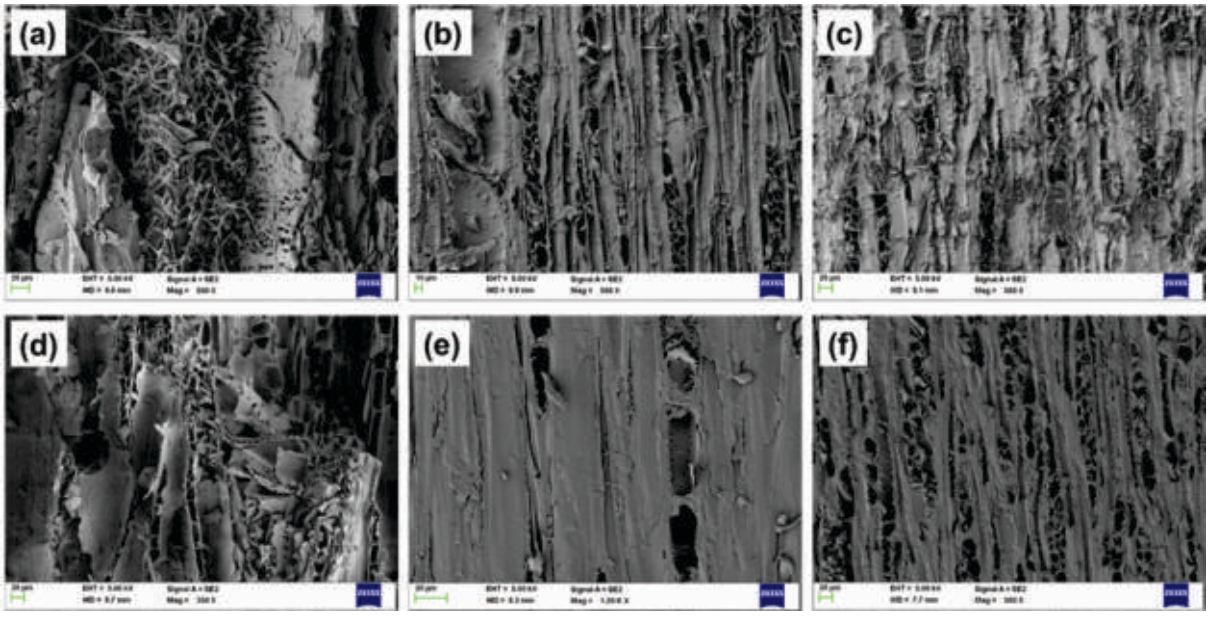

Fig. 4 SEM images of untreated and nanoemulsion treated specimens after exposure to white rot fungi (a-c): (a) untreated wood, (b) NE with nano ZnO treated wood, and (c) NE with nano CuO treated wood; specimens exposed to brown rot fungi (d-e): (d) untreated wood, (e) NE with nano ZnO treated wood, and (f) NE with nano CuO treated wood

- For improving quality of low density wood, Nano-Wood Composites (NWC) were prepared by impregnating nano particles (Boron Nitride and ZnO) fortified poly vinyl acetate and furfuryl alcohol resin systems. Higher concentration of boron nitride nanoparticles (5%) resulted in agglomeration which is evident from SEM image (Fig.2). Melia and Poplar wood with higher loading of zinc nanoparticle (3% and 5%) fortified PVAc exhibited excellent resistance against brown rot fungus.
- To improve the properties of wood composites using nanoparticles, resin formulations were prepared with urea formaldehyde and SiO2 nano-particles. It was observed that addition of nano-SiO2 reduced the amount of formaldehyde emissions from the boards. Mycological testing of 1% and 2% nano-SiO2 loaded boards exhibited improved resistance against fungal attacks.
- For development of nano-cellulose fiber filled composites, Cellulose Nano Fibrils (CNFs) were synthesized from bamboo, eucalyptus, bagasse and waste paper pulp. The CNF suspensions (0.1%) prepared with different number of passes exhibited long term stability in nano form (upto 30 days). CNF filled fibre composite boards were produced using 3% consistency CNF suspension mixed with banana and sisal fibers. Density of board varied from 0.84-0.95 g/cm3, MOR from 8.2-10.18 N/mm2 and MOE varied from 1687.74-1441.4 N/mm2. Boards were also prepared using Eucalyptus CNF and PVAc (3%) as a binder with banana fibers. MoR and MoE values were 26.93 N/mm2 and 1282.31 N/mm2 respectively. Addition of CNF in PVAc adhesive resulted in nearly 70% increase tensile shear strength (TSS) as compared to PVAc alone in Melia ply board suggesting the improvement in adhesive properties. Water absorption in the boards with CNF based adhesive was also significantly lower. The coating of CNF incorporated with ZnO nanoparticles was found to protect wood from photo-degradation.
- Cellulose Nano Crystals/Fibers (CNCs/CNFs) were synthesized from dry leaves of fig tree (*Ficus auriculata*) followed by preparation of wood coating material using polyvinyl alcohol with variable concentration of CNFs and methanolic extract of fruits of the trees. The coating material having 0.7% fruit extract concentration and 3% nanocellulose exhibited good mechanical, thermal and anti-bacterial activity. So, it can be used commercially for the coating purpose of instruments used in hospitals.

Fig. 5 *Lantana camara* infested forest lands in Mandorghat, Shimla Forest Division, HP

Highlights

- Eco-friendly wood preservatives/coating of linseed oil emulsion embedded with zinc oxide (ZnO) and cerium oxide (CeO2) nanoparticles embedded developed.
- A patent filed on 'An improved wood coating material' (Patent No. 202311033227 dt. 11-5-2023) in collaboration between ICFRE and IIT-R. Improved wood coating was developed from Cellulose Nano Crystals synthesized from dry leaves of fig tree (*Ficus auriculata*). It can be used commercially for the coating purpose of wood and instruments used in hospitals.
- Published 03 papers and presented 05 papers in national seminars.

7. All India coordinated Research project on "Assessment and monitoring of Invasive Alien Plant Species (IAPS) in India and formulation of strategies for management of key Invasive Alien Plant species in different regions of the country"

7.1 Objectives:

- To assess the spatial extent of selected IAPS using Remote sensing and GIS
- To assess the various ecological impacts of selected IAPS in the country
- To predict the future spread of selected IAPS using Species Distribution Models
- To explore bioprospecting and other utilization potential of selected IAPS
- To develop cost effective methods for eradication and control of selected IAPS
- To standardize restoration models for invaded areas with native species and develop a compendium on IAPS in collaboration with the SFDs

7.2 Progress:

- The project aims to map the spatial extent of selected Invasive Alien Plant Species, their impact on native plant diversity, their future invasion/spread potential using Species Distribution Models, their utilization potential with a view to come up with species specific management strategies. Information on the occurrence of *Prosopis juliflora, Lantana camara, Acacia mearnsii* and *Mikania micrantha* have been collected in different parts of the country. Spatial mapping studies showed that Prosopis juliflora occupied 6.82 Lakhs ha area in twenty five Districts of Tamil Nadu. Studies on impact of selected Invasive Alien Plant Species on the native plant diversity in different habitats showed decreased species richness in the invaded sites than the control sites. Similarly, the Prosopis invaded sites showed higher soil nitrogen content than the control sites. Bio-control agents under in vitro condition infecting *M. micrantha* has been isolated for controlling *Mikania invasion*. The host range of a seed bruchid (*Caryedon gonagara*) is being assessed for its efficacy in biological control of *Prosopis*. Native plant species suitable for restoration of the sites affected by invasive species have been shortlisted and planted in the affected areas.

Highlights

- Spatial mapping showed that *Prosopis juliflora* occupied 6.82 Lakhs ha area in twenty five Districts of Tamil Nadu.
- About 31% of the study area in the states of Chhattisgarh, Jharkhand, and West Bengal is presently susceptible to invasion by *Lantana camara.*
- Ecological impacts of *Prosopis juliflora, Lantana camara, Acacia mearnsii* and *Mikania micrantha* on soil physico-chemical properties and on native plant species is being assessed from various regions of the country.
- Bio-control agents for *Mikania* and *Prosopis* are being assessed under in vitro condition.
- Restoration trials for *Prosopis juliflora* (Pudukkottai, Tamil Nadu), *Lantana camara* (Solan forest division, Himachal Pradesh; Jabalpur, Madhya Pradesh;), *Acacia mearnsii* (Idukki, Kerala) and *Mikania micrantha* (Dissoi RF, Assam) invaded areas have been initiated.

8. All India coordinated Research project on "Conservation and productivity improvement of Red Sanders"

8.1 Objectives:

- To establish base populations of Red sanders with germplasm from natural populations.
- To select plus trees of Red sanders and lay multilocational progeny trials.
- To refine and develop silvicultural techniques for Red sanders.
- To develop molecular resources and techniques for Red sanders.

8.2 Progress:

- The all India coordinated research project on 'Conservation and Productivity Improvement of Red sanders (*Pterocarpus santalinus*)' got underway during 2020 and is in its fourth year of implementation. The project has got nine components being implemented by eight collaborating institutions. The component-wise cumulative progress/achievements are given here under.
- IFB and BIOTRIM: The component was initiated with review of published literature and working plans to document distribution of Red sanders. Subsequently, GIS based spatial analysis was done to understand geographical and climatic variation in the natural Red sanders zone and six provenances were delineated. The provenances were surveyed by the component collaborators and seeds were collected from 145 trees during 2022. The seeds were kept for germination at IFB Hyderabad and BIOTRIM, Tirupati. Altogether, 3724 seedlings have been raised by BIOTRIM and IFB.
- IFB: The component was initiated with review of published literature and working plans to identify natural ranges of Red sanders. GPS coordinates of trees were recorded during the provenance surveys taken up under Component 1. GPS coordinates of trees from earlier surveys of AP Forest Department was obtained and compiled. The consolidated GPS coordinates representing species presence were plotted and a distribution map generated. Global bioclimatic environmental layers were collected and clipped for use in niche modeling. Environmental niche modeling was performed with 1259 presence locations, 19 bioclimatic variables and elevation raster layers with Maxent modeling software. Bioclimatic variables with maximum loading were identified through their contribution to model building and jackknife test of variable importance. Potential habitat suitability maps were generated for Andhra Pradesh and whole of India.
- IFB, IWST, IFGTB, AFRI and BIOTRIM: The component was initiated by developing grading criteria for check tree method of mass selection, which was circulated among the collaborating PIs. Altogether, 62 plus trees have been selected using the grading criteria developed for Red sanders. During 2020-21 seeds were collected from 31 plus trees and shared among the five collaborating PIs for raising half sib progenies. Fresh seeds were collected during 2021-22 from 58 plus trees (both from previous year selections and new selections) by the collaborating institutions and were used for raising 1733 half-sib progenies at BIOTRIM and IFB.
- IFB and IFGTB: About 55% rooting success was observed in softwood cuttings at IFGTB, kept

inside poly tunnels and treated with 2000 ppm of IBA. Three sets of air layering trials to standardize diameter of coppice shoot, hormone concentration and method of hormone application were laid and rooting response was recorded at IFB Hyderabad. The diameter class of 10-15mm, IBA 1000 ppm and spray method of hormone application had best rooting response. In another trial rooting response to combined application of NAA and IBA was recorded. NAA 3000 ppm in combination with IBA 3000 ppm gave 70% rooting success and qualitatively better roots.

- S V University: A series of experiments were laid at S V University and best explant (axillary bud), best basal medium (MS medium), concentrations of PEG, activated Charcoal, Citric Acid (0.7%) and PVP (1.5%) were optimized to nullify effects of Phenols and Flavonoids. Hormone supplements to induce multiple shoots were experimented. The combination of BAP 2.5 mg/lit and TDZ 2.0 mg/lit on MS medium resulted in single shoot with small branches which were sub cultured to induce multiple shoots.
- IFGTB: In this component two strains of Rhizobium, three species of AM fungi (*Glomus geosporum, G. fasciculatum, G. aggregatum*) and one species of Phosphobacteria (*Bacillus megaterium*) have been identified so far. Various combinations of these biofertilizers alone and in various combinations were inoculated to Red sanders seedlings and rooted cuttings. VAM and Rhizobium inoculated seedlings showed more root nodules compared to control and commercial nursery seedlings. Seedlings inoculated with Rhizobium and Phosphobacteria showed more dry biomass than the other treatments. A field trial plot was established with Red sanders seedlings inoculated with AM fungi, Rhizobium and Phospobacterium alone in various combinations.
- University of Hyderabad: In this component, the DNA extraction protocol has been optimized; seven highly polymorphic RAPD primers, twenty polymorphic ISSR primers and six polymorphic SSR primers have been identified through primer screening. RNA was isolated from two diverse accessions (Rudravaram, Andhra Pradesh and Nayapakkam, Tamil Nadu) and de novo transcriptome analysis was done; about 40,389 EST-SSR repeats which included compound, mono, di, tri, tetra, penta, and hexa nucleotide repeat sequences have been identified; a total of 37,923 primer pairs have been successfully designed using Primer 3.0 software. Out of the 43 EST-SSR loci screened, 28 were found to be monomorphic and 15 were polymorphic in the initial screening. Polymorphic EST-SSRs were used to generate marker data for the genetic diversity and plus tree characterization studies.
- IWST: In this component, ERT data and actual heart wood cores have been collected from 67 plantations in Karnataka, Tamilnadu and Andhra Pradesh. A tomogram library has been prepared using the ERT readings. A linear regression model was developed using actual and ERT heartwood data. About 91 % ($R2 = 0.98$) similarity was observed. Soil samples have been collected from all the 67 plantations.
- IWST and CSIR-NBRI: In this component, 592 Red sanders heart wood cores have been analysed so far for stable carbon isotope composition (13C/12C) at the Central Instrumentation Facility of CSIR-NBRI, Lucknow. Part of this data was statistically analysed, however, no geographic variation was detected. Stable carbon isotope composition (13C/12C) of α-cellulose component was explored further to refine the process.

- In the second sub-component Chromatographic (HPLC) analysis of methanolic extract of Red sanders heartwood collected from different locations was carried out. HPLC analysis indicated at least 11 common peaks at retention time (tR) 3.1, 3.5, 8.9, 11.1, 12.8, 13.5, 14.9, 15.7, 17.9, 18.3 and 26.5 (minutes). Similarities in chromatographic pattern between the samples from different locations were evaluated using the principal component analysis (PCA). Isolation protocol has been standardized for polar phytochemicals and altogether 5 compounds have been isolated from heartwood extract of Red sanders.

Fig. 6 Half-sib progenies of plus trees maintained at BIOTRIM and IFB

Highlights

- GIS based spatial analysis was done to delineate 06 provenances. Seeds were collected from 145 trees of 06 provenances. 3724 seedlings have been raised at IFB, Hyderabad & BIOTRIM, Tirupati. The seedlings will be used to raise two provenance trials, one each in Andhra Pradesh SFD and Telangana.
- Potential habitat suitability maps were generated for Andhra Pradesh and whole of India using Maxent modelling. Potential habitats identified in northern parts of Eastern Ghats in Andhra pradesh and eastern aspects of Western Ghats in Karnataka.
- 62 plus trees have been selected from even aged plantations. Out of 62, seeds of 58 plus trees were used to raise 1733 half sib progenies at IFB & BIOTRIM.
- Vegetative propagation through air layering of coppice shoots was further refined. A combination of NAA and IBA 3000 ppm gave 70% rooting success with better quality roots.
- Two strains of Rhizobium, three species of AM fungi (*Glomus geosporum, G. fasciculatum, G. aggregatm*) and one species of Phosphobacteria (*Bacillus megaterium*) have been identified for redsanders.

9. All India coordinated Research project on "Quality teak production: capitalizing on cloning"

9.1 Objectives:

- Evaluation of existing teak clonal plantations. Mass production of new clones and evaluation through multi-location trials. Disseminate package of practices for cultivation in farmlands

9.2 Progress:

- Short rotation teak is grown in plantations worldwide. However, it has not taken off in India due to technical, biological and marketing constraints. This AICRP aimed to introduce micropropagation for the large-scale production of teak clones and popularising among farmers/tree growers. The clones are established in ~100 ha in Kerala, Tamil Nadu, Chhattisgarh, Maharashtra, Punjab, Gujarat, Karnataka, Jharkhand, West Bengal and Madhya Pradesh and Telangana and their performance is under evaluation. Interim results reveal that at the end of 4 years, the plants have attained a height of 10-12 m and a girth of 40-45 cm. **About 50 per cent of the trials are raised with the support of the Forest Departments / Forest Development Corporations of Maharashtra, Kerala and Chattisgarh.**
- **Encouraged by the initial results, West Bengal, Madhya Pradesh, Andhra Pradesh, Maharashtra, and Gujarat forest departments have requested further demonstration trials in the department lands. The Chattisgarh forest department has ordered 6.5 lakh teak plants from ICFRE-IFGTB for their green plantation programme for the year 2023-24.**
- ICFRE-IFGTB Coimbatore: The five commercial tissue culture labs have initiated mass production of teak through TC. One lab supplied 1.0 lakh plants during October 2022 to March 2023 while ICFRE-IFGTB lab supplied 35000 plants to Chhattisgarh Forest Department. A license agreement was signed between ICFRE-IFGTB and HU Gugle Biotech Pvt Ltd for commercial production of three clones of teak for 10 years. A revenue of six lakhs as lumpsum was received towards the license agreement. Trials were established in Chattisgarh in farmers' fields and forest department land. Simple sequence repeat primer details for genetic fidelity testing were provided to partner institutes.
- ICFRE-TFRI, Jabaplur : Field trials have been established at nine locations in Maharashtra and Madhya Pradesh. Land was allotted by Madhya Pradesh Forest Department at Bargi, Jabalpur. The plantations were done in RBD design with 7 clones and 7 replications. All the plantations in Madhya Pradesh and Maharashtra are being maintained through regular soil working, weeding, irrigation and fertilization. Casualty gap filling was also carried out in the plantations. In the teak trial at

Fig. 7 Clonal propagation through tissue culture, *in vitro* clonal shoots are subjected to rooting

Bargi 55-60% survival was observed and in bund plantation at Baghraji 80% survival was recorded. Survival in the FDCM plantations in Maharashtra is in the range of 71 to 97 %. Ex vitro rooting was achieved in 4 different clones (IFGTB 02, IFGTB 03, IFGTB 04 and IFGTB 05).

Highlights

- The clones of teak established in ~100 ha in Kerala, Tamil Nadu, Chhattisgarh, Maharashtra, Punjab, Gujarat, Karnataka, Jharkhand, West Bengal and Madhya Pradesh and Telangana.
- At the end of 4 years, the plants have attained a height of 10-12 m and a girth of 40-45 cm.
- About 50 per cent of the trials are raised with the support of the Forest Departments / Forest Development Corporations of Maharashtra, Kerala and Chhattisgarh.
- **The Chhattisgarh forest department has ordered 6.5 lakh teak plants from ICFRE-IFGTB for their green plantation programme for the year 2023-24.**
- ICFRE-IFGTB, Coimbatore, had entered into a license agreement with HU Gugle Biotech, Bangalore,for mass production and supply of three teak clones TG1, TG5 and TG11.
- IFGTB had entered into MoU with two more commercial tissue culture laboratories - Jagadamba Bio plants, Bangalore, and Meristem Biotech, Bengaluru for commercial production of teak.

10. All India coordinated Research project on "Developing seed testing and seed storage protocols of selected forestry species from diverse forest types"

10.1 Objectives:

- It envisages to develop a complete package on seed technology like seed collection, seed processing, handling, viability, storage physiology and developing seed storage protocols and nursery techniques of rare, endangered and threatened and less explored for important forestry species (77 species).

10.2 Progress:

- Fruit/Seed maturity and seed collection, processing and handling: Field survey done for demarcation of populations and fruit maturity assessment for *Acer pictum, Albizia julibrissin , Albizia odoratissima, Alnus nitida, Diospyros tomentosa, Erythrina suberosa, Heteropanax fragrans, Kydia calycina, Litsea chinensis, Pterospermum acerifolium, Premna latifolia, Quercus glauca, Sterculia villosa, Stereospermum suaveolens* and *Toona serrata* (15 species) (FRI) *Semacarpus anacardium, Sterculia villosa,, Buchnania lanzan, Butea monosperma, Stereospermum chelonoides, Kydia calycina, Hymenodictyon excelsum, Nyctanthes arbortristis, Putranjiva roxburghii* and *Mallotus philippensis* and continued in 4 species: F*eronia limonia, Pterospermum acerifolium, Cochlospermum gossypium* and *Commiphora wightii* (TFRI).

Perambulated different forest areas and identified seed sources of *Elaeocarpus serratus, Maesa indica, Cipadesa baccifera, Murraya paniculata, Bischofia javanica, Symplocos cochinchinensis, Cullenia exarillata, Leea indica Aphanamixis polystachya* and *Memecylon umbellatum*. Initiated flowering studies in these species. Collected fruits and standardized seed processing and extraction. Seed germination studies also conducted in the species (IFGTB).

- Distribution and location of the populations of *Garcinia indica, G. gummigutta, Kingiodendron pinnatum, Mammea suriga, Dimocarpus longan, Hopea parviflora, D. ebenum, Lophopetallum wightianum Dipterocarpus indicus, Knema attenuata,* and *Schleichera oleosa* (11 species) identified for observations on initiation of flowering, fruit maturity and to study suitable optimum period for fruit collection (IWST). Flower Anthesis and seed maturation studies on *Shorea robusta, Phoebe goaparensis, Dipterocarpus retusus, Chukrasia tabularis, Shorea assamica Magnolia champaca, Mesua ferrea Schima wallichii, Morus laevigata Strereospermum tetragonum, Pinus kesiya* and *P. merkusii* (12 secies) (RFRI), *Prunus cerasoides, Sorbus lanata, Betula utilis, B. alnoides* and *Rhododendron campanulatum* (HFRI), *Anogeissus latifolia, Capparis decidua and Salvadora persica* (AFRI)
- Investigating Seed Germination behavior of forestry species from various forest types: Seed quality evaluation through indirect tests, seed germination and dormancy pretreatments (if any) done in *Acer pictum, Albizia julibrissin, Albizia odoratissima, Alnus nitida, Erythrina suberosa, Heteropanax fragrans, Kydia calycina, Pterospermum acerifolium, Premna latifolia, Sterculia villosa, Litsea chinensis, Quercus glauca, Tsuga dumosa* and *Toona serrata* (FRI); *Semacarpus anacardium, Sterculia villosa,, Buchnania lanzan, Butea monosperma, Stereospermum chelonoides, Kydia calycina, Hymenodictyon excelsum, Nyctanthes arbortristis, Putranjiva roxburghii, Mallotus philippensis, Feronia limonia* and *Commiphora wightii* (TFRI)*; Elaeocarpus serratus, Maesa indica, Cipadesa baccifera, Murraya paniculata, Bischofia javanica, Symplocos cochinchinensis, Cullenia exarillata, Leea indica Aphanamixis polystachya* and *Memecylon umbellatum* (IFGTB)*; Knema attenuata, Hopea parviflora, Schleichera oleosa, Garcinia gummiguta, Diospyros ebnem, Dimocarpus longan, Vateria indica* and *Garcinia indica* (IWST)*; Elaeocarpus ganitrus , Shorea robusta, Phoebe goalparensis, Magnolia champaca, Mesua ferrea, Morus laevigata, Dipterocarpus macrocarpus, Duabanga grandiflora, Chukrasia tabularis, Schima wallichi, Shorea robusta, S.assamica* (RFRI); *Prunus cerasoides, Sorbus lanata, Betula utilis, Betula alnoides,* and *Rhododendron campanulatum* (HFRI); *Anogeissus latifolia, Capparis decidua, Salvadora persica* and *Santalum album* (AFRI). Seed germination behaviour of 65 species was studied.

Species	Pre- treatment	Germination (%)
Acer pictum	9 weeks of moist chilling	35
Alnus nitida	6 weeks of moist chilling	65
Betula utilis	-	75
Betula alnoides	Soaking in 100ppm GA3 24 hours	76
Diospyros tomentosa	-	95
Heteropanax fragrans	-	85

Garcinia indica	-	100
G. gummigutta	-	30
Litsea chinensis	Soaking seeds in 0.02% GA_3 for 24 hrs	45
Pterospermum acerifolium	-	94
Premna latifolia	Soaking seeds in 0.05% GA3 for 72 hrs	56%
Prunus cerasoides	Scarification	93.00
Tsuga dumosa	Soaking seeds in 0.01% GA_3 for 24 hours and 20 days moist chillin	35
Vateria indica	-	68

- Seed Storage physiology: Seed desiccation sensitivity and storage studies being conducted in *Albizia odoratissima,, Albizia julibrissin, Litsea chinensis, Heteropanax fragrans, Sterculia villosa, Pterospermum acerifolium, Quercus glauca, Kydia calycina, Toona serrata* (FRI); *Putranjiva roxburghii, Semecarpus anacardium, Mallotus philippensis, Buchanania lanzan, Butea monosperma, Stereospermum chelonoides, Kydia calycina, Hymenodictyon excelsum, Sterculia villosa, Nyctanthes arbor-tristis, Feronia limonia* and *Commiphora wightii* (TFRI)*; Cipadessa baccifera, Maesa indica, Cullenia exarillata Bischofia javanica, Aphanamixis polystachya, Elaeocarpus serratus* and *Leea indica* (IFGTB); *Schleichera oleosa, Garcinia gummiguta* and *Dimocarpus longan* (IWST); *Chukrasia tabularis, Phoebe goalparensis, Dipterocarpus macrocarpus, Mesua ferrea, Schima wallichii, Pinus kesia, Elaeocarpus ganitrus* and *Magnolia champaca* (RFRI); *Betula utilis, Betula alnoides, Rhododendron campanulatum, Prunus cerasoides* and *Sorbus lanata* (HFRI).
- Correlating seed storage category with ecological parameters: Image analysis for fruit and seed morphology was done for 10 species. Determined the respective weights (IFGTB). Seed shape, size, mass and moisture content of 6 species were studied from one location each. Ecological parameters such as rainfall, relative humidity, temperature recorded for each study location (IWST).
- Nursery techniques for production of quality seedlings: Nursery trials viz., effect of depth of sowing, potting media, container and time of sowing of *Prunus cerasoides, Betula utilis* and *Sorbus lanata* laid out in the nursery. Vegetative propagation trial of *Betula utilis* and *Sorbus lanata* also laid out in the nursery. Regular observations on their growth being recorded (HFRI). Seedling quality parameters studied for production of quality seedlings of *Anogeissus latifolia, Capparis decidua* and *Salvadora persica* (AFRI).

Fig. 8 Flowering & fruiting in *Symplocos cochin chinensis* Highlights

Highlights

- Population survey for seed source identification was done for 74 species in Uttarakhand and Uttar Pradesh; Himachal Pradesh; Tamil Nadu; Madhya Pradesh; Karnataka; Rajasthan; Assam, Arunachal Pradesh and Manipur.
- Seed germination behaviour of 65 species and Seed storage for 45 species studied.
- Seed desiccation studies revealed orthodox nature of seeds in 33 species and recalcitrant nature of seeds of 12 species.
- Nursery techniques for production of quality seedlings developed for 5 species.
- Publications: Forest Seed Identification- A Pictorial Guide for Northeast India, Lab Manual for Seed Biochemistry & Tree Blossom of North East India
- Trainings- Trainings conducted for 48 SFS Officers of CASFOS, Meghalaya & demonstrated the seed technology work to Forest department officials, Students, Ecological Task Force officers, Farmers, NGO etc. under various programmes.

11. All India coordinated research project on "*Dalbergia sissoo*"

11.1 Objectives:

- Screening *Trichoderma* spp. isolates against important Shisham pathogens viz., *Fusarium solani* and *Ganoderma lucidum*
- Development of protocol for extent of infection using biochemical markers
- Survey of shisham populations/areas for incidences of shisham mortality in the states of Bihar, Jharkhand, Madhya Pradesh, Chhatisgarh, Rajasthan, West Bengal, Uttar Pradesh, Uttarakhand, Delhi, Punjab, Haryana, Himachal Pradesh & Jammu & Kashmir and North Eastern states.
- Selection of genotypes/populations/areas unaffected/resistant to disease incidence
- Raising planting stock of selected genotypes in the nursery
- Artificial inoculation of shisham by *Fusarium solani* and *Ganoderma lucidum* for identifying disease resistant germplasm in the nursery and field.
- Raising quality planting stock of resistant genotypes for afforestation programme. Extension, Technology transfer and Capacity

11.2 Progress:

- The project was envisaged to identify the vulnerable areas, pathogen responsible for large-scale mortality in *D. sissoo* plantations, screen disease resistant host germplasm and potential Trichoderma sp isolates as biological control agent. Since inception of the project *Trichoderma* spp. *isolates* and *pathogen isolates* (*Fusarium solani* and *Ganoderma lucidum isolates*) were collected from Uttarakhand, Haryana, Punjab, Himachal Pradesh, Jammu and Kashmir, Jharkhand,

Bihar, Madhya Pradesh, Rajasthan, Gujarat and North East states of India. Total 161 *Trichoderma* spp. isolates are being screened for antagonism towards 133 pathogen isolates in dual culture tests to identify potential biocontrol isolates. For mass multiplication of *Trichoderma*, organic substrates comprising of agro wastes, weeds and other plant-based wastes were tested. For in vitro screening of *Dalbergia sissoo* genotypes against Fusarium solani and *Ganoderma lucidum* infection, calli cultures for different genotypes were produced. Based on the superiority in morphological characteristics promising CPTs and plus trees were selected.

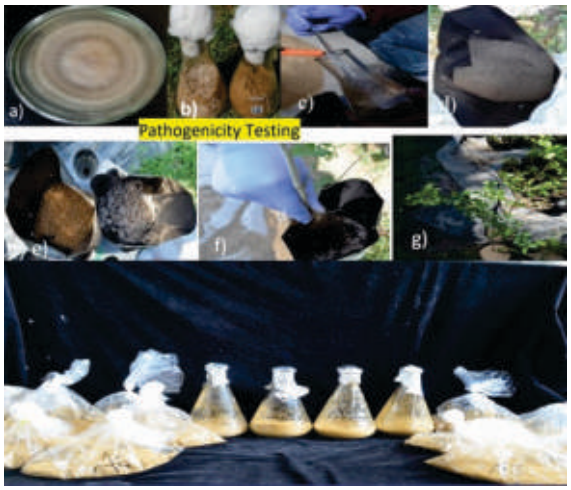

Fig. 9 (a) Pure cultures of *Fusarium* isolate, (b)*Fusarium* inoculated (left) and uninoculated (Right) on sorghum-chaff substrate, c) Mixing of Trichoderma-colonoized sorghum-chaff substrate (d) Sterile potting mixture (e) Addition of inoculated sorghum chaff substrate to potting mixture (f &g) Transfer of healthy shisham plants in polybag containing inoculated sorghum chaff substrate (h) Mass multiplication of *Fusarium* isolates

- In the experiments conducted to identify organic wastes for the artificial culturing of biological control agent *Trichoderma* species, *Eupatorium perfoliatum,* rice husk, neem leaf compost and Trichosanthes dioica peel also showed promising results. Highly antagonistic *Trichoderma* isolates in in vitro conditions having more than 90 percent mycelial growth inhibition activity against virulent *Fusarium solani* and *Ganoderma lucidum* were identified. Mass culture of *Trichoderma* isolate was inoculated in rhizosphere of diseased trees at Nalagarh, Solan for evaluating health recovery potential in plantation. Seeds from selected CPTs primed with *Trichoderma* sp exhibited 70 - 82% germination in comparison to control with 45.33 - 50% germination. For hazard mapping of areas under *Dalbergia sissoo* plantations, field survey for Himachal Pradesh, Jammu & Kashmir, Jharkhand, West Bengal and Bihar was conducted. All the desired GIS layers for modelling species distribution, climate models representing climate scenarios climate model MIROC5, IPSL_5A_LR, IPSL-CM6A-LR and MIROC6 were downloaded and digitised for the Indian administrative boundary. The distribution data collected from Himachal Pradesh and Jammu & Kashmir were compiled for preparation of distribution maps and will be used as the input layers for the habitat and hazard modelling. The point distribution map of eastern region, Himachal Pradesh and Jammu & Kashmir depicting affected and non-affected samples were prepared. The habitat suitability map for eastern region of India has been prepared. For in vitro screening and multiplication of *Dalbergia sissoo* genotypes against *Fusarium solani* and *Ganoderma lucidum* infection, nodal explants of 25 *Dalbergia sissoo* genotypes, callogenesis using leaf and root explants of 2 genotypes and Cell suspension culture of 6 genotypes was prepared. Cuttings of 29 selected CPTs were subjected to rooting and raised in net houses for the establishment of VMGs. Pathogenicity testing of pathogen cultures was conducted to identify virulent isolates. Around 20 acres clonal seed orchard of resistant and intermediate genotypes of *Dalbergia sissoo* was established. These genotypes were selected for productivity and later for disease resistance. These were raised at Meerpur and Bhitmera areas of Haryana Forest department. MoU for addressing *D. sissoo* mortality in Uttar

Pradesh was signed and now Forest Research Institute, Dehradun is helping the State Forest Department in disease identification for high mortality areas, *Trichoderma* treatments, production of disease-free plants using selected *Trichoderma* isolate, raising of CSO of resistant *D. sissoo* genotypes and establishment of clonal multiplication area for production of disease resistant clones.

Highlights

- 161 *Trichoderma* spp. isolates screened for antagonism towards 133 pathogen isolates to identify potential biocontrol isolates.
- Hazard mapping of areas under *D. sissoo* plantations, field survey for Himachal Pradesh, Jammu & Kashmir, Jharkhand, West Bengal and Bihar was conducted.
- Highly antagonistic *Trichoderma* isolates in in-vitro conditions having more than 90 percent mycelial growth inhibition activity against virulent *F. solani* and *G. lucidum* were identified.
- 20 acres clonal seed orchard of resistant genotypes of *D. sissoo* established at Meerpur and Bhitmera areas of Haryana Forest department.
- MoU for addressing *D. sissoo* mortality was signed with UP SFD.

12. All India coordinated research project on "Assessment of demand and supply of timber, fuel-wood and fodder in India"

12.1 Objectives:

- Demand and supply of timber, fuel-wood, fodder

12.2 Progress:

- **IWST:** Collected information from the secondary literature source related to timber, fuel wood and fodder and extracted the review of literature for outlined objectives of the project.The data collected from the different districts (Chitradurga, Kodagu and Udupi) of Karnataka during the household survey has fed in the prescribed format of Excel sheet.Conducted the Household survey for assigned district namely Bangalore Rural, Shivamogga,Tumkur and Bangalore Rural and the data entry in regard of the same has completed.Under cremation wood consumption pattern survey, Collected the Average wood consumption data in Bengaluru from BBMP linked NGO.In regard of SFD data fulfilment, once again the requesting letter has been sent to the PCCF level for both the state Forest department (Andhra Pradesh and Goa) and has been in a regular mode of follow up to know the status.
- Dhaba survey has initiated by collecting the basic information from the secondary sources. Gathering the wood related data in order to prepare the review paper in line of the project. Planning to conduct the household survey for the remaining assigned villages of Karnataka, Goa and Andhra Pradesh.Received the permission from Goa Forest Department to conduct the household survey

under the project

- **IFB:** The survey is distributed as survey of SFDs, households and other units utilizing fuelwood. The targeted household data collection from Odisha and Telangana has been completed. Data entry is in progress for 370 households. Among SFDs data from Jharkhand, Bihar and Telangana have been received. Among the industries survey has been completed in Odisha and Jharkhand and some industries of Telangana have been covered. Data has been received from total 45 industries. Among other fuelwood users' units data has been collected and compiled from – 23 dhabas/hotels and 05 crematoriums.
- **RFRI:** A mid-term project workshop of AICRP-12 was held in Tropical Forest Research Institute,
- Jabalpur. The questionnaire for the survey of households to assess their demand for timber, fuelwood and fodder was modified and finalized. Accordingly, survey of 680 Households of 68 villages of 5 districts (Sonitpur, Lakhimpur, Cachar, Kokrajhar and Dibrugarh) of Assam, 140 households of 14 villages of Tripura and 100 households of 10 villages from Mizoram was completed.
- Data Entry of 1220 questionnaires of Assam from 1380 questionnaires and 150 questionnaires of Tripura was completed. Survey of six saw mills in Barpeta, Jorhat, Golaghat, Kokrajhar and Dhubri district of Assam and 16 Wood based industries (saw mills) of Tripura were also conducted.
- **AFRI:** Survey of dhaba/ hotel in Jodhpur division was conducted from Jodhpur to Barmer in distance of 200 km and the hotel and dhabas for 200 km at national highway was 54 and all were using LPG cylinders. The route to Sindari from Barmer state highway the frequency after 60 km was only one dhaba which was using fuelwood of khejri and Salvadora per day consumption was 35 to 50 kg depending upon sale of meals. Fuelwood supply in form of charcoal is done in most of the places of Bhilwara and adjacent areas of Ajmer Division, the *Prosopis juliflora* is the main tree species used for fuel wood . The panchayats auction the trees from revenue land not from forest land. One hectare of area produces raw tree logs 50 tones and after processing by conventional methods it come to be 15 tonnes coal and average per hectare revenue is approx 4.5 lakhs.

State	Sl.No.	Place of trial	Village No.	Households No.
1.Assam	1.	Kokrajhar	30	300
	2.	Sonitpur	8	80
	3.	Lakhimpur	20	200
	4.	Cachar	10	100
	5.	Jorhat	10	100
	6.	Golaghat	20	200
	7.	Dibrugarh	20	200
	8.	Darrang	10	100
	9.	Dhuburi	10	100
	Total		**138**	**1380**

2.Tripura	1.	North Tripura	10	100
	2.	South Tripura	10	100
	Total			**200**
3.Mizoram	1.	Mamit	10	100
Grand Total		**12**	**168**	**1680**

Highlights

- A total of 58 commodities of wood products are under import and export in India(Panels and Wooden Products; Pulpwood; Printed Materials; Furniture; Sport Goods)
- In FY 2021-22, the total quantity of approximately 60 Million CUM RWE of wood products was traded internationally with 46 m CUM RWE under import and 14 m CUM RWE under export.
- The import and export value for wood products in India during FY 2021-22 was Rs.54730 Cr. and Rs.36881 Cr., respectively, comprising of Rs.91611 Cr. in international trade.
- The import and export value for wood products in India during FY 2021-22 was 7344 m US$ and 4948 m US$, comprising of 12292 m US$.
- The total exports from India were US$ 417.81 billion during FY 2021-22 with a surge of 43.18% and 33.33% in respect of exports during FY 2020-21 and FY 2019-20, respectively. However, the exports of the wood products were US$ 4.95 billion during 2021-22 with a surge of 54.29% and 55.35% in respect of FY 2020-21 and FY 2019-20 respectively.

13. All India coordinated research project on "Valuation of forests for GDP, green GDP and payment of eco-system goods and services"

13.1 Objectives:

- To develop methodologies for forest valuation, both direct and indirect. To determine the contribution of forests to the GDP of India, the value of ecosystem goods and services per unit area for different forest types, the replacement cost of forests when diverted for non-forestry purposes

13.2 Progress:

- **AFRI:** Conducted survey of 200 Households in Nagore, Udaipur, and Sikar District in Rajasthan and Banaskantha and Surat District in Gujarat for collection of information on Socio-economic status viz. Educational qualification, type of house, primary and Secondary profession, agricultural land, cooking energy source, total family income, employability in forestry activity, use of timber, wood, wooden furniture, fuelwood collection and consumption, use of cooking devices, livestock population, source of fodder collection, information on grazing and grass collection, NTFPs and medicinal plants collection and consumption etc. Data of 600 Households were entered in computer in prescribed format. Conducted survey of 180 HH in Alwar district of Rajasthan covering Very Dense Forest (VDF) and Medium Dense Forest (MDF) and recorded data in prescribed format.
- **IFP:** Literature on relevant topics has been reviewed. Census and Sample-based secondary data

has been collected. Literature reviewed on the total economic value of forest and Net Present Value (NPV) from similar studies is going on. In Forest Group Type 5 (Tropical Dry Deciduous Forest) Survey has been done in 54 villages/ 540 Households before the allotment of desired forest types in (Oct 2021-Dec 2021) Quarter in Dhanbad, Jamtara, Bankura, Medinipur & Purulia districts.

Objective 2: Surveyed a total of, 80 villages/800 households in Saraikela-Kharsawan, Koderma, Rohtas , Gaya, Alipurduar, Pakur, West Medinipur & Nawadha District

Objective 3: Surveyed a total of 360 households in the villages of (Darjeeling, Jalpaiguri, Cooch Behar & Alipurduar, Kalimpong and Saraikela-Kharsawan) districts neighboring Type – 3 Forest

- Forest Type 4: Surveyed a total of 280 households in the villages of South & North 24 Pargana districts neighboring Type – 4 Forest

- **HFRI:** The data was collected from 10 villages in Sirmour, 6 villages in Kangra and 7 villages in Shimla district and 230 questionnaires were filled. Data was collected from 230 household.to determine the contribution forests in GDP. The data was also collected on tangible and intangible services provided by forest types and the information was collected from 10 villages in Udhampur, Doda districts in J&K and 10 villages in Spiti valley in Himachal Pradesh.
- The database was collected on timber, fodder, fuelwood, forest floor and medicinal plants from 4 villages in Sirmour and 04 villages in Kangra, 10 villages in Mandi, 13 villages in Shimla and 20 villages in Bilaspur districts in Himachal Pradesh and 10 villages in Udhampur district in J&K to determine the contribution in GDP. A total of 610 households were surveyed. The data was also collected on tangible and intangible services provided by forest types and the information was collected from 10 villages in Udhampur and Doda districts (J&K) and 100 households were surveyed.
- **IWST:** The data collected from the different district (Chitradurga, Kodagu and Udupi) of Karnataka during the household survey has fed in the prescribed format of Excel sheet (around 900 house hold till data). IWST conducted the Household survey for assigned district namely Bangalore Rural, Shivamogga, Tumkur and Bangalore Rural on 20th October 2022, 2nd to 7th November 2022, 17th, 18th & 20th of January 2023 and 9th of February 2023 respectively and the data entry in regard of the same has completed.

  Under Ecotourism, Conducted the pilot survey for the Contingent valuation method to undertake ecotourism study (focussed on Recreational Service) in the place of Kodachadri, Shivamooga (6th November 2022), Skandandiri, Chikkaballapur (16th November 2022), and Savandurga, Ramnagar (4th March 2023) and data in concern of same has been submitted to the component coordinator for further action. In connection of above, Completed 2 CVM study in the place of Bannerghatta, Bengaluru (17th, 18th, 22nd & 23rd December 2022) and Skandagiri, Chikkaballapur (26th and 27th of November 2022 & 4th, 5th and 10th of February 2023) and the collected has sent to the concerned component coordinator on 29th December 2022 and 12th February 2023 respectively.

  In regard of SFD data fulfilment, once again the requesting letter has been sent to the PCCF level for

both the state forest department (Andhra Pradesh and Goa) on 14th February 2023 and has been in a regular mode of follow up to know the status. Selected the villages based on the forest type with help of the LAMPS planning to carry out the household survey as per the format.

Review paper has prepared on "Green GDP- An Opportunity for Green Growth in India" by referring the secondary literature and submitted in EPRA- ECEM Journal on 30th March 2023.

- **IFB:** 2531 HH have been surveyed belongs to 250 villages of total 21districts of T.S(10) & Odisha (11) belongs to Phase-I & phase-II namely, Sangareddy, Siddipet, Bhadradri-Kothagudem, Mahabubabad, Khammam, Kamareddy, Nizamabad, Nalgonda, Adilabad,Nagarakurnol & Kandhmal, Nabarangpur, Jharsuguda,Jajpur, Puri, Malkangiri, Rayagada, Nayagarh, Ganjam,Dhenkanal, Sundaragarh respectively. Collected the secondary data for census-based parameters from TSFD. 2161 households survey data has been entered in excel format.

Institute	State	FT Code	HH Surveyed
RFRI	Assam, Tripura, Mizoram	FT02, FT01, FT03, FT12	1670
IWST	Karnataka	FT02, FT05	900
HFRI	Himachal Pradesh	FT13, FT12, FT14	820
AFRI	Rajasthan, Gujarat	FT03, FT05, FT06	640
IFGTB	Tamil Nadu	FT02, FT03, FT05, FT08	1350
IFB	Telengana, Odisha	FT03, FT05	2531
IFP	Bihar, Jharkhand, WB	FT02, FT03, FT05	600
TFRI	MP, Maharashtra, Chhattisgarh	FT03, FT05	1060
ICFRE/FRI	UP, UK, HR	Ft03, FT05, FT06, FT09, FT12, FT14	2915
		Total	**12,486**

The analysis for valuation of ecosystem services towards contribution to GDP is in progress. Completed 12086 survey valuation for ecotourism services through Contingent Valuation Method (CVM) for 23 sites in the 11 states of the country summarized as below

S.No	Ecotourism site	State	HH Surveyed
1	Lacchiwala	Uttarakhand	503
2	Badrinath	Uttarakhand	545
3	Dumna Nature Park	Madhya Pradesh	569
4	Okhla Bird Sanctuary	Uttar Pradesh	550
5	Lalkhatanga-Biodiversity Park	Jharkhand	509
6	Birsa Biological Park	Jharkhand	502
7	Bannerghatta Biological Park	Karnataka	541
8	Van Vihar, Bhopal	Madhya Pradesh	525
9	Sultanpur National Park	Haryana	572

10	Kahna National Park	Madhya Pradesh	515
11	Pichavaram Mangroves	Tamil Nadu	542
12	Sariska Tiger Reserve	Rajasthan	501
13	Athirapally	Kerala	525
14	Ranthambore National Park	Rajasthan	521
15	Skandagiri	Karnataka	542
16	Barathpur	Rajasthan	505
17	Chail	H.P	508
18	Kufri	H.P	520
19	Kasauli	H.P	516
20	Renuka Wildlife Sanctuary	H.P	525
21	Ganagsagar Island	West Bengal	501
22	Savandurga Hills	Karnataka	542
23	Lamahata Ecopark	West Bengal	507
		Total	**12,086**

Highlights

- Forests provide a natural pollution abatement strategy by acting as a surface area for the deposition of PM (PM2.5 and PM10). Deposition flux and total PM removal across sixteen forest type groups of India were estimated based on 2019 dataset of particulate matter (PM) using reanalysis models and RS&GIS.
- Analysis reveals that deposition of PM was high in Littoral and Swamp forests followed by Tropical Semi Evergreen forests, Tropical Moist Deciduous forests and Subtropical Pine forests.
- The air pollution abatement service by forests for PM removal was 188 M US Dollars (USD) with externality-based removal service as per literature and 2009 M USD using the cost of PM removal by the pollutant control equipment.
- The net PM removed by all forests of India was approximately worth 59-81 million dollars for PM2.5 and worth 7093-15327 million dollars for PM10 based on valuation using value transfer method.

14. All India coordinated research project on "Forest Fire Research and Knowledge Management"

14.1 Objectives:

- Generating knowledge and capacity building to minimize the devastating impact of forest fires; to carry out research on forest fire and to develop appropriate management strategies for the forested areas which are most vulnerable to forest fires.

14.2 Progress:

- As part of project baseline data on timber, fuelwood, fodder, NTFP, floral biodiversity (including Invasive alien species), carbon storage, carbon sequestration, soil nutrients from burnt and unburnt forest areas of five forest types viz., Tropical Semi Evergreen Forest, Tropical Wet Evergreen Forest, Tropical Moist Deciduous Forest, Tropical Dry Deciduous Forest, Sub-Tropical Pine Forest covering 15 States viz., Uttarakhand, Himachal Pradesh, Madhya Pradesh, Maharashtra, Chhattisgarh, Odisha, Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, Kerala, Assam, Meghalaya, Mizoram and Nagaland is being collected.
- FRI has also developed fire-fighting tool kit and fire safety clothing's kit in collaboration with University of Petroleum and Energy Studies, Dehradun. The kits have been sent to Kerala, Uttarakhand and Odisha State Forest Department. The kits were also tested in Dehradun Forest Division by FRI. The feedback on utility of fire-fighting tools and safety clothing's after testing in actual field condition have been received from Kerala, Uttarakhand and Odisha State Forest Department. Based on feedback received from SFDs and headquarters the fire-fighting tools will be modified accordingly. Signing of MoU for designing and developing fire-fighting hand tools kit by IIT, Roorkee is under progress. Mapping and categorization of fire prone areas in five pilot districts viz., Amravati, Aizwal, Kadapa, Pauri Garhwal and Idukki based on historical fire data and ecological model is under progress. Designing and development of strategy for awareness campaign on forest fires in selected fire vulnerable landscapes is being undertaken in this project which will be based on cause specific awareness strategy on forest fire.

Highlights

- The baseline data on 8 parameters (timber, fuelwood, fodder, NTFP, Biodiversity, Carbon storage, Carbon sequestration, Soil nutrients) collected for 5 forest types covering 15 states.
- Analysis of field data for few sites is completed
- Sample tool kits (Kit-1 hand tools (15 sets) and Kit-2 safety clothing (06 sets)) has been sent to SFDs of Uttarakhand, Odisha and Kerala for testing in actual field conditions. Feedback on utility of fire fighting tools and safety clothing have been received from these states.

15. All India coordinated research project on "Tamarind (*Tamarindus indica* Linn.): Domestication, conservation and deployment of genetic resources for sustenance and livelihood amelioration"

15.1 Objectives:

- To develop a National Registry and a National Germplasm Bank of Tamarind towards initiating systematic domestication in the country.
- To shortlist high yielding tamarind genetic resources and deploy them with site specificity and precision silviculture methods across multi-locations in order to accomplish higher yield in avenue, farm and industrial plantations.

- To build a National Tamarind Consortium for channelizing superior raw material from genetically improved selections to various industrial stakeholders thereby improving the overall product quality and enhancing the economy.

15.2 Progress:

- Morphological characterization of the tamarind genetic resources available at Tamil Nadu, Telangana, Andhra Pradesh and Gujarat was carried out. Data collected on vegetative and reproductive Phenophases of different tamarind genetic resources. Passport data collected from 75 tamarind clones for developing National Tamarind Registry as per the guidelines of PPVFRA. Gum recovery percentage was assessed for 22 different sources of Tamil Nadu to develop tamarind genotypes with high TSG value. Physicochemical properties of seed gum such as pH, ash content, volatile matter, cold water solubility, viscosity, bulk density, particle density and moisture content was estimated. Biochemical characterization of tamarind seed polysaccharides was also conducted. Biometric characteristic of tamarind clones available at Achuthapuram, Telangana were documented. Categorized 75 Tamarind clones based on flowering behaviour and fruit setting pattern. Investigation on time of anthesis, floral visitor, pollen biology and breeding systems was conducted. Studied leaf anatomical variation to understand the foliar morphology among the red, sour and sweet variants.
- Maintenance of VMG of Tamarind through regular watering, weeding and fertilizer application for higher production of scion shoots is being carried out. Raised about 5000 tamarind seedlings for root stock purpose. Optimized grafting season for large scale multiplication of tamarind genetic resources. Shortlisted 15 high productive clones at VMG, Forest Campus; Red and sweet Tamarind germplasm bank at Salem. Produced 5000 grafts in 15 high productive clones.
- Established and maintained three multi location clonal trail of tamarind at IFGTB field research station, Neyveli, Cuddalore Dt., Kangeyam Tirupur Dt., and Melur Madurai Dt. with 25 shortlisted high productive clone of Red, Sweet and Sour tamarind. Data on growth traits were recorded from the different clones. Established Tamarind clonal trials at Bayala, Thumkkuru; and Naickenpalayam, Coimbatore. Seeds were collected from the high yielding tamarind trees and National Germplasm Bank of Red and Sweet Tamarind at Salem. The seeds were subjected to pre-treatments with biofertilizers to test the resistance of seedlings towards diseases and the biometric characteristics were recorded. Established Tamarind plantations with 5000 seedlings at selected lands at panchayat, temples, schools, avenues and village roads for restocking of TGRs towards the livelihood improvement of rural population. Maintained the Tamarind plantations established in Bhodakaadu and Mullainagar panchayats, Dharmapuri district; Pallipatti, Krishnagiri Dt; Kallimandhayam, Ottanchatram with people's participation.
- Collected base-line data on Tamarind processing Industries in Dindigul and Theni Dt. Three farmer's producer organisations were identified and each FPO is having beneficiaries of more than 1000 farmers each. Communications made to farmers producer company for developing tamarind consortiums. Preliminary arrangements are made for forming consortium of tamarind primary processing, secondary processing and value addition with FPOs, Industries, Machinery Manufacturers and Exporters. The formation of tamarind consortium for enabling value chain of

tamarind seed gum is initiated. The tamarind growing farmers who have FPO were identified in Dharmapuri regions. Proposal on collaborated training (IFGTB- FCRI, Mettupalayam) on tamarind value addition is submitted for the approval.

Highlights

- Passport data was collected from 55 tamarind clones for developing National Tamarind Registry.
- Fruit morphometric characterization, flowering behavior and fruit setting pattern completed in 55 clones.
- Gum recovery percentage assessed in 22 clones.
- Established 8 Multi-location clonal trials of Tamarind at Neyveli, Cuddalore; farmers field at Kangeyam, Tiruppur; farmers field at Mellur, Madurai in Tamil Nadu; farmers field at Bayala, Tumkur in Karnataka and Forest department land at Mulugu, Hyderabad in Telangana, Centre for Crop Improvement, SDAU, Banaskantha; Agricultural Research Station, SDAU, Mehsana and Cotton Research Station SDAU, Talod, Gujarat.
- 2 Clonal Demonstration Trials were established at Community land at Pallipatti, Dharmapuri and farmers field at Naickenpalayam, Coimbatore (1 acre). Established Tamarind plantations with 5000 seedlings at selected lands at panchayat, temples, schools, avenues and village roads for there stocking of TGRs towards the livelihood improvement of the rural population.
- Developed tamarind based value added products such as tender tamarind pickle and Tamarind flower gulkhand, Squash, wine and evaluated phytochemical and organoleptic properties of the product.

16. All India coordinated research project on "Bioprospecting for industrial utilization of lesser known forest plants"

16.1 Objectives:

- Survey, evaluation and prioritization of the targeted LKFPs
- Systematic chemical genotypes screening of the populations of the prioritized LKFPs and identification of their chemically superior genotypes.
- Identification of industrially viable genotypes among the chemically superior genotypes.
- Standardization of produce specific protocols for downstream processing of industrially viable.
- Development of technology for production of value added marketable products from qualitatively qualified commercial produces of the industrially viable genotypes.
- Extension of the project outcome to various stakeholders for generation of awareness towards plantations of promising LKFPs, commercial applications and improving livelihoods.

16.2 Progress:

- Documentation and analysis of current knowledge/information of 50 lesser known forest plants (LKFPs) have been completed, and a structured format for prioritization of the LKFPs has been developed. Scoring of the institute-wise selected 50 LKFPs was done in the format, and the following 26 LKFPs were prioritized for their intended investigations:

AFRI	*Balanites aegyptiaca, Citrullus colocynthis, Xanthium strumarium, Sterculia urens*
FRCER	*Vitex negundo, Pithecellobium dulce, Mallotus philippensis*
FRI/ HFRI	*Neolitsea pallens, Cupressus torulosa, Punica granatum, Prinsepia utilis*
IFB	*Soymida febrifuga, Buchanania axillaris, Gardenia gummifera*
IFGTB	*Balanites aegyptiaca, Careya arborea, Cassine glauca, Vitex altissima*
IFP	*Cinnamomum cecidodaphne, Pithecellobium dulce, Schima wallichi*
RFRI	*Litsea cubeba, Mallotus nudiflorus, Carallia brachiata*
TFRI	*Anogeissus pendula, Careya arborea, Cyperus rotundus, Woodfordia fruticosa*

- Draft of the technical database containing information on local name, common name, Taxonomic classification, Botanical Description, Distribution, Ethnobotanical significance, Phytochemistry, Biological activities, Toxicology, Patent and Commercial Products, Salient points and Overview, and Scope of further R&D in respect of selected 50 LKFPs was completed. Surveys were conducted, 432 populations of 25 LKFPs were identified, and their geocoordinates were recorded. Chemical screening of the identified populations was undertaken to determine their chemical variability and to identify chemically superior genotypes. Fatty oils of the seeds collected from 15,5,9,8,17,1,20 populations of *Balanites aegyptiaca, Citrullus colocynthis, Xanthium strumarium, Pithecellobium dulce, Prinsepia utilis, Vitex altissima* and *Mallotus nudiflorus;* essential oils of the leaves collected from 13,13,14, 10 populations of V*itex negundo, Neolitsea pallens, Cupressus torulosa* (needles), and *Cinnamomum cecidodaphne*; of the seeds collected from 16 populations of *Litsea cubeba*; of the rhizomes collected from 7 populations of *Cyperus rotundus;* and dyes from the fruits of 5 populations of *Mallotus philippensis*; from the peels of 6 populations of Punica granatum; from the flowers of 6 populations of *Woodfordia fruticosa*; from the bark of 31, 15, 4, 16, 18 populations of *Soymida febrifuga, Buchanania axillaris, Careya arborea, Schima wallichi, Carallia brachiate,* respectively were isolated and their contents were determined. Altogether chemical screening of 249 populations of 21 LKFPs was completed. For fatty oils, 4, 2, 4 populations of *Prinsepia utilis* in Chakrata, Kanasar, Sukki (Uttarakhand) and Shillrru (Himachal Pradesh); *Mallotus nudiflorus* in Bilasipara and Boko (Assam); and *Balanites aegyptiaca* in Alagapuri-Virudhunagar, Thalamalai- Sathyamangalam Tiger Reserve, Bannari-Sathyamangalam Tiger Reserve, and Palavanatham- Virudunagar (Tamilnadu); for essential oils, 3, 3,2 populations of *Cupressus torulosa* in Ogla, Bhatwari and Gopeshwar (Uttarakhand); *Neolitsea pallens* in Dalhousie, Jahal-devidarh road and Khajjiar (Himachal Pradesh); *Litsea cubeba* in Mebo and Pasighat (Arunachal Pradesh) and for natural dyes, 7, 2,1,1 populations of *Soymida febrifuga* in Kondapur c-329, Narsapur urban park, Mosra, Kondapur c-328, Eklaspur, Rudraram, and Medambanda (Telangana); *Careya arborea* in Kalakad Mundanthurai Tiger Reserve- II, and Topslip-

Anamalai Tiger Reserve (Tamilnadu); *Buchanania axillaris* in Lenkagadda (Telangana); and *Punica granatum* in Potters Hill (Himachal Pradesh), respectively, were identified to be chemically superior populations. A total of 29 populations of 10 LKFPs were identified to be chemically superior for industrial applications. GC-FID and GC-MS assisted chemical compositions of the needles and leaves derived essential oils isolated from 3 and 4 chemically superior populations of *Cupressus torulosa* found in Ogla, Bhatwari and Gopeshwar (Uttarakhand) and *Prinsepia utilis* located in Chakrata, Kanasar and Sukki (Uttarakhand), and Shillrru (Himachal Pradesh) were established. GC-MS assisted chemical compositions of the seeds derived fatty oils isolated from 4 chemically superior populations of *Balanites aegyptiaca* situated in Alagapuri - Virudhunagar, Thalamalai - Sathyamangalam Tiger Reserve, Bannari-Sathyamangalam Tiger Reserve and Palavanatham-Virudunagar ; and of the fruits derived essential oils isolated from 2 chemically superior populations of *Litsea cubeba* located in Mebo and Pasighat (Arunachal Pradesh) were determined. Chemical profiles of 25% aqueous methanolic extracts of the leaves of *Prinsepia utilis*, and Neolitsea. pallens, and needles of *Cupressus torulosa* collected from the populations grown in Munsyari, Majhrana, and Gopeshwar, respectively, were unveiled, and 68, 30 and 62 compounds, respectively, belonging to classes of organic acids, esters, flavonoids, phenolic acids and their derivatives, lignans, phenylpropanoid glucosides, alkaloids, terpenoids, glycosides, fatty acids and their derivatives, heterocyclic compounds, and quinones were identified. Protocols for recovery of natural dye in the yield of 28.1%, 19.7%, 24.6%, 12.83%-13.00%, 3.75%, 13. 47% and 16.06% from the peels of *Punica granatum*, barks of *Soymida febrifuga, Buchanania axillaris, Careya arborea,* and *Schima wallichi,* fruits of *Mallotus philippensis*, and flowers of *Woodfordia fruticosa,* respectively were optimized. Sensory evaluation of the essential oils isolated from chemically superior populations of *Cupressus torulosa* located in Ogla, Bhatwari and Gopeshwar of Uttarakhand revealed the suitability of the oils from Ogla and Bhatwari for making the perfume blends. Sensory assessment of the leaves derived essential oils isolated from 2 chemically superior populations of *Neolitsea pallens* located in Dalhousie and Khajjiar (Himachal Pradesh) showed the suitability of the oil from Dalhousie for fine fragrances and other perfumery applications; and that from Khajjiar for oil based products. Using Box Behnken design, conditions for dyeing of silk, wool and cotton fabrics with the *P. granatum* peels derived dye were optimized. The dye was also found to be promising for incorporation into food and cosmetics products. Functional performance of the dye isolated from the bark of chemically superior population of *Soymida febrifuga* was evaluated as hair colorant gel and the dye was qualified. The essential oils isolated from the needles of *C. torulosa* of Ogla origin displayed excellent *in-vitro* insecticidal activity (LC50, 0.23ppm and LC90,0.58ppm; 0.30 ppm and 0.62 ppm, respectively) against stored grain pest *Sitophilus oryzae* (Rice weevil) and validated the traditional claim of the insecticidal property of the needles. Evaluation of the dye isolated from the flowers of *Woodfordia fruticosa* showed its for coloring cotton textile and hairs. Six processes for making a pain relieving balm Vita-5 from essential oil of *Vitex negundo* leaves; preparation of Golden ink from fruit pericarp of *Mallotus philippensis*; for making a novel formulation for the management of type-2 diabetes mellitus and complications associated with diabetes (Patent Application no. 202311010779; Dated 17/02/2023); making a topical herbal gel formulation for the treatment of pain (Patent

Application No. 202311013393; Dated 28/02/2023); for recovery of natural dye from *Soymida febrifuga* bark (Patent Application No. 202341007697; Dated 07/02/2023) and making a herbal hair colouring composition (Patent Application No. 202341023759; Dated 30/03/2023) were developed.

Fig.10 Herbal analgesic gel & herbal analgesic oil

Fig.11 *Soymida febrifuga* bark dye derived hair colorant gel

Highlights

- Prepared a technical database of 60 LKFPS. Prioritized 26 LKFPS for chemical screening to determine their chemical variability.
- Patent filed on a novel formulation for the management of type-2 diabetes mellitus and complications associated with diabetes (Patent Application no. 202311010779; Dated 17/02/2023)
- Patent filed on a topical herbal gel formulation for the treatment of pain (Patent Application No. 202311013393; Dated 28/02/2023)
- Patent filed on recovery of natural dye from *Soymida febrifuga* bark (Patent Application No. 202341007697; Dated 07/02/2023)
- Patent filed on preparing a herbal hair colouring composition (Patent Application No. 202341023759; Dated 30/03/2023)

17. All India coordinated research project on "Enhancement of fodder availability and quality to reduce unsustainable grazing in the forest"

17.1 Objectives:

- Standardising planting, management, protection and fodder sharing procedures for enhancing tree fodder availability in fodder scarcity regions of India
- Improving nutritive value and storage life for greater fodder availability during lean period
- Capacity building of project personnel and stakeholders in raising high-yielding fodder plantation

17.2 Progress:

- The major focus of the project is on conducting field trials in the mandated regions of nine institutes of ICFRE. Field trials have been established at 19 sites (Table 1). Tree species were selected as per the site conditions and planted in high density spacing (1m x 1m, 1.25m x 1.25m and 1.5m x 1.5m) and managed with different frequencies of coppicing. Fodder harvest frequencies being tested are once/year, twice/year and thrice/year. Grass species are also being tested in the field trials.

Table: No. of field trials established under the project

Name of institute	No. of sites of field trial
ICFRE-AFRI Jodhpur	2
ICFRE-FRI Dehradun	2
ICFRE-HFRI Shimla	2
ICFRE-IFB Hyderabad	1
ICFRE-IFGTB Coimbatore	3
ICFRE-IFP Ranchi	2
ICFRE-IWST Bengaluru	3
ICFRE-RFRI, Jorhat	1
ICFRE-TFRI Jabalpur	2

- A total of 19 field trials were maintained during the period including those established during 2021-22 and 2022-23. Plants that had attained suitable size were coppiced to produce multiple shoots. The field trials are being maintained. Fodder yield and quality will be assessed starting from the next year.

Highlights

- Identified as fast-growing fodder species (*Glyricidia sepium, Morus alba, Bauhinia purpurea, Ailanthus excelsa, Moringa oleifer* and *Sesbania grandiflora*) from 18 sites.
- Uttarakhand Livestock Development Board, Kalsi (Dehradun), Indian Grassland and Fodder Research Institute, Dharwad, University of Agricultural and Horticultural Sciences, Shivamogga, Regional Fodder Station, Hessaraghatta (government organisation, one site each), Dakhinpat Satra, Jorhat (an NGO, one site), farmers/gram panchayats (at five sites) and SFDs (at eight sites) have provided land for field trials.
- Field trials have been laid out at 18 sites by planting the preferred tree species of respective sites at close spacing. The spacings are 1m x 1m, 1.25m x 1.25m and 1.5m x 1.5m and managed. The plantations are being maintained by coppicing at different frequencies viz. once/year, twice/year and thrice/year. Grass has also been planted.

18. All India coordinated research project on "Silvicultural interventions for productivity enhancement and carbon sequestration in plantations of important tree species"

18.1 Objectives:

- To study the effect of various micro-irrigation regimes in block and boundary plantations of Teak, Gmelina, Adina, and Cadamba
- To investigate effect of various tree density on qualitative and quantitative improvement in rainfed plantations of Ailanthus, Neem and Pungam in block and in boundary planting
- To investigate effect of various tree density on qualitative and quantitative improvement in Adina plantations
- To investigate effect of mixed planting of *Casuarina* and *Acacia auriculiformis* with Teak on qualitative and quantitative improvement in plantations in block and in boundary planting.
- To investigate the influences of silvicultural interventions on wood quality
- To assess carbon sequestration potential and financial analysis of plantation of important tree species under varied silvicultural interventions.

18.2 Progress:

- In the recent years, trees outside the forests (ToFs) is receiving increased attention and play a vital role in increasing wood supply and enhancing livelihood support to the farming communities. However, there exists dearth of information on optimum silvicultural requirement particularly in water and spacing requirements. The study also envisages on assessment on the complimentary benefits of mixed planting systems particularly mixed planting of teak with N-fixing trees like *Casuarina*/ *Acacia auriculiformis*. The institute-wise progress made till now under this project is as below:

- **IFGTB**

  I) Completed assessment on growth in 45 boundary planting and 15 block plantations of Teak; Completed assessment on growth in 29 *Gmelina arborea* plantations.

  ii) Collected data in 15 boundary plantations and 7 block plantations of Neem; 11 Pongamia boundary plantations; 11 block plantations and 6 boundary plantations of Ailanthus.

  iii) Completed establishment of block plantation of mixed planting of Teak & Casuarina in three locations viz., Kangeyam, Kundadam and KVK-Myrada. Completed establishment of block plantation of mixed planting of Teak & *Acacia auriculiformis* in three locations viz. Kundadam, Kangeyam and Dindigul. Completed establishment of mixed boundary planting of Teak & Casuarina in three locations – Kanchipuram, Tiruppur and Dindigul.

  iv) Established Teak & Acacia mixed boundary planting in one location - Kangeyam.

  v) Completed analysis of data collected from existing plantations of teak and salient observations

showed that: In boundary plantations, a) out of 45 boundary plantations surveyed, 72.7% of plantations are irrigated and remaining 27.3% plantations are rainfed with initial protective irrigation b) productivity of these irrigated plantations was 3.61 m3/ha/year in plantations which are irrigated weekly once, 3.31 m3/ha/year in plantations receiving irrigation once in 15 days and 2.68 m3/ha/year in plantations receiving irrigation monthly once. Mean productivity of rainfed teak plantation was 1.95 m3/ha/year. In Block plantations, a) out of 15 block plantations surveyed, 93% are irrigated and 7% are rainfed with initial protective irrigation, b) productivity of these irrigated plantations was 7.10 m3/ha/year in plantations which are irrigated in a twice week and 5.20 m3/ha/year in plantations receiving irrigation in a once week. Mean productivity of rainfed teak plantation was 2.70 m3/ha/year. Fig. 12 Recording growth parameters in the trial plot of Haldina at TFRI

- **TFRI:** Established and maintained field trials of *Haldina cordifolia* under spacing -3m x 3m and 5m x 5m pit size- 30cm and 45m established at field of Tropical Forest Research Institute, Jabalpur(M.P.) and recorded growth - 30.24cm @ 3x 3m and 31.30 cm @ 5m x 5m and survival percentage (98%) while in farmer's field, Dhemerkheda village, the height ranges 43.67cm @3mx3m and 39.60cm @ 5m x 5m with 100%. Maintained the mixed boundary plantation of teak with *Acacia auriculiformis* at farmer's field of Hinotiya, Barela, Jabalpur district and recorded data on survival 85 % and growth (263.64cm of Acacia and CD- 8.67cm) and height of was recorded teak 50cm.

Fig. 12 Recording growth parameters in the trial plot of Haldina at TFRI

Established mixed boundary plantation of Teak and Casuarina at Mangatta village Chhattisgarh (C.G.). Recorded survival percentage (100 %) and growth ranges 36.12cm. Extensive survey was carried out in the 20 farmer's fields in Madhya pradesh to assess the Gmelina growth under different irrigation regimes and recorded performance data showed that 20 year old Gmelina stand recorded maximum frequency 88 trees under girth class 60-80 cm followed by 69 under 90cm girth class nder sprinkler irrigation system while young plantation of 5 year maintained under micro irrigation system recorded maximum frequency 47 trees under the girth class 10-20cm followed by 29 in 20-30cm girth class existing in the farmer's field of Tewar and Kundam village respectively. Survey was also carried out to collect data of haldina plantations in Chhattisgarh region and reported that maximum frequency 46 trees(8 years old) under 10-20cm girth class under unirrigated conditions while maximum frequency 63 tree observed under Girth class 20-30cm (8 years old) under irrigated (micro-irrigation) conditions.

- **IWST**

I) Survey of teak plantations was completed i.e 15 block plantations and 15 boundary plantations of teak were completed.

ii) Documented the data of teak plantations and calculated the biomass value of 15 block and boundary plantations of teak. Initiated land preparation works. Weed removing and cleaning of boundary line for establishment of boundary plantation was completed.

- iii) Established the field trials under mixed block plantation of Teak and Casuarina in two ratios viz, 1:1 ratio and 1: 3 ratios under irrigated condition.

- **AFRI**

I) Recorded growth data in International Provenance Trials of Neem in AFRI and also in scattered trees of Neem in Jodhpur.

ii) Recorded growth data height, girth, basal diameter and crown diameter of Ailanthus, neem and *Pongamia pinnata*. Mostly Ailanthus, neem and *Pongamia pinnata* are scattered distribution. Surveyed and recorded growth data of two boundary plantation of Neem at Jodhpur area and one boundary plantation of Ailanthus at Jaipur area.

iii) Surveyed at Kota area and recorded growth data of a) one boundary plantation of Neem, b) one block plantation of Ailanthus and iii) two boundary plantations of Pungam. Also recorded Data of *Ailanthus excelsa, Azardirachta indica* and *Pongamia pinnata* in Sikar, Churu and Jhunjhunu.

iv) During last six months period, surveyed at sikar, Churu, Jhunjhunu area and recorded growth data of i) 1 block plantations and 3 boundary plantations of Neem, ii) 1 block plantations and 1 boundary plantations of Ailanthus and iii) two boundary plantations of Pungam.

- **FCRI**

I) Assessed and documented growth biometry of 23 Block Plantations of farm grown teak under 3 age class (5-10, 10-15 ,15-20 years) in Western Agro climatic zone of Tamil Nadu

ii) Assessed and documented growth biometry of 22 Boundary Plantations of farm grown teak under 3 age class (5-10, 10-15 ,15-20 years) in Western Agro climatic zone of Tamil Nadu

iii) Estimated tree volume of 45 farm grown teak plantations (45 Block Plantations, 44 Boundary Plantations) under 3 age class (5-10, 10-15 ,15-20 years) in Western Agro climatic zone of Tamil Nadu

iv) Yield model construction and validation was developed for *Tectona grandis* in all three age classes (5-10 years, 10-15 years and 15-20 years) with particular reference to Western agro-climatic zone (WZ) of Tamil Nadu.

v) Analysed and documented wood quality parameters such as heartwood, sapwood, bark content and wood density with respective age classes on two agroclimatic zones namely North eastern zone (NEZ) and North western zone (NWZ) of Tamil Nadu.

vi) Metabolic profiling of teak heartwood samples collected from different agroclimatic zones was conducted by Gas chromatography–mass spectrometry (GC-MS)

5 – 10 years 10-15 years

Fig. 13 Wood samples collected from teak plantations in Western zone of Tamil Nadu

5 – 10 years 10-15 years

Fig. 14 Wood samples collected from teak plantations in Cauvery Delta zone of Tamil Nadu

Highlights

- Growth assessment completed in 265 plantations of Teak, Gmelina and Haldina under different irrigation and planting configurations.
- In existing plantations of teak in TN, out of 45 boundary plantations, 72.7% irrigated (mean productivity: 3.20 m3/ha/year) and 27.3% plantations rainfed (mean productivity: 1.95 m3/ha/year).
- For micro-irrigation in teak boundary plantations, mean productivity is 3.61 m3/ha/year (weekly), 3.31 m3/ha/year (forthnight), 2.68 m3/ha/year (monthly)
- Out of 15 block plantations, 93% irrigated (productivity: 7.10 m3/ha/year) and 7% rainfed (productivity: 2.70 m3/ha/year.)
- In Ailanthus plantations mean wood production was 128.9 MT/ha with mean productivity of 14 MT/ha/year under block planting. Mean wood production was 3.67 MT/ha with mean productivity of 0.41 MT/ha/year under boundary planting.
- Maintained the mixed boundary plantation of teak with *Acacia auriculiformis* at farmer's field of Hinotiya, Barela, Jabalpur district (23"5'45" N; 80"31'08"E) (survival 85%).
- Established mixed boundary plantation of Teak and Casuarina at Mangatta village

19. All India coordinated research project on "Assessment of water requirement of different forest tree species and its impact on subsoil moisture"

19.1 Objectives:

- To quantify water requirement for transpiration of selected forest tree species commonly used for plantation by various State Forest Departments.
- To quantify the cumulative effect of evapotranspiration and infiltration on subsoil moisture.
- To develop correlation between transpiration rate and subsoil moisture status for species under study.

19.2 Progress:

- This All India Coordinated Research Project aims at identifying the best suitable forest species for plantation under different rainfall conditions in the country with an objective to maximise water yield from a catchment. Under the study, nine forest tree species are being studied by the participating institutes. The total water requirement for transpiration of a particular tree species is measured with the help of sap flow monitoring systems.

Institute	Sites	Species
IFGTB	IFGTB campus/expt. area	*Prosopis juliflora, Azadirachta indica, Tectona grandis, Melia dubia*
TFRI	Kanha National Park/ Tiger Reserve, TFRI Experimental area	*Shorea robusta,Tectona grandis, Anogeissus latifolia, Terminalia tomentosa*
FRI	Mussoorie watershed, Uttarakhand; Sanjay Van, New Delhi (Ridge forest) and Champion Block, Forest Research Institute, Dehradun.	*Pinus roxburghii, Quercus leucotrichophora, Shorea robusta, Prosopis juliflora*
AFRI	AFRI Expt. area and Sita Mata Sanctuary, Chittorgarh, Rajasthan	*Prosopis juliflora, Azadirachta indica Anogeissus latifolia, Tectona grandis*

Geo-locations	
Champion Block, FRI	: 30º 20' 18.20" N; 78º 00' 39.40"E
Mussoorie watershed	: 30º 32' 02.10" N; 77º 11' 02.76"E
Sanjay Van, New Delhi	: 28º 32' 02.00" N; 77º 10' 57.00"E
Sitamata Wildlife Sanctuary	: 24° 17' 12.984" N; 74° 29' 30.012" E
AFRI expt. area	: 26° 13' 51.096" N; 73° 1' 50.304" E
IFGTB, Coimbatore	: 11° 01' 01.2" N; 76° 57' 3.6" E
TFRI Expt. area	: 23° 06' 03.9168" N; 79° 59' 23.0712" E
Mawai	: 22° 29' 44.5416" N; 81° 04' 40.6488" E
Kanha NP	: 22° 24' 29.0376" N; 80° 34' 41.3832" E

- Protocol for instrumentation, data recording, and design of the experiment has been finalized and the major equipment, 144 sap flow monitoring systems, have been procured (36 for each participating institute). Installation of sap flow monitoring systems completed by all the partner institutions for the respective species except for *Pinus roxburghii* at FRI Dehradun.
- Soil profiling and root zone identification have been done at all the partner institutes (*Shorea robusta* forest, Champion Block, FRI; *Prosopis juliflora* forest, Sanjay van, New Delhi; *Quercus leucotrichophora*, Binog wildlife sanctuary, Mussoorie; *Tectona grandis*, *Anogeissus latifolia* forest, Sitamata wildlife sanctuary; *Azadirachta indica , P. Juliflora* at AFRI, Jodhpur; experimental site at Coimbatore, TFRI campus, Mawai rest House, East Mandla forest division and Kanha Tiger

Reserve) in their respective experimental sites except for *Pinus roxburghii* by FRI.

- The soil moisture variation is being measured by multi-profile soil moister and temperature sensor (Make Odyssey) installed at the study sites. The soil moisture sensors are located at 0-20cm, 20-40cm, 40-60cm, 60-80cm, and 80-100cm.
- Soil infiltration and hydraulic conductivity have been estimated at the experimental sites
- Sap flow rate and cumulative sap flow in different species are being estimated after entering the tree and wood parameters required for the analysis of sap flow velocity in the software.
- Initial data indicated that the daily transpiration rate in oak trees varies between 5-65 liter per day in different individuals.

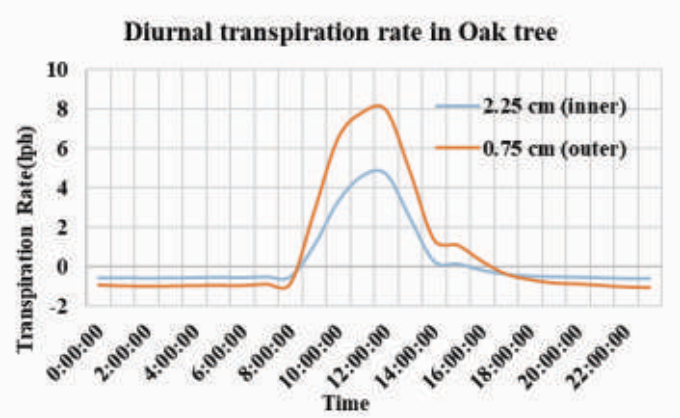

Fig. 15 Diurnal transpiration rate

Fig. 16 Data acquisition from sap flow meter

- Weather parameters are recorded at the experimental sites through automatic weather stations.
- A workshop on "Understanding hydrological processes in forests through sap flow instrumentation" was organized. Principal investigators from all the participating institutes participated in the workshop and learned the details of data retrieval and interpretation. Dr. Rajeev Kumar Tiwari, IFS, Principal Commissioner (Delhi Development Authority), who was the NPC of the project during his tenure at ICFRE; Dr. Peter Cull, Head of Plant Science Applications & Research for ICT International, New South Wales, Australia also attended the workshop.

Highlights

- Sap flow rate is being recorded for nine forest tree species (*Prosopis juliflora, Azadirachta indica, Anogeissus latifolia, Tectona grandis, Pinus roxburgii, Quercus leucotrichophora, Shorea robusta, Terminalia tomentosa, Melia dubia*) by sap flow monitoring systems at nine experimental sites.
- Water use /transpiration in oak varied between 5-65 l/day during December 2022, with a sap velocity of 2.1 to 5.2 cm/hour at Mussoorie watershed.
- Transpiration rate of 20-60 liter per day was recorded in *Prosopis juliflora* at Sanjay Van, New Delhi.
- Four experiments are established in protected areas in collaboration with the state forest departments (Kanha National Park (MP), Mawai Forest, Sitamata Wildlife Sanctuary (Rajasthan), Mussoorie watershed (Uttarakhand)) and one in Sanjay Van, New Delhi in collaboration with DDA.

20. All India coordinated research project on "Development of Biopesticide products/formulations from extracts of tree borne oil seeds and tissues of wild plants for management of insect pests"

20.1 Objectives:

- To tests the efficacy of the biopesticidal formulations of Tree PALH and Crawl clean at multi locations across the country against targeted forest pests.
- Bioassay directed characterization of active principles or compounds from selected tree borne oil seeds and plant tissues.
- To develop biopesticidal formulations using most effective bioactive principles for the management of insect pests of forestry crops.

20.2 Progress:

- Tree PALH and Crawl were supplied to participating ICFRE institutes for nursery and field evaluation against key forest pests as per the data format given. Lab and field evaluation of Tree PALH and Crawl clean at the prescribed dosages were carried out at different jurisdiction areas of respective institutes to ascertain their bioefficacy on different insect pests of different forestry crops at different locations and in different seasons. Performance of Tree PALH resulted in better management of key pests than Crawl clean both in lab and field trials. No phytotoxicity was observed.
- Bioassay directed characterization of active principles or compounds from selected tree borne oil seeds and plant tissues.
- Biosafety of different concentration of Mahua and Jatropha seed oil on egg parasitoids *Trichogramma raoi* and *T. chilonis* under lab conditions had little impact on egg parasitoid with adult emergence. Similarly, the different concentration of mahua seed oil also showed least adverse effect on parasitisation, of *T. raoi* and *T. chilonis.*
- The effect of seed oil of mahua and jatropha on the adult of *Canthecona furcellata* revealed low adult mortality at 96 HAT.
- Bioassay for insecticidal activity of extracts/ oil formulations for determination of LC-50&LD-50 values have been initiated and is in progress.

Fig. 17 Treated seedlings of Cedrus deodara in nursery

- The toxicity of *B. albiflora* was detected at the time intervals of 24 hours, 48 hours, and 72 hours of treatment, with LC50% values of 0.90, 0.98, and 0.94 against the Shisham defoliator *Plecoptera reflexa,* followed by LC50% values of the extract against the insect pest *Agrotis ipsilon* as 0.94, 0.96, and 0.96 respectively with significant effect at $p \leq 0.05$.

Highlights

- Testing of Biopesticide Tree PALH at multi locations (7 locations) across the country against insect pests of commercially important tree species showed significant results.
- Multi location trials in respective Institute or State Forest Department nurseries and plantations at the Institute jurisdiction areas like Himachal Pradesh, Uttarakhand, Rajasthan, Madhya Pradesh, Telengana, Karnataka and Tamilnadu with biopesticide Tree PALH showed significant mortality of key insect pests.
- 03 lab and field trials each for insect pests of teak (*Hyblaea puera* and *skeletonizer Eutectona machaeralis* and white grubs, *Holotrichia* spp.) *Ailanthus defoliators* (*Eligma narcissus* and *Atteva fabriciella*) Shisham defoliator (*Plecoptera reflexa, Agrotis ipsilon* (cutworm) insect pests of *Tecomella undulata* (*Patialus tecomella*), pest of *Dalbergia sissoo* (*Plecoptera reflexa*), seed pest of *Prosopis cineraria* (*Caryedon serratus*), insect pests of *Pterocarpus* and *Gmelina* shoot borer recorded 67-70% mortality at 1.5% concentration in 24hrs.

21. All India coordinated research project on "Development of superior bio-fertilizer products for enhanced plants productivity"

21.1 Objectives:

- To evaluate the efficacy of different bio-fertilizers (both commercial and IFGTB developed) on quality seedling production in nursery for developing potential bio-fertilizer consortia.
- To determine the bio-control efficacy of bio-fertilizers against soil/root borne pathogens of seedlings in nursery.
- To assess out-planting performance of bio-fertilizers inoculated plants in different field conditions.
- To conduct training-cum demonstration about the bio-fertilizer production technology to various stakeholders to improve their livelihood.

21.2 Progress:

This project has a aim to evaluate the efficient bio-fertilizers for productivity enhancement of economically important forestry species and to disseminate cost effective AM bio-fertilizer technology to end users for sustainable production and use vis-à-vis livelihood enhancement. The superior biofertilizers will be identified based on the performance in the plants under nursery as well as field conditions in this project. ICFRE- IFGTB has developed biofertilizer and biocontrol products which are used in the selected commercial trees such as *Gmelina arborea, Melia dubia*, *Santalum album, Dalbergia sissoo* and *Capparis deciduas*. The tree species were inoculated with IFGTB as well as commercial biofertilizers. This study will help to assess the performance of biofertilizers so as to identify the efficient and suitable biofertilizers for each tree species. Nitrogen fixers (*Azospirillum, Azotobacter*), Phosphate solubilizers (*Bacillus*, AM fungi), Potassium mobilizers (*Frateuria*), and biocontrol agent (*Trichoderma*) were used in this project. The products

of these biofertilizers were issued to all the collaborative institutes for multiplication and application.

Interestingly the biofertilizers Azospirillum, Azotobacter, and Bacillus were found that they are capable to control the pathogen as they are producing siderophores. The antagonistic activity also confirmed that biofertilizers are efficient to control the pathogens like *Fusarium oxysporum, Alternaria alternata , Diploidia* and *Colletotrichum gloeosporioide*s). Further the tissue nutrient contents (N P K) were also showed higher in the ICFRE- IFGTB biofertilizer inoculated plants. The improved tree species of *Dalberia sissoo, Santalum album, Gmelina arborea* and *Melia dubi*a were planted by the respective institutes in their jurisdiction for further assessment.

- **ICFRE- IFGTB:** The IFGTB developed bio-fertilizers such as *Azospirillum lipoferum, Azotobacter chroococcum, Phosphobacteria, Potash Mobilizer* and *Trichoderma viride* have been mass produced and supplied 5 litres each together with 10 kg VAM bio-fertilizer to the participating Institutes of ICFRE viz., FRI, Dehra Dun, IWST, Bangalore TFRI, Jabalpur, AFRI Jodhpur and RFRI, Jorhat for nursery experiments application. Procured seeds of *Gmelina arborea* and *Melia dubia* from KFRI, Peechi, Kerala for raising seedlings and conducting nursery experiments at IFGTB. Tested the commercially available VAM, PSB and Azospirillum bio-fertilizers procured from the open market and the study revealed that the products had low infective propagules at the rate of 2.2/g VAM, 1 x 10-4 cfu/ml PSB, and 1 x 10-3 cfu/ml *Azospirillum*. Seedlings of IFGTB targeted tree species viz., *Santalum album, Gmelina arborea* and *Melia dubia* have propagated in the nursery with inoculations of biofertilizers. The inoculated biofertilizers showed improved growth and biomass in the nursery and thus improved planting stocks were transplanted in the field. The siderophores were identified in biofertilizers that helps to control the pathogens in the lab as well as nursery.
- The siderophore producing biofertilizer *A. brasilense* was tested for the antagonistic activity against pathogens as suggested by the PEG. The *A. brasilense* colonies showed suppressing the growth of pathogens *F. oxysporum, Alternaria alternata, Colletotrichum gleosporoides* and *Diploida* sp. under laboratory conditions This experiment showed the A. brasilense is effective for controlling the pathogens. *Santalum album* seedlings were planted with suitable biofertilizer (AM fungi, PSB, *A. brasilense*, and *K mobilizer*) and provided a host plant *Alternanthera sessilis* that gives good survival in the field. Because *A. sessilis* provides good shade and nutrition to the *Santalum album* seedlings. Similarly the growth parameters of *Melia dubia* species inoculated with IFGTB biofertilizer showed the height of 135.5 cm and stem girth 2.5 cm on averages. These seedlings were planted at Thenkasi district in a farmers land. Growth parameters of planted Gmelina arborea have recorded after 6 months of planting. The suitable consortia of biofertilizer found in *Gmelina arborea* is AM fungi + Phosphobacterium + Azospirillum. These combinations improved the growth up to 220 cm and the girth showed < 2.5 cm. Similarly, observation of field trials of *Santalum album* and *Melia dubia* is undertaken.
- **ICFRE – FRI:** *Dalbergia sissoo, Melia dubia, Santalum album* and *Gmelina arborea* were propagated under the project and inoculated with IFGTB biofertilizers and commercially available biofertilizers. *In vitro* detection of siderophore formation by the known PGPR's (*Azospirillum*,

Azotobacter, Phospho bacteria and Potash mobilizer) of IFGTB developed bio-fertilizers are analysed and tested positive These PGPR's turned the blue colour of agarto yellow colour indication gutilization of Fe and thus, indicated the production of siderophore. The size of siderophore zones was measured with High zone scales/ micrometers (HiMedia) formed by the PGPR's. Standardized dosage of inocula of IFGTB developed bio-fertilizers was given to all seedlings. Seedlings of *Dalbergia sissoo* were treated with commercial biofertilizer and growth parameters were assessed. Seedlings of *Dalbergia sissoo* attained 180 days were processed for analysis of dry weights of shoots and roots. Awareness cum training programme on AM Bio-fertilizers production to the stakeholders was conducted.

- **ICFRE- AFRI:** The biofertlizers IFGTB and commercial source were inoculated in *Dalbergia sissoo* and *Santalum album* planted at Jaisalmer and Jodhpur respectively. The initial growth data has been recorded. Pathogenecity testing and in vivo use of biofertlizers on pathogen affected seedlings has been conducted. Collected data of the planted seedlings of *S. album* and *D. sissoo.* Propagated *Capparis decidua* in root trainers and inoculated with biofertilizers.
- **ICFRE- TFRI:** Biochemical characterization of bio-fertilizers (commercial and IFGTB), viz., *Azospirillum* sp., *Azotobacter* sp., *Pseudomonas* sp. (*Phosphobacteria*) and *Bacillus* sp. (*Potash mobilizer*) have been studied. The seedlings of *Dalbergia sissoo, Santalum album* and *Gmelina arborea* were propagated and inoculated with biofertilizers that showed the improved growth and biomass Artificial inoculation of pathogens along with bio-fertilizers to the healthy seedlings was undertaken. Testing the efficacy of different biofertilizers against selected pathogens is under progress, through artificial inoculation of pathogens and bio-fertilizers to healthy seedlings. The bio-fertilizer products (Commercial and IFGTB biofertilizer) such as Azospirillum (10 ml)Azotobacter(10 ml), Phosphobacteria (10 ml) AM fungi (20 gm) and Potash Mobilizer (10 ml) used for bio-inoculation experiments with the seedlings of *Gmelina arborea* and *Dalbergia sissoo.* Accordingly, growth parameters such as shoot length (cm), root length (cm), collar diameter (cm), shoot and root dry weight (g / plant), absolute growth rate, relative growth rate, and microbial inoculation effects are being recorded
- **ICFRE-IWST:** Biofertilizers were procured from IFGTB and commercially available (IIHR products) products. Collected the samples of *Santalum album, Melia dubia* and *Gmelina arborea* for dry weight analysis of the seedlings. Observations on growth data of seedlings in nursery were subjected for statistical data analysis. Documentation of healthy and infected seedlings based on the symptoms was carried out. Taken up the plantation in Attivatta village for the assessment of the out-planting performance of bio-fertilizers inoculated plants in different field conditions. (Attivatta is the demo village of IWST, Bangalore). Before taking up the plantation of seedlings in the field, soil samples were collected from the plantation sites and those samples were given for soil analysis (pH, EC, Soil organic carbon, Major and minor nutrients). Planted the saplings of *Santalum album, Melia dubia* and *Gmelina arborea* at Attivatta village. After plantation of the seedlings in the fields, the seedlings were look after for the staking arrangements and water management. Observations regarding the survivability of the seedlings and growth were taken.

  The efficacy of different bio-fertilizers (both commercial and IFGTB developed) in the form of

consortia for quality seedlings (Sandal, Melia and Gmelina) in nursery conditions were studied. In addition evaluation of the bio-control efficacy of bio-fertilizer consortia against soil/root borne pathogens of seedlings was also executed. The data's were published in the peer reviewed journals. The out planting performance of established plants in farmer's field of different field conditions (block plantation / bund plantation / home-garden plantation) of the VVK village, named Attivatta of Hoskote Taluk, is pursued. Fabrication of VAM production Unit at VVK Centre, Gottipura initiated.

- **ICFRE- RFRI:** Potential bio-fertilizer consortia for enhanced productivity of forest tree species were identified. Seeds of *Dalbergia sissoo* will be collected at the time of maturity. Commercial as well as IFGTB developed Biofertilizers such as *Azospirillum, Azotobacter, Phosphobacteria*, AM fungi and Potash Mobilizer (Tricho-K) was procured from Assam agriculture University, Jorhat and IFGTB, Coimbatore respectively for nursery trial. Site was selected for raising of seedlings in nursery. Polybags having potting media soil, sand and FYM at the ratio of 2:1:1 prepared for raising of seedlings The statistical design followed in nursery trial is CRD. Physico-chemical characteristics such as pH, Electrical Conductivity (EC), available Nitrogen (N) available Phosphorus (P) and available Potassium (K) were done. To determine Bio-control efficacy against soil/root borne pathogens of seedlings pathogenic organism *Fusarium oxysporium* was isolated and mass cultured for application in the nursery trial for testing the efficacy of different bio-fertilizers against selected pathogens. Collection of growth data of *Dalbergia sissoo* for biometric analysis completed for both IFGTB and Commercial bio fertilizers. Maintaining the pure culture of *Fusarium oxysporum* and mass multiplication of *Fusarium* for inoculation along with biofertilizer. Growth data record of 180 days old seedlings of *Fusarium* and biofertilizer inoculated *Santalum album* is completed. *Dalbergia sissoo* seedlings were transplanted (both bio fertilizer treated seedlings) to field. One year data collection of *Gmelina arborea* in field is completed. CFU count and AM fungi root colonization was recorded in one year old *Gmelina arborea* at field.
- The bio-fertilizer products (Commercial and IFGTB biofertilizers) such as *Azospirillum brasilense* (10 ml) Phosphobacteria (10 ml) AM fungi (20 gm) and Potassium mobilizer (10 ml) used for bio-inoculation experiments in *Gmelina aborea, Santalum album* and *Melia dubia. In-vitro* detection of siderophore formation in *Azospirillum brasilense* (nitrogen fixing bacteria), and phosphobacteria and Potash mobilizer was observed. Siderophore formation is confirmed that the biofertilizers capable to control the pathogen as well as supply the nutrient from soil. Growth parameters of planted *G. arborea* have recorded after 12 months of planting. Inoculation of AM fungi + Phosphobacterium + Azospirllum in seedlings of *G. arborea* was found to be suitable consortia of biofertilizers for the growth after field planting. These combinations improved the growth up to 220 cm and the girth showed < 2.5 cm. Thus the The suitable consortia of biofertilizers are found in *G. arborea* is AM fungi + Phosphobacterium + Azospirllum.
- Pure culturing and mass multiplication of pathogenic cultures under in vitro have made also for tested the efficacy to control the pathogens (*Fusarium oxyporum , Alternaria alternata, Diploidia sp. Colletotrichum gleosporoides*) *Santalum album* seedlings were planted with suitable biofertilizers (AM fungi, PSB, A. brasilense, and K mobilizer) and provided a host plant *Alternanthera sessilis*

that gives good survival in the field. Because, *A. sessilis* provides good shade and nutrition to the *Santalum album* seedlings. Similarly the biofertilizers of IFGTB and commercial source were inoculated in *Dalbergia Sisso* and *Santalum album* planted at Jaisalmer, Jodhpur respectively. In Sotai village and JIST campus near RFRI the seedlings of *S. album* were planted and showed that biofertilzers inoculated *Santalum album* seedlings improved growth and biomass rather than the control. These field experiments showed that biofertilizers are improving the growth of the plants through nutrient transportation from soil.

- Plantations of *Santalum album, Melia dubia* and *Gmelina arborea* at Attivatta, Hoskote taluk, Karnataka for showed 95% of survival.

Fig. 18 *Dalbergia sisoo* seedlings inoculated with biofertilizers

Highlights

- The IFGTB developed bio-fertilizers such as *Azospirillum lipoferum, Azotobacter chroococcum, Phosphobacteria, Potash Mobilizer* and *Trichoderma viride* to be used in *Gmelina arborea, Melia dubia, Santalum album, Dalbergia sissoo* and *Capparis decidua* across ICFRE institutes.
- Siderophore formation is confirmed in *Azospirillum brasilense, phosphobacteria* and *Potash mobilizer* indicating that the biofertilizers capable to control the pathogen as well as supply the nutrient from soil.
- Inoculation of AM fungi + Phosphobacterium + Azospirllum in seedlings of *G. arborea* was found to be suitable consortia of biofertilizers for the growth after field planting
- Plantations of *Santalum album, Melia dubia* and *Gmelina arborea* at Attivatta, Hoskote taluk, Karnataka showed 95% of survival inoculated with biofertilizer consortium of AM fungi, *Azospirillum, Phosophobacterium* and *Potassium mobilizer.*
- Plantation trials established in the farmers' fields at Dharmapuri, Tenkasi districts (Tamilnadu) and in State Forest Departments lands (Karnataka)

22. All India coordinated research project on "Preparation of Forest Soil Health Cards under different Forest Vegetation in all the Forest Divisions of India"

22.1 Objectives:

- To prepare forest soil health cards under different vegetations and adjoining degraded land in all the Forest Divisions to enhance deficient nutrients through sustainable management practices and making plantations more successful
- ·To diagnose forest soil fertility related constraints with the help of standard procedures, uniform sampling, data compilation and analysis thereof and to suggest divisional level management practices
- ·To promote soil test-based nutrient management practices in different forest vegetations in the forest divisions for enhancing nutrient use efficiency
- ·To build capacities of officials / field level staff of SFD's for promoting nutrient management practices for effective plantations
- ·To strengthen the Forest Soil Testing Laboratories and develop a network with state owned soil testing laboratories.
- ·To launch a forest soil health card portal on website for easy access to the various stakeholders.

22.2 Progress:

HFRI, Shimla: The official nomination of Nodal Officers were received from the state of Himachal Pradesh Forest Department and Ladakh UT. Total 2067 soil samples were collected from the various sampling points. The soil parameters like pH, EC, Bulk density, Organic Carbon, N, P, K, Zn, Cu, Fe, Mn etc. have been estimated from the soil samples collected from 02 forest divisions of Ladakh UT and 23 forest divisions of Himachal Pradesh. The processing and analysis of remaining soil samples for various parameters are in progress. The Forest Soil Health Cards of two territorial forest divisions of Ladakh UT viz., Leh and Kargil has been prepared. An online pre-release consultation meeting with the stakeholder's of Ladakh UT was organized to discuss the contents of the cards. The meeting was chaired by Sh. Jigmet Takpa, PCCF, Ladakh UT and other senior officers and field functionaries also participated in this meeting.

FRI, Dehradun: All the required instruments under the project have been procured and successfully installed in the soil laboratory, FE&CC Division, FRI. Procurement of chemicals and glassware needed for soil analysis were done. The successful renovation of the advanced soil testing laboratory of the FE&CC division, FRI was done under the project. Continuously working on maintenance and upkeeping of the lab is under process. Under the project collection of 94.37 % soil, plant litter and bulk density samples from 370 given FIDs have been done successfully from 24 territorial forest Divisions of Uttarakhand. Also, all the collected soil, plant and bulk-density samples were analysed for 12 given parameters. 100 % soil and plant sample collection have been done for 4 territorial forest Divisions of Delhi (UTs), Chandigarh Forest Division (UTs), 22 forest Divisions of Haryana, and 16 forest Divisions of Punjab.Total 897 soil and 299 bulk-density

samples were collected from 299 FIDs distributed inside all the forest divisions of Punjab. In Chandigarh, 19 given FIDs were visited for 57 soil and 19 bulk-density samples. In Haryana, 341 FIDs were visited for 1023 soil and bulk-density samples. From 4 territorial divisions of Delhi 195 soil and 65 bulk-density samples were collected for soil testing. Currently, Uttar Pradesh state was visited for the collection of a total of 480 soil and bulk-density samples (collected from 120 given FID). Complete soil analysis for all the 12 given parameters have been performed for Delhi, Chandigarh and Haryana. The Pre-release Consultation Meeting on Forest Soil Health Cards of Haryana was conducted on 16th February, 2023 at Van Bhavan Panchkula, Haryana. The Pre-release Consultation Meeting on Forest Soil Health Cards of Delhi on 21st March 2023 Vikas Bhavan, Delhi. Forest Soil health cards of Delhi, Chandigarh and Haryana have been prepared under the project and ready for release.

IFGTB, Coimbatore: Information pertaining to the number of Territorial forest divisions under the jurisdiction states viz, Tamil Nadu, Kerala, and UTs (Puducherry and Andaman and Nicobar islands) duly verified by the Nodal Officer was collected and the same was communicated to the NPC.Soil samples (1564 Nos.) were collected from 524 sampling points covering different forest types in the forest divisions of Tamil Nadu state and Puducherry UT at three depths viz, 0-30, 30-60 and 60-90 cm.For bulk density estimation, soil cores (524 Nos.) were collected using core sampler. 1048 nos. of litter samples were collected from the representative sites.100gm sample of the litter from each litter collection plot was collected separately for determination of dry weight and stored for further analysis. Processed soil samples were analyzed for the various physico-chemical properties and bulk density. Forest Soil Health Cards for two divisions of Puducherry UT were prepared and a Pre-release Consultation meeting with the Puducherry Forest Department was organized. All the equipments approved under the project required for the analysis of soil and litter samples were procured and installed.

TFRI, Jabalpur List of territorial forest divisions (64 – M.P., 56 – Maharashtra and 37 – Chhattisgarh) was prepared and information on forest vegetation and degraded areas in the selected divisions was complied. Procured all the instruments under the project and installed. Prepared Forest Soil health cards of 63 forest divisions of Madhya Pradesh and pre-consultation meet was conducted at Bhopal on 15 March, 2023. Soil samples from 85 forest divisions and 1375 FIDs (63 forest divisions; 975 FIDs of MP and 06 forest divisions; 131 FIDs of Maharashtra and 16 forest divisions; 269 FIDs of Chhattisgarh) were collected.pH & EC for 3395 and Organic carbon - 3197 soil samples were estimated.Whereas for macro elements for 3341 N, 3366 P, 3297 S and 3423 K soil sampleswere analysed. A total of 3300 soil samples were estimated for micro-nutrients (B, Cu, Fe, Mn and Zn). The results of analysis have been tabulated.

IFB, Hyderabad: The Nodal Officers have been nominated from State Forest Departments (Telangana and Odisha).The approved equipment/ instrument have been procured.The collection of soil samples has been completed from the 43 forest divisions of Telangana.The soil samples collected from 43 forest divisions of Telangana state have been sent to Regional Soil Laboratory (IFB, Hyderabad) for their processing and analysis of 12 parameters. The processed soil samples have been analyzed for their physicochemical properties (pH, EC, organic carbon). Most of the

soils are acidic in nature and have pH values less than 7.0. The processed soil samples from 30 forest divisions of Telangana have also been analyzed for their chemical Properties including macro and micronutrients. Due to rat damage in AAS, the remaining 13 forest divisions of Telangana have been analyzed only for macronutrients including available N, P, K, and S. The results show that most of the soils are deficient in available nitrogen.

IFP, Ranchi: Soil health card of Jharkhand state was prepared and released. Soil sample collection and analysis are under progress for State of West Bengal and Bihar. Soil sample collection and analysis are under progress for State of West Bengal and Bihar. 16800 samples of West Bengal have been processed out of 18000 (remaining1200 soil samples processing is going on). Out of 1608 proposed sampling points in Bihar, a total of 495 (30.78 %) soil samples were collected from 12 Forest divisions. Out of 18000, 16800 (93%) Soil samples of West Bengal processed and analysed. Details analysis showed below: (1396 samples of pH, 1396 samples of EC, 1402 samples of OC, 1402 samples of AN, 1402 samples of AP, 1402 samples of AK, 1402 samples of Cu, 1402 samples of Zn, 1402samples of Mn, 1402 samples of Fe, 1402 samples of S, 1402 samples of B) analysis has been done. In West Bengal,104 samples of pH, 104 samples of EC, 98 samples of OC, 98 samples of AN, 98 samples of AP, 98 samples of AK, 98 samples of Cu, 98 samples of Zn, 98 samples of Mn, 98 samples of Fe, 98 samples of S, 98 samples of B, analysis will be completed (remaining 1200 soill samples).

AFRI, Rajasthan: Forest division wise actual location of Soil sampling point in Rajasthan, Gujarat Dadra Nagar Haveli and Daman & Diu have been identified for soil sample collection. Information collected on number of forest divisions from Rajasthan and Gujarat. List of forest divisions and related forest vegetation prepared. Nine equipments have been purchased and purchase of rest two equipments are under progress. Procurement of consumables have been started. Sampling methodology for soil and litter sample collection has been decided. Soil sampling point of Rajasthan, Gujarat and UTs Forests has been received. Forest division wise actual location of soil sampling point in Rajasthan Gujarat and UTs has been identified for soil sample collection. Status of soil sample collection point has been shared with Nodal Officer of Rajasthan, Gujarat and UTs and concern DFO for soil sample collection. Soil and litter sample collection and analysis work has been started. Soil and litter samples from total 20 forest division have been collected including 16 divisions of Rajasthan (Ajmer, Alwar, Bikaner, Bikaner IGNP, Barmer, Jalore, Pali, Sirohi Churu, Jaisalmer, Nagour , Sikar, Udaipur, Udaipur north, Dungarpur and Pratapgarh) 1 Banaskantha in Gujarat. Soil sampling and analysis has been completed for Daman& Diu and Dadar & NH. Nomination of nodal officers from Rajasthan and Gujarat states has been done. Two Nodal Officers from Rajasthan and Gujarat are nominated.

RFRI, Jorhat:Under this project RFRI is collecting and analysing soil samples for 8 states viz Assam, Nagaland, Arunachal Pradesh, Manipur, Meghalaya, Tripura, Sikkim and Mizoram. A total of 6279 sampling points were selected. Overall, 2067 samples were collected from 31 division of Assam, 6 divisions of Tripura, 2 division of Meghalaya, 3 division of Mizoram and 7 divisions of Arunachal Pradesh. Total 19278 samples have been analysed for the state of Assam, Arunachal Pradesh, Mizoram, Meghalaya, Tripura. Sampling is yet to begin in Sikkim, Nagaland and Manipur

State. Remaining soil analysis will be analysed in due course of time. All the project staffs have been recruited and currently 2 JPFs and 3 PAs are working in project. The sanctioned instruments have been procured and are working properly. The five states i.e. Mizoram, Meghalaya, Nagaland, Tripura and Sikkim nominated nodal officers while nominations from other states are awaited.

IWST, Bangalore: A total of 1506 soil samples and 868 leaf litter samples collected from Benguluru rural, Chitradurga, Tumkur, Mercara, Davangere, Haveri, Hunsur, Virajpet, Bandipur, M M Hills, Banglore Urban, Bellary, Shivmogga , bhadravathi, Mysore, Mandya, Hassan, Kolar, Chikballapura, Belagavi, Dharwad, Bagalkote, Gadag, Gokak and Vijaypura Forest Divisions. Analysis of 7956 soil samples for macro- and micro nutrients has been completed in KVK Hirehalli and Chintamani.

Total 19126 samples were collected and 167291 samples were analysed by all the nine participating institutes. Overall, 46% sample collection is completed and 37% samples has been analysed.

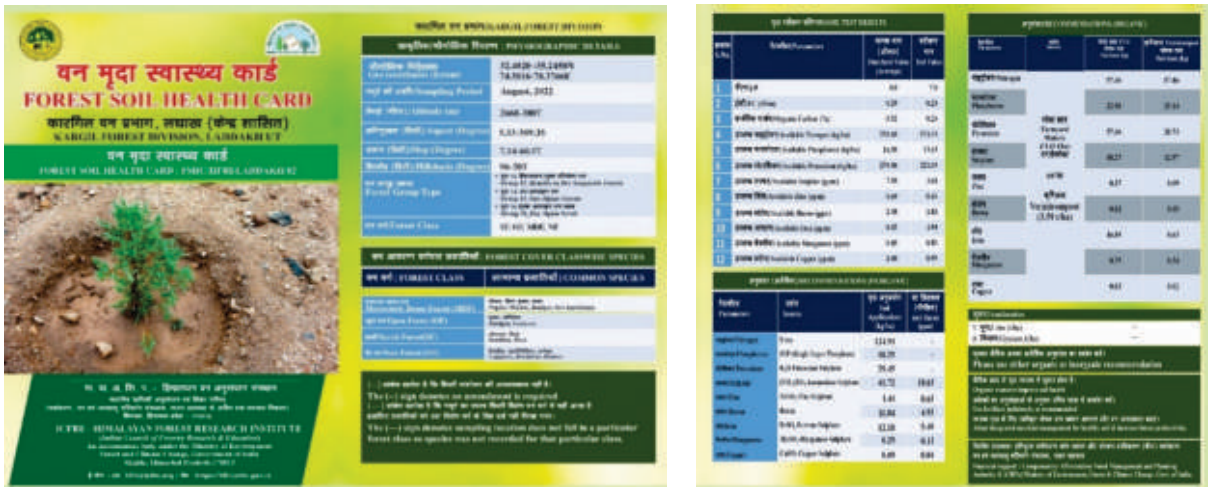

Fig. 19 Forest Soil Health Card of Kargil Forest Division, Ladakh UT

Highlights

- A total of 19,126 soil samples collected and 167291 samples have been analyzed for 12 physico-chemical parameters.
- A total of 125 Forest soil health cards have been prepared and released for the state of Jharkhand , Madhya Pradesh, Haryana, Delhi, Ladakh, Chandigarh and Puducherry.

23. All India coordinated research project on "Genetic improvement and value addition of *Madhuca longifolia*"

23.1 Objectives:

- To select and characterize germplasm using morphological and physico-chemical markers.To study the status of natural regeneration in areas of its distribution.To develop value added products and assess their shelf life and nutraceutical value.
- To estimate genetic diversity parameters at molecular level.To produce quality planting material from selected phenotypically superior trees.
- To establish vegetative multiplication gardens/clonal seed orchards at different locations.
- To document ITKs for post harvest techniques of mahua.To identify and develop improved variety/cultivar. (Second phase)

23.2 Progress:

On the basis of criteria of flower yield, 1188 phenotypically superior trees of Mahua have been selected throughout its natural distribution range in India; 460 trees from 23 different locations of Chhattisgarh, Madhya Pradesh and Maharashtra by ICFRE-TFRI, Jabalpur; 100 trees from 16 different locations of Tamil Nadu and two locations in Kerala by ICFRE-IFGTB, Coimbatore; 160 trees from Uttar Pradesh by ICFRE-ERC, Prayagraj; 186 trees from 30 different locations of Jharkhand, Bihar and West Bengal by ICFRE-IFP, Ranchi; 282 trees from 9 locations in Odisha, Telangana and Andhra Pradesh by ICFRE-IFB, Hyderabad. Growth data of all the selected trees on morphometric parameters viz., Total tree height, Clear bole length, Girth breast height, Crown diameter, Crown length and Number of primary branches was recorded along with biotagging.

Flowers and seeds were collected from selected trees situated at different locations. Sugar was estimated in flowers of 573 trees (Range 23- 75%) and oil was estimated in seeds of 341 trees (Range 22.3-71 %). Studies on natural regeneration were carried out at Chhatarpur, Umaria, Mandla, Dhar, Khandwa and Dindori in Madhya Pradesh, Surajpur in Chhattisgarh and Markundi range, Chitakoot, Uttar Pradesh. Frequency of 96.48% was recorded at Mandla and density of 67.55% and abundance of 55.10% was recorded at Chattarpur. At Surajpur frequency (64.15%), density (64.78 %) and abundance (39.11%) was observed. Regeneration study has been carried out in Coimbatore, Ramanathapuram and two locations in Madurai. Density and abundance of 31.6% was recorded in Coimbatore. No natural regeneration was recorded in the study sites by IFP, Ranchi and IFB, Hyderabad.

TFRI, Jabalpur collected scions from 285 selected phenotypically superior trees, cleft grafting was carried and 363 grafted plants were produced. IFP, Ranchi collected scions from 96 phenotypically superior trees and 400 grafted plants were produced. IFGTB, Coimbatore, produced 250 grafted plants. IFB, Hyderabad collected scions from 50 phenotypically superior trees and 117 grafted plants were produced. Grafting success of 40-50 % was achieved. A total of 180 air layers were made through air layering by IFB, Hyderabad. Seedlings have been raised by TFRI from seeds collected from 200 selected trees.

Institute	Phenotypically superior trees	Locations	Area covered
ICFRE-TFRI	460	23	Chhattisgarh, Madhya Pradesh and Maharashtra
ICFRE-IFGTB	100	18	Tamil Nadu, Kerala and Pondicherry
ICFRE-IFP	150	30	Jharkhand, Bihar and West Bengal
ICFRE-IFB	282	9	Odisha, Telangana and Andhra Pradesh
ICFRE-ERC	160	4	Uttar Pradesh

The process of producing grafted quality planting material of *Madhuca longifolia* (mahua) for the purpose of domestication was standardized through cleft grafting. Vegetative Multiplication Gardens have been successfully established with grafted Mahua plants at TFRI campus, Jabalpur, Madhya Pradesh (Lat. 230 5' 54" N, Long. 790 59' 20" E), at IFP Campus, Ranchi, Jharkand (Lat. 23.35866 E; Long. 85.24677 N) and at KVK, Myrada, Thalamalai, Tamil Nadu (Lat. 11.37452E; Long. 77.00099N).

Laboratory bioassay and nursery trial were conducted to test the effect of biopesticides against leaf webber *H. recurvalis*, results revealed that Spinosad 45% (0.0125%), Azadiractin 10000 PPM (0.02%), NSKE (5%) was found effective with maximum mortality of 83.33%, 75.0%, 66.66% and 58.33% larval mortality at 72 hours after treatment (HAT) respectively. Whereas in nursery trial, Spinosad 45% (0.0125%), Azadiractin 10000 PPM (0.02%), NSKE (5%) registered highest mortality with 69.69%, 65.71% and 63.63% larval mortality of *H. recurvalis* at 72 HAT respectively.

At TFRI, Jabalpur, DNA extraction and quantification work has been carried out from the leaves of 230 phenotypically superior trees and at IFGTB, Coimbatore DNA was extracted from 60 trees for genetic diversity assessment.

FRC-SD, Chhindwara developed products like energy bars, herbal tooth paste, herbal cream and hair conditioner. Consumer acceptability/nutritional parameters, shelf life are being assessed. Application was filed for FSSAI licensing of Mahua chocolate bars developed from dried flowers. Development of wine, wound healing cream and herbal hand wash utilizing mahua flower and the underutilized plant parts like leaves and bark is underway.

Fig. 20 Collection of scions from selected phenotypically superior trees of *Madhuca longifolia*

Phytochemical analysis of extracts of leaves and bark was done. Positive results were obtained for Flavonoids, Carbohydrates, Alkaloids, Phenol, Tannins and Saponins.Fig. 19 Collection of scions from selected phenotypically superior trees of Madhuca longifoliaPhytochemical testing of products viz. Hand wash and Cream was conducted. Alkaloids,

phenol and saponin gave positive test for handwash sample. Formulated mahua cream was assessed for the wound healing activity. Results revealed the presence of wound healing activity in developed herbal mahua cream MLB2. The complete wound closure was observed in standard and MLB2 formulation treated groups within 14-16 days. Liquor (wine) was distilled under laboratory conditions. Different physical properties - odour and colour have been assessed. Absorbance (0.051-0.095) of different distillates indicates variation in chemical quality of liquor.

Different ITK practices viz., for storage of flowers, processing of flowers and seeds, traditional uses, etc. were documented through questionnaire, videos and photos from 11 locations in Madhya Pradesh, 4 locations in Chhattisgarh, 4 locations in Maharashtra, 12 locations of Tamil Nadu, 10 locations in Telangana and 4 location in Jharkhand and Bihar. Leaflet entitled "*Madhuca longifolia* (Mahua): A Useful NTFP Species of Madhya Pradesh" has been published in English and Hindi.

Highlights

- 1152 phenotypically superior trees of Mahua selected in consultaion with SFDs of Chhattisgarh, Madhya Pradesh, Maharashtra, Tamil Nadu, Kerala, Pondicherry, Jharkhand, Bihar, West Bengal, Odisha, Telangana, Andhra Pradesh and Uttar Pradesh.
- Sugar was estimated in flowers of 573 trees (Range 23- 75%) and oil estimated in seeds of 341 trees (Range 22.3-71 %) to characterize germplasm using morphological and physico-chemical markers.
- The process of producing grafted quality planting material of *Madhuca longifolia* was standardized through cleft grafting.
- Vegetative Multiplication Gardens have been successfully established with grafted Mahua plants at TFRI , IFP , KVK, Myrada,Tamil Nadu.
- Developed products like energy bars, herbal tooth paste, herbal cream and hair conditioner. Application was filed for FSSAI licensing of Mahua energy bars developed from dried flowers.
- Indigenous Traditional Knowledge (ITKs) practices were documented in 46 locations from the states of Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu, Telangana, Andhra Pradesh, Jharkhand and Bihar.
- Leaflet entitled "*Madhuca longifolia* (Mahua): A Useful NTFP Species of Madhya Pradesh" has been published in English and Hindi.

24. All India coordinated research project on "Combating desertification by enhancing vegetation cover and people livelihoods in degraded dry lands and deserts of India"

24.1 Objectives:

- Survey and selection of indigenous herbs/grass, shrubs, and trees species and their combinations for effective use in various restoration programmes
- People mobilization and development of live fencing around a cluster of farmer's field for soil and water conservation to enhance farm production and people livelihoods.
- Restoration of degraded hills, hillslopes, sand dunes, ravines and saline areas through introduction of new genotypes/ varieties/ species and natural resource conservation in different landscape.
- Assessment of the impact of different species under afforestation/reforestation on vegetation recovery, soil health improvement and carbon storage..Popularization of ecological, environmental and economic benefits of improved practices of mitigation of the effect of land degradation and desertification among the local people

24.2 Progress:

This project is focusing on combating desertification covering treatments of farmlands, community lands and degraded forest lands as well as restoration works. In farmland treatment, live fencing or boundary plantation around a cluster of farmer's field has been done in various parts of country (Rajasthan, Madhya Pradesh, Himachal Pradesh and Tamilnadu) for increasing tree/vegetation covers on farmlands and conserving soil and water with co-benefits of farm protection and enhanced farm production.

Two cluster of farmer's selected at Chouradia (eight farmer's land of 6.0 ha) and Khet Singh Nagar (three farmer's land of 29.60 ha), Jodhpur, Rajasthan. ((26.63372 N and 72.319355 E). *Acacia senegal* seeds were sown on boundary of selected farmer's land as live hedge fencing and 3640 seedlings of *A. senegal* were also planted. In addition silvi and horti species seedlings were planted on the farmer's lands in the trial. Clusters of farmers selected in villages Maine, Sushna, Tabo, Lalung & Gue at Himachal Pradesh and constructed snow harvesting devices/ structure at these sites for augmenting water supply. The plantation of Seabuckthorn (350), Salix (400), Rosa (300) and Poplar (400) was carried out along the field boundaries of five villages Tobo (N 32°05'46.36" E 78°23'20.20")and Gue (N 32°08'04.7" E 78°33'51.8") of Lahul and spiti in Himachal Pradesh.

Three clusters of farmers (Cluster 1: Three farmers - 7.70 ha, Cluster 2: Two farmers – 2.50 ha, Cluster 3: 0.80 ha) have been selected in Morena, Madhya Pradesh (Nayapura 26° 51'35.47" N, 78°21'28.33" E, Useth 26°51'38. 33" N, 78°21'09.29" E, Bheelpur, Esah Haveli N26°39'37.7" E078°06'57.2") for erecting live fencing around their farms. 1900 seedlings of *Carissa carandas* with a spacing of 1m were planted on farmers' field boundaries of 2 villages Bheelpur and Esah Haveli with the cluster size of 3.30ha. Bund raising was also done before carrying out plantations along the field boundaries of clustered farms for augment water supply through rainwater harvesting. For erection of live fencing or boundary plantations in salt-affected soils of Cauvery

delta zone, Western and Southern Zone of Tamilnadu, cluster of farmers were identified. Casuarina sp. was planted in cluster of farmer's field along the field boundaries in the Cauvery delta zone at K.Pettai, Kammanallur villages and in the Southern agroclimatic zones at Pappanpatti and Kambur in 1 ha area. Neem seedlings were planted as boundary plantations in cluster of farmers' field in the Cauvery delta zone at Kammanallur village in 0.5 ha and in the Southern zone at Pappanpatti and Thoppadaipatti villages in 0.6 ha. Maintnance of plantation and data of soil and plant growth has been done at all above sites.

Restoration of degraded landscape like semistabilised dunes, saline lands, degraded hills, hillslopes, ravines and mine overburdens areas have been targeted under this project and field trials/plantation established in total 74.68 ha area at various parts of country. The plantation of *Juniperus polycarpos* in 1 ha area has been done at Badami Bag, Leh and its maintenance is continuing. The plantation of *Populus nigra, Salix alba, Juniperus polycarpos, Rosa webbiana, Hippophae rhamnoides* and *Elaeagnus angustifolia* has been carried out in 8.0 ha area in 3mx3m spacing at Sushna and Tabo area of cold desert in Himachal Pradesh for restoration of hillslopes. Plantation including 5 tree species (*Acacia catechu, Azadirachtaindica, Acacia tortilis, Anogeissus pendula* and *Commiphora wightii*) in an area of 16.20ha was raised on the Chambal ravine land owned by SFD and plantation of 2 tree species (*Aegle marmelos* and *Phyllanthus emblica*) in an area of 6.48ha was raised on the Chambal ravine land owned by RVSKVV. Application of biofertilizers (Rhizobium, Azotobacter and Azospirillum) and mulching (Wheat husk, stone pebbles and leaf litter) also done at both selected sites Chambal ravines. In order to control gully erosion, nine check dams across wide gullies were formed in plantation sites to hold the runoff from the monsoon rains, and also to improve the water table. Seeds of Acacia nilotica were also sown in three rows over these check dams to mitigate soil erosion. For restoration of degraded sandy plain plantation has been done at Karah Jod, Jaisalmer, Rajasthan in 15 ha area. Five tree species *A. indica, P. cineraria, S. oleoides, Z. mauritiana, A. nilotica and five shrub species like Mytenus emarginata Vachellia jacqumontii, Calligonum polygonoides, Cordia gharaf, Z. nummularia* were planted Different soil amendments treatment like Biochar (200gm/plant), Hydrogel (20gm/plant), Neempati (500gm/plant), Sewage sludge (500gm/plant) and Consortium of bio fertilizer (20ml/plant) has been applied in planted tree and shrub species. For rehabilitation of degraded hill in arid area six indigenous species namely *Anogiessus sericea/Cordia gharaff , Azadirachta indica, Holoptelia integrifolia, Moringa concanensis, Ziziphus mauritiana,* and *Commiphora wighttii* were planted at lunawas, Jodhpur, Rajasthan in 12 ha area. Soil amendment like farmyard manure 5kg /plant, Sewage sludge 5 kg / plant, Hydrogel 20 gram /plant has been applied. One level of rainwater harvesting devices (Trenches) made to harvest rainwater in the area and stone mulching has been done. For stabilize reactivated sand dune with suitable surface cover species in hot arid region plantation has been done on 10 ha Land at reactivated sand dune at Udasar (27.546279 N, 73.285182 E), Nokha, Bikaner,Rajasthan. Six shrub species were planted in between the old plantation as well as in the gaps (*Vachelia jacqumontii, Calligonum polygonoides, Ziziphus nummularia Lycium barbarum, Leptadenia pyrotechnica* and *Mytenus emarginata*). Seed of *Cassia angustifolia* and *Lasiurus sindicus* were also sown as cover species to check the wind erosion.

For establishment of field trials in the Southern, Western, North-Western and Cauvery delta Agro climatic zones of Tamilnadu salt-affected farmers land was selected. Neem seedlings (260 nos.) planted as boundary plantations in cluster of farmers' field in the Southern zone at Thoppadaipatti village and Cauvery-delta zone at Kammanallur village (400 nos.) in 1.0 ha were maintained. Casuarina sp. planted in cluster of farmer's field along the field boundaries in the Cauvery delta zone at K. Pettai (254 nos.), Kammanallur (233 nos.) villages and in the Southern agroclimatic zone at Kambur (193 nos.) was maintained. For restoration of saline site superior populations have been identified from the native range of distribution of *Salvadora oleoides* and *Salvadora persica*. The fruits of 30 accessions (mother trees) of *S.persica* and *S. oleoides* have been collection from Rajasthan and Gujarat. Their de-pulping, drying, and then raising of the nursery beds has been conducted at four sites, namely Site 1: Babina Forest Range, Jhansi Forest Division (Uttar Pradesh Forest Department), Site 2: Central University of Punjab (CUP), Bhatinda and Site 3: Chaksarker, Ferozepur (Punjab Forest Department). And Site 4: FRI, Dehradun. For rehabilitation of mine overburden area suitable species (Trees, Shrubs and herbs) have been screened in on the basis of literature survey and the indigenous species in the nearby ecosystem of the site. Site has been selected at Kiriburu (Iron mine of Steel Authority of India). On the slopes of the selected site continuous contour trenches and staggered contour trenches were prepared to check the water flow and hence the soil erosion and plantation on slopes were carried out. After site leveling, layout and design and pit digging, plantation of screened species with different soil amendments has been done in 5.70 hectare area.

The observations on initial plant growth parameters of planted species were recorded and soil samples were collected from the plantation area for estimation of soil parameters from all above sites.

Highlights

- 3640 *A. Senegal* seedlings (02 clusters of farmers in Jodhpur), 1900 *Carissa carandas* seedlings (03 clusters of farmers in Madhya Pradesh), 400 Neem seedlings (Tamil nadu) planted as live hedge in boundary plantation.
- The plantation of seedlings of Seabuckthorn (300), Rosa (300), Salix (400) and Poplar (400) carried out along the field boundaries of five villages in Himachal Pradesh.
- Total 74.68 ha area. targeted for restoration under various types of degraded areas.
- Plantation of five trees species done 16.20 ha near Ambah in Morena forest division.
- The plantation of Populus *nigra, Salix alba, Juniperus polycarpos, Hippophae rhamnoides* and *Elaeagnus angustifolia* carried out in 5.0 ha area at Sushna, Spiti area of Himachal Pradesh.

25. All India coordinated research project on "Domestication, genetic characterization, improvement and diversified utilization of poplars"

25.1 Objectives:

- Standardization of cultivation practices for native poplars
- Introduction trials of *Populus alba* in high altitude areas of Uttarakhand and Arunachal Pradesh and P. *gamblei* in Gangetic plains
- Genetic improvement of *P. deltoides* and *P. gamblei* through classical tree improvement and molecular approaches and their DNA characterization
- Management of major insect pests and diseases of native and exotic poplars
- Assessment of wood quality and studies on diversification of usage/products from poplars

25.2 Progress:

- Field trials of 16 clones of *Populus deltoides* were established maintained at six sites. The same set of clones has been planted in randomized complete block design. The trials are being maintained. Data were collected during January-February 2023 at the age of one year and growth was found to be encouraging.

Name of institute	Field trials of P. deltoides clones established during 2022-23	
	No. of sites	Name of district (State)
ICFRE-HFRI Shimla	1	Solan (Himachal Pradesh
ICFRE-FRI Dehradun	4	Yamunanagar (Haryana), Hoshiarpur (Punjab), Saharanpur (Uttar Pradesh), Kushinagar (Uttar Pradesh)
ICFRE-IFP Ranchi	1	Araria (Bihar)

Data on survival and growth parameter has been analysed for the provenance trial of *Populus ciliata* at Brundhar, Kullu, Himachal Pradesh. Layout has been prepared in field for setting up trial on soil moisture conservation treatments of *P. alba* at Gue, Lahaul and Spiti district, Himachal Pradesh. Cuttings of Populus alba alongwith Populus ciliata, *Populus nigra* and *Salix alba* have been planted by ICFRE-FRI Dehradun in the nursery for introduction trials by ICFRE-FRI Dehradun and ICFRE-RFRI Jorhat in their respective regions. The germplasm of the four species was supplied by ICFRE-HFRI Shimla. Studies on DNA extraction and standardisation of DNA markers are in progress at ICFRE-FRI Dehradun, ICFRE-HFRI Shimla and ICFRE-RFRI Jorhat. Surveillance of insect pests and diseases has been completed by all the four institutes in their respective regions. Fulfilment of Koch's postulates established *Calonectria* sp. as an incitant of blight disease of *P. deltoides*.

Fig. 21 *P. deltoides* trial in Saharanpur district (Uttar Pradesh) after 7 months

Natural biocontrol agents of different insect pests of *P. deltoides* were recorded belonging to Braconidae, Inchnomonidae, Mucidae and Eupelmidae groups. Bio-efficacy experiments of entomo-pathogenic nematodes were conducted for management of leaf defoliator *Clostera* sp. Highlights SFD.

Surveillance of insect pests and diseases has been completed in all regions. Wood sample of *P. gamblei* was obtained after completing necessary approvals and testing started for various wood properties.

Highlights

- Field trials of 16 clones of *P. deltoides* have been laid out at FRI (4 sites), HFRI (1 site) and IFP (1 site).
- Data on survival and growth parameter has been analysed for the provenance trial of *Populus ciliata* at Brundhar, Kullu, Himachal Pradesh at the age of 22 years. Gaganshil provenance exhibited maximum height (18.43 m), GBH (51.80 cm) and clean bole height (6.43 m) while minimum height (9.56 m), GBH (35.70 cm) and clean bole height (3.69m) were exhibited by Khanola provenance.
- Fulfilment of Koch's postulates established *Calonectria* sp. as an incitant of blight disease of *P. deltoides.*
- Surveillance of insect pests and diseases has been completed in all regions: 6 places by ICFRE-HFRI, 10 by ICFRE-FRI, 3 by ICFRE-IFP and 3 by ICFRE-RFRI.
- Five farmers have provided their own land and active support for conducting clonal trials of *P. deltoides:* Punjab, Haryana, Bihar (one farmer each) and Uttar Pradesh (two farmers). Land for field trials of *P. alba* in Himachal Pradesh has been provided by the concerned

26. All India coordinated research project on "Genetic Improvement of *Azadirachta indica* A. Juss. (Neem)"

26.1 Objectives:

- Identification of superior genotypes and seed sources from different agro-climatic zones of India for high Azadirachtin and oil content.
- Chemical evaluation of seed samples collected by different Institutes from different agro-climatic zones of India. Genetic Characterization of high azadirachtin and oil yielders identified after three years.
- Phenology and Reproductive biology studies. Development of genetic transformation methods for frost/cold tolerance .Production of Azadirachtin through cell suspension culture

26.2 Progress:

- Objective A. Identification of superior genotypes and seed sources from the different agro-climatic zones of India for high Azadirachtin and oil content.
- **AFRI, Jodhpur:** In the fruiting season of 2022, Neem seeds were collected from marked 100 CPTs

each from Gujarat (ACZ-13) and Rajasthan (ACZ-14), that is total seed collection from 200 seed sources was completed. Variation in fruit and seed morphometric characters was quantifed.

- **TFRI, Jabalpur:** During fruiting season, surveys and field tours were carried out in the states of Madhya Pradesh and Uttar Pradesh, 100 CPTs of Neem were selected. Seeds were extracted from fruits and oil extraction from kernels is completed. So far, the total oil from all 100 samples of Neem seeds has been extracted. IFGTB, collected fruits from the 220 selected CPTs and the seeds were processed as per common methodology in proposal for further estimation. Variation in fruit and seed morphometric characters was quantifed. Wide variation recorded on fruit and seed morphometric traits. IWST under taken survey and selection were made in the state of Karnataka and Telangana for collection of seeds. In addition to the area covered in Karnataka, survey was made in certain parts of Mysuru and Kollar District. Fruits were collected from already selected trees and other trees selected at the time of fruit collection. In addition, survey and fruit collection were made from Telangana. Fruits were collected from 100 trees of which 84 trees were from Karnataka and 16 trees from Telangana. The quantity of seeds collected from the trees varied. At IFP, survey was undertaken in agroclimatic zones 3, 4, and 7, comprising districts in Jharkhand, West Bengal, Bihar, and Uttar Pradesh. A total of 349 phenotypically superior CPTs have been chosen. For each selected tree, data on tree height, GBH, crown diameter, number of branches, and so on were collected. At IFB,CPT's data of 229 individuals were collected. Marking of the trees with geo-coordinates was done. Out of these, 100 trees were selected and collection of seeds from 100 trees has been done. Data on kernel morphological parameters from seed of 100 CPTs has been taken collected.
- Objective B. Chemical evaluation of seed samples collected by different institutes from different agro-climatic zones of India.
- **AFRI, Jodhapur:** Aza results for the seed samples were received. For ACZ 13 the lowest and highest values of Aza were found to the time of 174.12 and 2412.67 ppm respectively. Likewise, for ACZ 14 the lowest and highest values were found to be 114.93 and 2052.11, respectively. Oil estimation of 100 seed samples for ACZ 14(Rajasthan) was achieved in which the lowest and highest oil percentage values were found to be 25.03 and 52.17%, respectively. For ACZ13 (Gujarat), the oil estimation results ranged between 21.16 and 48.1. At TFRI, Aza estimation results were evaluated, in which the lowest and highest values, in ppm units, were found to be 81.64 and 2483.14, respectively. Seeds were extracted from fruits and oil extraction from kernels is completed. So far, the total oil from all 100 samples of Neem seeds has been extracted. The range of total oil % is Min. 18.38 to Max. 53.97. At IFGTB, Aza estimation results were evaluated, in which the lowest in ppm units, were found to be 256.2 (ACZ 10B) and 243.8 (ACZ 11) while Highest reported, in PPM were 3764.1 (ACZ 10B) and 3570.8 (ACZ 11).The oil was extracted from 200 seed lots and quantified. Estimated oil percentage, specific gravity, refractive index and viscosity from the seeds collected from the selected CPTs of Neem. Wide variations were recorded on the physical properties of oil and oil content (25.06 to 45.45%). At IWST, for azadirachtin estimation, the results varied from 485.29 ppm of aza present to 4643.45 ppm.Oil content from rest of the 84 seed sources were estimated. For all the neem seed samples, oil estimation results ranged from

14.5 to 46.4% of oil content.

- **IFP, Ranchi:** For ACZ3 the resulting oil percentage was found to be ranging from 39.6% to 58.9%. For ACZ4, the lowest value of extracted oil was measured at 40.1% to highest at 58.5%. Likewise, for ACZ7, the oil estimation results varied from 36.5% to 58.3%.Estimation of kernel-oil content of 100 CPTs selected from each agroclimatic zones, viz., 3, 4 and 7 is completed. The target of kernel-oil estimation is achieved.The biochemical analysis of azadirachtin content for 100 CPTs selected from each agroclimatic zones, viz., 3, 4 and 7 has been received from Amity University, Noida.
- **IFB, Hyderabad:** Data on Aza content was received from Amity. The obtained data showed that aza content varied from 760.34 ppm to 70.21 ppm. The highest was recorded in J038 (760.34) followed by J036 (736.18) and J045 (717.21) while J094 showed lowest aza content (70.21). Neem seed oils content from 100 CPTs were determined using Soxhlet method. Data showed the variation in oil content (%) ranged from 24.7±1.2 to 67.65±2.2. the highest content was found in seeds of J051 (67.65±2.2).
- Objective C& D . Genetic Characterization of high azadirachtin and oil yielders identified after three years. Phenology and Reproductive biology studies.
- **AFRI, Jodhapur:** Review of Literature, Survey and marking of Neem trees at AFRI, Jodhpur. Recording of morphological data like tree height, diameter, health, crown etc. for each of the marked trees. Recording of phenological data like leaf initiation, flowering, and fruiting pattern for each of the trees marked at Jodhpur (Rajasthan). Passport data was recorded for all the CPTs.At TFRI, phenological data viz., Leaf initiation, Leaf fall, flowering initiation, peak flowering etc. was recorded from 30 trees of three different locations of Madhya Pradesh (Shahpura, Jabalpur and Katni). Phenological data related to fruit formation, leaf initiation, leaf fall, peak flowering, and flowering initiation was recorded for 30 trees of three different locations of Madhya Pradesh (Shahpura, Jabalpur and Katni). Phenological observations were recorded. Leaf initiation and flowering were observed in the Neem trees of the campus. At IFGTB, the data was collected on phenology, reproductive biology, and pollinator interaction and breeding systems of Neem in different zones of Tamil Nadu. Assessed variations on phenological and reproductive traits in different Neem populations. At IFP, flowering data of CPTs from different locations were recorded. Variations in fruit and seed attributes have been quantified among collected seed lots.
- For Development of genetic transformation methods for frost/cold tolerance at AFRI, protocol for rooting with IBA based rooting media was developed and experimented. Transformed shoots were kept for root initiation. Putative transformed shoots with glyIII gene developed roots on the half MS and IBA (1mg/ml) combination MS nutrient media. The shoots were further transferred to soilrite with half MS and without vitamin nutrient medium for enhanced root development. Putative double gene incorporated calli were maintained by regular subculturing. PCR assay experiments for the same did not produce optimum results so these experiments are being repeated. Cold tolerance experiments for putative double gene transformants are being planned to be initiated post positive transformation results.
- For Extraction Production of Azadirachtin through cell suspension culture at IFGTB, accessions

were identified on the basis of earlier works on neem improvement for seed collection. Maintenance of callus is being done on a regular basis. Estimation of aza from callus and suspension culture, obtained from callus initiated by flower, was executed..

Fig 22 (Clockwise from top left): A selected Neem tree (seed-source); tree-borne seed collection directly from branches, seed processing, washing, de-pulping, drying and grading, oil extraction through grinding of kernel, Soxhlet apparatus and neem oil from all selections of ACZ 13

Highlights

- Selections of 1000 seed sources was completed from 9 agro-climatic zones by the 6 ICFRE institutes. Seeds were collected from all the selected 1000 seed sources during the fruiting season (May-July) in the year 2022.
- Overall, Oil Concentration ranged showed variation ranged from 14.5% (ACZ12) to 67.65% (ACZ 9)
- Azadirachtin and oil estimations from the first year (2022-23) data revealed that highest Aza content of 4643.45 PPM was reported from zone 10 and lowest 12.84 PPM was reported from zone 7, with average Aza content of 2534.85 PPM.

27. All India coordinated research project on "Conservation and sustainable management of wild edible fruiting species"

27.1 Objectives:

- To study the distribution pattern, natural regeneration and ethno-botanical uses of selected wild edible fruiting species . To identify superior plants of selected wild edible fruiting species based on fruit production and quality and physical parameters of plant. To standardize the techniques of propagation through seeds and vegetative parts for mass multiplication
- To standardize potting media, irrigation schedule, shade and fertilizer requirements for production of Quality Planting Stock of selected wild edible fruiting species
- To conserve the selected germplasm as seeds and by vegetative meansTo study the factors affecting sustenance of the species in natural habitat.
- To Study the performance of the germplasm at different locations. To produce value added products from wild fruits. Extension of the technology for livelihood support

27.2 Progress:

- **TFRI, Jabalpur:** Literature survey has been done on botanical description, habitat, ecological factors for their growth, phenology, reproductive system and fruit maturation along with importance and use of *Semecarpus anacardium* and *Flacourtia indica*. Forest Division working plans of MP, MH and CG were referred and locations for the availability of the selected species in all the Divisions were rewarded. Primary survey for site selection carried out in 18 divisions so far, for identification of potential areas where these selected underutilized wild fruit species located. Phyto-sociological and ethnobotanical studies initiated on the selected sites. Identified 50 and 40 superior plants of *Semecarpus anacardium* and *Flacourtia indica* respectively, based on the basis of fruit and/or plant characteristics in Madhya Pradesh, Maharashtra and Chhattisgarh states. The morphological data on the description of fruits, seeds and the plant of the selected trees was recorded. Fruit and seed collection carried out from the selected 17 and 47 superior trees of *Semecarpus anacardium* respectively. Fruits collected were dried and stored for further analysis. Seed germination pretreatment standardized for *Semecarpus anacardium*. Among different treatments best result obtained by chemical scarification using conc. sulfuric acid for 15 minutes. It not only increases seed germination but also reduce germination period. Seeds were sown on different media (paper, soil and cocopeat) for germination test. Best potting media was found mixed soil for *Semecarpus anacardium* and coco peat for *Flacourtia indica.* In Stem cutting, no root was produced in any treatment on *Semecarpus anacardium*. But 1000 ppm IBA in basal cutting produced maximum shoot and root in *Flacourtia indica*. Cutting of girth size 0.4-0.5cm was found suitable for propagation of *Semecarpus anacardium*. Vegetative propagation of *Semecarpus anacardium* was found successful by air-layering and profuse rooting was observed in several treatments, but air layering in *Flacourtia indica* produced only callus. Further refinement of both seed and vegetative propagation protocols is going on. Nursery beds, polythene bags and root trainers have been taken up for carrying out experiments on vegetative propagation. Polythene

bags were found best for vegetative propagation. Different ratio of sand, soil and FYM were used to get best media for growing plants. 1:2:1 ratio was found best for seedlings of *Semecarpus anacardium*. In combined experiment of weed, light and soil, weed-free plot was best for under sun, but weed didn't affect much when planted under shade. Under sun found daily irrigation is necessary, but under shade alternate day irrigation gave better result. On the basis of different trials, the seeds of *Flacourtia indica* and *Semecarpus anacardium* can be considered as orthodox seed. Stored seeds of *Flacourtia indica* were sampled after 3, 6 and 12 months of storage. Seeds stored at 3-8% moisture content were viable even after one year of storage. Seedlings of 6 selected promising trees of *Semecarpus anacardium* were transplanted in TFRI campus, but all the planted seedling were damaged by porcupine. Further this year, land preparation work is going on for establishment of field gene bank from collected accessions of Flacourtia indica and *Semecarpus anacardium* at TFRI Campus. Request letter for allotment of land for research trials have been submitted recently to PCCF of Madhya Pradesh, Maharashtra and Chhattisgarh. Value added products such as Karonda chips, Energy drink, Karonda Powder, Khatmithgoli, Karonda Candy, karonda pickle and Cherry karonda have been prepared. Nutritional analysis of value-added products was done as per the protocol of AOAC International, (2016 Work is going on for the preparation of Pickle and Candy from *Semecarpus anacardium.*

- **FRI, Dehradun:** Conducted extensive filed surveys to different forest divisions of Uttarakhand, Punjab, Haryana and Uttar Pradesh for the habitat and distribution of *Pyrus pashia* and *Ficus palmata*. Phytosociological survey was conducted using quadrat method and laid 170 number of quadrats in Uttarakhand, 40 number of quadrats in Punjab, 90 number of quadrats in Haryana and 50 number of quadrats in Uttar Pradesh. Collected fruit and seeds of *Ficus palmata* from Mussoorie, Tehri, Nandpryag range of Uttarakhand. Ethno botanical survey was carried out in 10 villages of Pilibheet, Lakhimpur North and Lakhimpur South and Shahjhapur division of Uttar Pradesh. Nutritional Analysis was carried out for the fruits samples of *Ficus palmate* for Carbohydrates, Protein, Moisture %, Total Ash %, crude fibre and crude fat, vitamin-C collected from Nandpryag Range of Badrinath FD, Mussorie, Tehri Forest Division. Selected 36 number of superior trees of *Pyrus pashia* from Uttrakhand. A total of 22 number of superior trees of Ficus palmata were selected from Uttarakhand (11), Punjab (02), Haryana (04) and Uttar Pradesh (01). Prepared seven number of value added products including four products (i.e. Molu candy, Molu Jam, Molu Pickle, Molu Murabba) from *Pyrus pashia* and three (Himalyan Fig Jam, Himalyan Fig Candy, Dried Himalayan Fig) from *Ficus palmata*. Three potting mixtures and three net shades have been tried for vegetative propagation trials. Vegetative propagation trials has been tried with IBA 3000ppm, 6000ppm, 8000 ppm and NAA 3000 ppm & 6000 ppm.
- **HFRI, Shimla:** Surveyed natural population of species in Kullu, Mandi, Chamba, Kinnaur, Sirmaur and Shimla districts of Himachal Pradesh and Kathua district of Jammu. After the survey, 28 sites were selected for *Myrica esculenta* and 22 sites for *Prunus cornuta* in Himachal Pradesh and Jammu. Seeds/fruits of *Myrica esculenta* were collected from 23 sites and from 19 sites of *P. cornuta.* Vegetative propagules of *P. cornuta* collected from Kothi (Kullu), Narkanda and Kufri (Shimla), Katgoan (Kinnaur) and *Myrica esculenta* were collected from Baragaon (Shimla), Shilly (Solan), Majgaon, Sangrah and Lajwa (Sirmaur) and Panjiyara and Kathal (Chamba) and Siara and

Kardoh (Jammu). Morphological and physical characteristics of the tree were recorded, and superior trees were marked. Collected fruits were processed in the laboratory to record physical parameters like fruit shape and size, seed size, seed weight, etc. Nutritional analysis of *P. cornuta* and *Myrica esculenta* fruits were done for Carbohydrate by Anthrone method, Protein by Lowry's method and Crude fat by soxhlets method. Moisture content of the seeds was also analysed. In case of *Prunus cornuta* maximum Carbohydrate content found in fruits collected from Rupi (6.54%), protein in Kufri (3.88%), Crude fat in Rakchham (5.4%). Phyto-sociological studies were carried out in sample plots following quadrat methods in Mandi, Kullu and Shimla district for both the species. Seed germination and vegetative propagation trials of *Prunus cornuta* and M*yrica esculenta* has been established at FRS Brundhar, Manali and FRS Shillaru, Shimla. Air layering in the branch of *Myrica esculenta* was done in Shilly (Solan) and Baragaon (Shimla). Ethno-botanical data on *Myrica esculenta* was collected from Shimla, Sirmaur and Chamba district of HP and Kathua of JK UT and Shimla and Kinnaur for P. cornuta. Seeds of *Myrica esculenta* and *P. cornuta* were stored in good condition in 4°-6° C in Refrigerator and in Seed Storage Cabinet for further seed viability studies. Seed germination in polyhouse conditions was recorded maximum in Chailchowk (70%) and minimum in Kotmoras (28%). Maximum germination of 76% (winter sowing) was recorded in *P. cornuta* in polyhouse conditions at FRS, Brundhar. Prepared a review manuscript and review article on *Myrica esculenta* and abstract article for *P. cornuta* and submitted the same for publication in journal.

- **IFGTB, Coimbaotre:** Surveyed and identified 29 populations of *L. acidissima* and 31 populations of *Pithecellobium dulce*, in Tamil Nadu and Kerala. Recorded flowering and fruit collection time in *Limonia* and *Pithecellobium* at different areas. Regeneration studies were done in 26 areas using stratified random design method. Developed a questionnaire for Ethnobotanical survey. Conducted the studies at forest fringe villages of Coimbatore (Anaikatty and Siruvani), Thiruvannamalai (Thumbakkadu & Vilankuppam), Trichy (Sengattupatti, Perumparappu & Sittur), Nilgiri (Thekkupadi, Lightpadi, Yanaipadi), Dharmapuri (Sitheri Hills) and Palakkad (Nadupathy, Chavadipara & Vathyarchalla) (13 forest fringe villages). Arrived at CPT selection criteria for *Limonia acidissima* and *Pithecellobium dulce* CPTs based on fruit yield. Selected 244 CPTs of *Limonia acidissima* on initial field survey. Selected 142 CPTs of *Pithecellobium dulce*. Collected the passport data, geo-coordinates of the CPTs on initial field survey Collected fruits, processed, standardized and carried out fruit and seed morphometric characterization through image analysis for 45 CPTs of *L. acidissima* and 32 CPTs of *P. dulce.* Analysis of nutritional parameters were done for 38 CPT's of *L. acidissima* and 32 CPTs of *P. dulce.* Carried out seed germination studies in *Limonia acidissima* on fresh seeds at 5.7% moisture content and no pretreatment was required. Carried out seed germination studies in *Pithecellobium dulce* on fresh seeds at 54.4% moisture content where no pre-treatment was required. Germination studies in seeds of *Pithecellobium* and *Limonia* has been completed. Vegetative propagation in *Limonia* were not successful. Hence seed propagation has been concluded to be the suitable method. Rooting studies on *Pithecellobium* dulce showed that 5-7mm diameter thick stem cuttings are suitable for vegetative propagation than 8-10 mm of stem cuttings. In *P. dulce* rooting experiments showed that powder dip method was better than liquid dip method for IBA, however control excelled the IBA treatment. Effect of temperature on germination showed that *P. dulce* requires temperature range of 25 to 40 ^{o}C for

good germination and growth of *Limonia* and *Pithecellobium*. Effect of storage temperature on *L. acidissima* and *P. dulce* is under progress. In *P. dulce* at 45% seed moisture germination was 92.5% which drastically declined at 10% Moisture to 55% which further decreases at 5% MC indicating it as a shortlived seed. Raised CPT-wise seedlings of *P. dulce* for 32 CPTs and Limonia for 38 CPTs. Totally *Limonia acidissima*. - 950 seedlings and *Pithecellobium dulce* -1650 seedlings have been transplanted for hardening. Recorded factors such as temperature, rainfall, anthropogenic activities, other biotic and abiotic factors on sustenance of the study species at the different study areas. Effect of shade, weed and soil on germination and seedling growth was completed for *Limonia*. Completed fruit maturity studies in *P. dulce*. Pink fruits recorded highest germination of 92.5% while greenish pink showed 67.5% and green fruits recorded 50% germination. Initiated fruit maturity studies in *L. acidissima.*

- **RFRI, Jorhat:** Consulted available literature on the target species (*Spondias pinnata* and *Prunus jenkinsii*) and collected distribution of the species in different districts of Assam and Mizoram. Fruit pulps of *Spondius pinnata* and *Prunus jenkinsii* are edible. Ripe fruits of *Spondius pinnata* are made pickles. Decoration of fruit pulp is taken orally against stomach disease (diarrhoea, dysentery etc). Fruit pulp of *Prunus jenkinsii* is used for preparation of jam in Assam. Explored the distribution of *Prunus jenkinsii* in community forests of Hmuifang, ReiekTlang, Saitual and *Spondias pinnata* in Sairang, Selesi, Mizoram and collected the ethno-botanical information. Explored distribution of *Spondias pinnata* and *Prunus jenkinsii* in different RFs/WLS (Gibbon WLS, Jorhat and Nambor-Doigrung WLS, Golaghat, Dihing Patkai National Park, Dibrugarh, and Poba RF, Dhemeji, Kakoi RF, Lakhimpur, and Sonai-Rupai WLS, Sonitpur district and different areas of Majuli district, Assam and recorded the regeneration status of the species. Maximum regeneration potentials 19 ± 9 per hectare of *S. pinnata* at Nambor-Doigrung WLS, Golaght, maximum saplings (< 10 cm dbh) 15±5 and tree > 10 cm dbh 13±4 per hectare was recorded in Abhaypur RF, Charaideo. Recorded 50 genetic resources of *Spondias pinnata* in homestead gardens/ reserved forests of Jorhat, Sibsagar, Charaideo, Karbi-Anglong, Lakhimpur, Dhemaji, Tezpur district, Assam and made pass port data; selected 10 CPTs of *Spondias pinnata* and collected seeds 1.0 – 1.5 Kg from each of CPT and put in nursery for further studies. Being conserved 20 different genetic resources of Spondias pinnata and 3 of *Prunus jenkinsii* which collected from different areas of Golaghat, Karbi-Anglong, Jorhat, Sibsagar, Charaideo districts, Lakhimpur, Sonitpur,Dhemaji and Majuli districts, Assam. Produced 300 seedlings of *Spondias pinnata* and 150 seedlings of *Prunus jenkinsii* at RFRI nursery.
- **IFP, Ranchi:** Surveyed forest areas and villages markets of Ranchi, Dumka, Simdega, Ramgarh, West Singhbhum, Hazaribagh, Khunti, Deoghar, Gumla, East Singhbhum, Palamu, Garhwa, Pakur, Sahibganj and Lohardaga districts and documented wild fruits found in the region. Identified 64 (Total wild edible fruits recorded: 64; Unidentified wild edible fruits: 6) wild edible fruits and recorded information on their botanical description, habitat, importance and their use by ethnic groups through framed questionnaire. Information on list of species present and the dominant species have been documented. Dominant species found in forest areas are *Diospyros melanoxylon, Buchnania Lanzan, Schleichera oleosa, Semecarpus anacardium, Aegle marmelos, Solanum torvum, Artocarpus heterophyllus, Syzygium cumini, Madhuca indica, Ziziphus mauritiana, Tamarindus indica, Solanum nigrum, Mangifera indica, Coccinia grandis, Momordica*

charantia, Phoenix sylvestris, Woodfordia fruticosa. 13 wild edible fruits species are found less in the natural forests as per population of the species observed during quadrat sampling. 56 no. of village markets have been surveyed dealing with sale and purchase of wild edible fruits in 37 blocks. Wild edible fruits found in village markets are *Tamarindus indica, Solanum torvum, Coccinia grandis, Semecarpus anacardium, Diospyros melanoxylon, Spondias pinnata, Madhuca indica, Buchnania lanzan, Mangifera indica, Aegle marmelos, Artocarpus heterophyllus, Syzygium cumini, Ziziphus mauritiana, Momordica charantia, Phoenix sylvestris, Terminalia bellerica, Terminalia chebula, Phyllanthus emblica, Momordica dioica, Borassus flabellifer* etc. Market location, Market rates, amount collected, amount sold, amount consumed, and time used for collection of wild edible fruits have been documented. Geotagged information has been Fig. 22 Value added Products Prepared at TFRI Jabalpur {Karonda Energy Drink, Karonda Jam, Khat mith goli, Dry Chips, Cherry karonda, Karonda churan} documented.

Fig. 23 Value added product of *Ficus palmata* and *Pyrus pashia* at FRI Dehradun

Fig. 24 Value added Products Prepared at TFRI Jabalpur {Karonda Energy Drink, Karonda Jam, Khat mith goli, Dry Chips, Cherry karonda, Karonda churan}

Highlights

- Prepared value added product (11 Nos) (Karonda chips, Energy drink, Karonda Powder, Khatmithgoli, Karonda Candy, Karonda Pickle, Cherry Karonda from *Semecarpus anacardium* and Molu candy, Molu Jam, Molu pickle, Molu Murabba from *Pyrus pashia*).
- Standardized the techniques (4 Nos) of propagation through seeds and vegetative parts for mass multiplication for *Semecarpusan acardium*, *Flacourtia indica, Limonia acidissima* and *Pithecellobium dulce* while standardization is ongoing for *Pyrus pashia, Ficus palmate, Myrica esculenta* and *Prunus cornuta*. further refinement of the propagation techniques is ongoing
- Standardized potting media (1 Nos) for *Semecarpus anacardium* while standardization of potting media irrigation schedule, shade and fertilizer requirements for production of Quality Planting Stock of *Flacourtia indica, Limonia acidissima, Prunus jenkinsii, Spondias pinnata, Pithecellobium dulce, Pyrus pashia, Ficus palmate, Myrica esculenta* and *Prunus cornuta* is ongoing.
- Identified superior plants of *Semecarpus anacardium* (50 Nos), *Flacourtia indica* (40 Nos), *Pyrus pashia* (36 Nos),*Ficus palmate* (22 Nos),*Myrica esculenta* (46 Nos), *Prunus cornuta* (38 Nos) based on fruit and plant characteristics.
- Request letter for allotment of land for research trails have been submitted to PCCF of Madhya Pradesh, Maharashtra and Chhattisgarh. Talk at different levels going on.

28: All India coordinated research project on "Population status, collection, characterization and evaluation of genetic resources of Indian Rosewood, *Dalbergia latifolia*"

28.1 Objectives:

- Undertake studies on population structure and natural regeneration in different forest areas.
- Selection of superior trees from identified populations.
- Clonal propagation of identified superior trees and establishing of Field Gene Bank (FGB).
- Characterization and evaluation of the clones. Undertake studies on reproductive biology.
- Seed collection, establishment of germplasm banks and progeny trials.
- Quantify genetic variation in different populations and creating baseline data on diversity.
- Understanding mating / breeding systems in different populations using molecular markers.
- Undertake research on seed technology, Silvicultural practices, nursery and plantation techniques, root inhabiting microsymbionts as well as harvesting and selling of timber.
- Develop agro-forestry models with *D. latifolia* as tree component.
- Monitor insect pests and diseases of nurseries and plantations and develop suitable management practices.
- Identification of bioactive principles from *D. latifolia.*

28.2 Progress:

- Through field survey in different forest divisions of Tamil Nadu, Karnataka and Kerala viz., Coimbatore, Gudalur, Erode, Salem, Dharmapuri, Theni, Thirunelveli (Tamil Nadu); Ranni, Konni, Thenmala, Parambikulam tiger reserve, Nemmara, Wayanad, Nilambur (Kerala) Haliyal, Dharwad, Shimoga, Bhadra Tiger Reserve (Karnataka) continued selection of plus trees; collected seeds from the selected plus trees were shared among different institutes for further raising progeny trials.
- Progeny trials cum germplasm banks have been established using RBD at Chandwa, Latehar (Jarkhand), Mohabata Chapra village, East Champaran (Bihar), Jabalbur (MP). Further maintenance of established field germplasm bank have been carried out.
- The SSR primers synthesized through cross species amplification has been screened for high polymorphism. The amplification of isolated genomic DNA of 165 plants by using 13 microsatellite markers and genotyping of amplified product (amplicon size) have been carried out using GenAlEx, STRUCTURE, Power Marker etc. software.
- Wood samples of different logs with varying colour from different locations were collected from Dandeli and Thitimathi Timber Depot (Karnataka) were collected to study the colour variation of wood. Information on receipt and sale of rosewood timbers were collected from Dandeli and Thithimati timber Depot.

- Disease surveys were conducted in *D. latifolia* nurseries/plantations. Thirty-five fungal isolates (*Colletotrichum* sp. (7), *Alternaria* sp. (03), *Pestolotiopsis* sp. (02), *Neopestolotiopsis* sp. (01), and *Fusarium* sp. (01)) were obtained in pure culture from the infected leaf samples. Twenty insect species of different groups: defoliators, sap-sucker leaf-folder have been observed.
- *Dalbergia latifolia* trees infested with *Viscum nepalense* Spreng. Family: Santalaceae - a stem parasite leading to tree mortality was recorded in Cauaveri Wild Life Sanctuary and Bhadra Tiger Reserve.
- Infestation of pinhole borer [Euplatypus parallelus (F.)] on living trees of *Dalbergia latifolia* was observed in Chitradurga, Karntaka. This was a first report from India and elsewhere.
- Continued raising seedlings of selected superior trees (QPM) of *Dalbergia latifolia* for germplasm bank establishment and for supply to farmers to conserve this vulnerable tree species.

Highlights

- Progeny trials cum germplasm banks have been established using RBD at Chandwa, Latehar (Jarkhand), Mohabata Chapra village, East Champaran (Bihar), Jabalbur (MP). Further maintenance of established field germplasm bank have been carried out.

29. All India coordinated research project on "Sustainable management of NTFP's through conservation and value addition"

29.1 Objectives:

- To identify superior germplasm of NTFPs yielding species
- ·To standardize and domestication of package of practices
- ·To standardize sustainable harvesting techniques of NTFPs
- ·To document Indigenous Traditional Knowledge(ITKs) on medicinal formulations used for treatment of different chronic diseases in different regions
- ·To standardize post harvesting process and value addition techniques of NTFP's for providing sustainable livelihood. To develop value chain. Capacity building of different stakeholders

29.2 Progress:

- Surveyed, identified the locations and collected germplasm of 03 Rare and Threatened species(*Thymus serphyllum, Rheum australe, Diploknema butyracea*), 10 Endangered species(*Taxus wallichiana, Aconitum hetrophyllum, Pimpinella tirupatiensis, Schumannianthus dichotoma, Tacca integrifolia, Aoprosa octandra, Hydocarpus kurzii, Mesua ferrea, Oroxylumindicum, Curcuma angustifolia*), 02 Critically Endangered species (*Embeliatsjeriam-cottam, Gentiana kurroo*), , 03 Vulnerable species(*Desmodium gangeticum, Terminalia pallida, Dioscorea deltoida*), 01 Near threatened species (*Costus speciosus*).

- ·The quality of collected germplasm were assessed and established in germplasm bank by the respective institutes. The content of baicalein in samples of *O. indicum* varied 0.0349±0.00 - 0.1597±0.00 %. Total alkaloid content in root samples of *D. gangeticum* varied 0.026±0.003 - 0.392±0.03 %, minimum in Sogda (Jashpur, CG) and maximum in Chanda (Dindori, MP) respectively.
- ·The emblien and phenolic contents in samples of *E. t. cottom* fruits varied 0.885±0.053 - 5.488±0.317 % and 1.23±0.23 - 4.68±0.81 %, respectively. The lupeol content in samples of *U. picta* roots found maximum in Butigad Dhamtari, CG (0.280±0.01%) and minimum Tikariya West Mandla, MP (0.119±0.01%).
- ·The flavonoid content in *R. australe* and *T. serpyllum* varied 1.87 mg - 9.15 mg and 1.30 mg - 5.81 mg Quercetin Equivalent/g respectively. The nutritional evaluation of *Phyllanthus acidus* fruits was carried out, 100g of edible fresh fruit contains moisture: 84.5±1.9, protein: 0.24±0.97 and carbohydrate: 4.7 ± 0.68. The rhizomes of *C. speciosus* (15 population) and *G. superba* (16 population) were analysed for diosgenin content and colchicine content, ranged 2.25% - 0.04% and 0.03-0.55% , respectively from different geographical location in Telengana.
- ·The propagation trails were carried out for the establishment of different targeted species. Value addition of *P. acidus* fruits and herbal chocolates were developed using *M. oleifera* leaves, evaluation of nutritional value and shelf life studies were assessed.
- Herbal Wound healing Cream and Herbal Hand wash were formulated using various concentrations of *Cassia tora* leaves extract. Antibacterial activity was found in developed handwash.

Fig. 25 Herbal gulal Made from *Butea monosperma* Flowers

Highlights

- Surveyed, identified the locations and collected germplasm of 03 Rare and Threatened species, 10 Endangered species, 02 Critically Endangered species, 03 Vulnerable species & 01 Near threatened species and established germplasm bank.
- Gene bank established for 29 species {HFRI (04), TFRI (04), FRC-SD (02), AFRI (04) IFP (02), FRI (04), IFB (05) & RFRI (04)}.
- Standardized nursery and propagation techniques for *O. indicum, D. gangeticum, U. picta* and *E.tsjeriam-cottam.*
- Domestication of package of practices of 02 species by TFRI, Jabalpur.
- Standardize sustainable harvesting techniques of NTFPs yielding 09 species {HFRI (01), TFRI (06), FRC-SD (01) & FRI (01)}.
- Collected information on Indigenous Traditional Knowledge (ITKs) of medicinal plants/formulations used for treatment of 04 chronic diseases i.e. Cardiovascular, Diabetes, Bronchial and Arthritis in different regions.
- Developed 17 value added products (black pepper powder, Candles, Lip Balm, Herbal Soap, Hand wash, Pickle & chocolates etc.) from NTFPs.

30. All India coordinated research project on "*Gmelina arborea* Roxb."

30.1 Objectives:

- To establish Germplasm bank of *G.arborea* and evaluate genetic diversity using morphological and molecular markers.
- To establish and evaluate *G.arborea* based agroforestry systems in the selected regions of India.
- To screen major insect – pest of *G.arborea* and its management in monoculture as well as in agroforestry system .
- In-situ evaluation of wood (density, stiffness, mechanical and physical properties) in standing trees using non-destructive / less invasive tools.
- ·To develop value chain in *Gmelina* based industrial agroforestry.
- ·To disseminate package of practices and develop farmer's friendly 'mobile app' for *G.arborea*.

30.2 Progress:

- In order to select CPTs of *Gmelina arborea*, extensive survey work was carried out in the selected agro-climatic zones of India, including the Northern, Eastern, and Central Indian regions. A total of 340 CPTs were identified (210 in Jharkhand & Bihar, 130 (70 in CG, 15 in Dapoli, MS, and 45 in MP)

under the project. Established progeny trials in the selected sites i.e. Two in Haryana (Seothi (Kurukshetra district and Bithmara (Hisar district) Two in eastern region i.e. one in NB farm Chandwa, Bihar and another at Ukdimadi village, Torpa, Khunti, Jharkhand and one at TFRI campus, Jabalpur (MP) whereas in southern region Vegetative Multiplication Garden was established with 10 shortlisted high productive clones and produced 1000 cuttings at Coimbatore, 2000 cuttings from 30 best CPTs at Ranchi, 5000 from 25 clones and 3000 planting stock for QPM and two CSOs i.e. one at Horticultural Research Station, Kahikuchi and another one at Regional Research Station, Diphu and one SSO at Sugarcane Research station, Buralikson(Golghat) Assam. Half sib progeny trials were established by IFGTB at Kurumbampatti, Salem and at Neyveli and TFRI, Jabalpur (MP).

- Observations on Survival percentage of different progenies have been recorded in established field trials was found 95 - 97 % with growth parameters including plant height (ranged from 1.5m to 2.2m) , Collar Diameter (12cm - 22cm) in Haryana and TFRI, the height was 2.75 to 4.51m within one year of plantation. Genomic DNA isolation protocol has been standardized and isolated for 135 CPTs by IFP. The isolated DNA has been assessed for its quality and quantity by utilizing NanoBio photometer and 0.8% agarose gel electrophoresis. The amplification of genomic DNA by using 20 SSR primers have been completed. Twenty microsatellite primers was designed and synthesized Twenty new SSR primer sequences have been shared with the partner ICFRE institute by IFGTB. Sixty eight progenies were completed by Coimbatore and 24 by TFRI for SSR profiling. 20 each of Microsatellite markers(SSR primers) by Ranchi , Coimbatore and 10 by Jabalpur synthesized for molecular characterization of selected CPTs,
- Established 6 *Gmelina* based agroforestry models in the selected agroclimatic region of India viz. Gmelina + Banana at Vadakadu, Pudhukottai, T.N. and *Gmelina* + Papaya at Kangeyam, Thiruppur, T. N., *Gmelina* + *Casuarina* + Ground nut at Sulakkal, Pollachi, Kerala; Gmelina + Mustard and Gmelina - Gram at Jabalpur, M.P. and *Gmelina*-Chilly at Hyderabad and recorded growth and yield data and calculated economics of the systems and found that each models are site specific models and are economically viable during initial stage of the system.
- Insect-pests of the species was also observed through the survey in Nursery and plantation and recorded leaf webber *Pagyda* spp, *Megalurothrips peculianis* and *Oxianniti dula, Ectropis bhurmita, Odontotermu* spp., *Macrotoma fisheri* and *Inderbela quadinota* and *Phyllocnistis amydropa*. Laboratory bioassay was conducted to test the effect of biopesticides against leaf webber, results revealed that Spinosad 45% (0.0125%), Azadiractin 10000 PPM (0.02%), NSKE (5%) was found effective with maximum mortality of 83.33,75.0, and 66.66 per cent mortality of larvae at 72 hours after treatment (HAT) respectively. Survey was initiated in the plantation site existing at Hoskotte, Karnataka and Vellore, Tamilnadu for wood traits analysis and collected data on DBH and recorded acoustic velocity. Determined the dynamic modulus of elasticity from the acoustic data. Collected physical and mechanical properties of Gmelina wood and tested at both fresh and dry condition which will serve as the benchmark for comparison. Value chain study was carried out in Tamilnadu, Kerala, Chhattisgarh and Madhya Pradesh to assess the market potential of Gmelina wood and its products and recorded that in Kerala and Coimbatore, many small cottage industry are using its wood for making articles.

S. No	Clone Code	Source of Selection
1	IFGTBGA-7	Clonal Screening Trials, Suthamalli, Ariyalur
2	IFGTBGA-9	Clonal Screening Trials, Suthamalli, Ariyalur
3	IFGTBGA-10	CSOP,IFGTB-FRS, Neyveli
4	IFGTBGA-12	Progeny Trials, IFGTB-FRS,Salem
5	IFGTBGA-13	Progeny Trials, IFGTB-FRS,Salem
6	IFGTBGA-16	CSOP,IFGTB-FRS,Neyveli
7	IFGTBGA-17	Clonal Screening Trials at Lingamalai
8	IFGTBGA-32	Clonal Screening Trials at Lingamalai
9	IFGTBGA-43	CSOP,IFGTB-FRS, Neyveli
10	IFGTBGA-65	CSOP,IFGTB, Neyveli

Fig. 26 *Gmelina* plantation intercropped with Brassica compestris

Fig 27 *Gmelina* plantation intercropped with *Cicer arietinum*

Fig. 28 Overview of Established *Gmelina* based agroforestry system

Highlights

- Total of 340 CPTs were selected for the study (210 in Jharkhand & Bihar, 130 (70 in CG, 15 in Dapoli, MS and 45 in MP).
- Established 5 progeny trials (Haryana Bihar, Jharkhand and MP).
- 3 clonal seed orchards established.
- Established 6 Gmelina based agroforestry models.
- Value chain study was carried out in Tamilnadu, Kerala, Chhattisgarh and Madhya Pradesh to assess the market potential of Gmelina wood and its products and recorded that in Kerala and Coimbatore, many small cottage industry are using its wood for making articles.
- Wood of Gmelina is using for making Face Mask of Kattakalli Dancer in Kerala State.
- Established one region Vegetative Multiplication Garden of Gmelina arborea with 10 shortlisted clones selected from clonal screening trials and progeny trials of IFGTB. Multiplication clones from VMG is under progress.
- Production of QPM of Gmelina was started i.e. 1000 cuttings at Coimbatore, 2000 cuttings from 30 best CPTs at Ranchi, 5000 from 25 clones and 3000 planting stock.
- Value added product prepared (*Semecarpus anacardium* (Biscuits from fruits); 'Karonda chips/energy drinks, Jam, Squash, Murabba, Candy, pickle. Himalyan fig jam, candy, fig pickle, and Molu pickle prepared from riped fruits.

31. All India coordinated Research Project on "Study of climate driven effects on Indian forests through long term monitoring"

31.1 Objectives:

- ·To observe and record detailed temporal and spatial changes in structure and function of selected forest types and grasslands of India.
- ·Monitoring climate change driven effects on carbon regulating services and nutrient dynamics of Indian forests.
- ·To study impact of Climate Change on distribution of major Forest Types of India.
- ·Monitoring biodiversity in selected forest types with special emphasis on invasive species.
- ·To study and monitor health of forest soils.
- ·To study micro climatic effects of forests in India.

31.2 Progress:

- ICFRE has established permanent research plots (Ten 10 ha plots; two 5 ha plots, one 4ha plot; two 3ha plots; Thirty-two1ha plots) in different forest types with an area of 152 ha, to monitor the impact of climate change on Indian forests through its nine institutes and four outside institutes [Indian Institute of Science (IISc), Bangalore; French Institute of Pondicherry (IFP); Ashoka Trust

for Research in Ecology and the Environment (ATREE), Bangalore and Kerala Forest Research Institute (KFRI)]. The project encompasses studies on detailed temporal and spatial changes in structure and function, carbon regulating services, nutrient dynamics, biodiversity, phenology, invasive species, pest and disease incidence, soil health, etc. in selected forest types.

- The project inception workshop was organized at Mudumalai, Tamil Nadu on 18th February 2020 by the lead institute in collaboration with IWST Bangalore and IISc. Bangalore and was attended by all participating institutes. Organized training of trainers (TOT) for all participating institutions at Mudumalai, Tamil Nadu on 19th & 20th February 2020 by the lead institute in collaboration with IISc., Bangalore, and other resources.
- Common protocols developed and shared with all partner institutes. Web meetings of the Component Coordinator, PIs, CO-PIs/associates, and project staff working on various components were held from time to time to discuss the protocols in detail, their implementations, and difficulties faced (if any) by different institutes. All the required equipment have been procured and installed.
- The biodiversity of the respective area has been studied following the belt transect method (30 transects of 250 m length) by all the institutes with the estimation of various vegetation parameters and indices. These transects are used for repeated observations on fungal species, insects, pests, pollinators, and regeneration status. A total of 2921 individuals of trees and shrubs belonging to 264 species have been geo-tagged for periodic phenological observation. Data recorded so far suggest that *Ageratum conyzoides, Lantana camara, Chromolaena odorata, Eupatorium adenophorum* are the most common among 37 invasive species recorded across different forest types. In Dry and moist deciduous and dry thorn forest (Mudumalai) seedlings of dominant canopy species were found to be underrepresented. However, in the Himalayan moist temperate deciduous forest (Binog wildlife sanctuary) the canopy species (*Q. leucotrichophora*) dominated the regeneration count.
- Layout and gridding of the experimental plots have been completed by all the institutes and enumeration is in progress. HFRI, Shimla; IISc, Bengaluru; French Institute, Pondicherry, and FRI, Dehradun have completed the enumeration of all woody individuals above 1 cm diameter (DBH) in 10 ha plots following the common protocol. Enumeration is in progress in all the institutes. A total of 1,38,667 woody individuals above 1 cm DBH have been measured, mapped and tagged with unique numbers so far covering 64 ha following CTFS (Center for Tropical Forest Science) protocol.


Fig. 29 Laying of the permanent plot at Soraipung range of DPNP

Fig. 30 Enumeration and tagging at Binog wildlife sanctuary, Mussoorie

- Observations on flowering host plants, their pollinators, and the frequency of insect pollinators are being recorded. An outbreak of Lepidopteran larvae (Defoliator) in the Seyog beat of Water Catchment WLS has been observed. One Cicada species was also found to be feeding on the sap of Cedrus deodara at water catchment wildlife sanctuary. Two insect species (*Antheraea perny, Leptocorisa oratoria*) infesting the Oak (*Q. floribunda*) at Shikari Devi were identified.

Fig. 31 An outbreak of Lepidopteran larvae (Defoliator) at Water Catchment WLS

Fig. 32 Lepidopteran larvae feeding on *Quercus semecarpifolia* leaves

- Fungal fruit bodies and their abundance, fruiting pattern, and host preferences are being recorded along with the geo-tagging. Transect-wise insects were observed and recorded with reference to GPS Coordinates. Insect monitoring was performed by yellow pan trap, visual observation, crown trap as well as sweeping methods. Insects were observed, collected, and preserved for further identification. Insect pests and pollinators were photographed and the frequency of insects has been recorded. At Binog wildlife sanctuary the order Lepidoptera was observed to have the highest species richness and species diversity whereas, Diptera has minimum species richness in the study site
- The phenological study is being conducted on 2921 geo-tagged individuals belonging to 264

species in different forest types. Soil samples are being collected and analysed for the estimation of various physicochemical properties. Litterfall production in the study plots is being recorded through the litter trap method and litter decomposition study is being conducted.

- Physiological parameters are being recorded in the dominant tree and shrub species of the study area. Soil CO2 Flux (soil respiration) is being measured in different forest types. Weather parameters are being recorded from the weather stations installed in the experimental sites and from the nearest weather stations of IMD to study the impact of forests on the microclimate.

Highlights

- ICFRE has established permanent research plots an area of 152 ha, to monitor impact of climate change on Indian forests for long term.
- A total of 2921 individuals of trees and shrubs belonging to 264 species have been geo-tagged.
- *Ageratum conyzoides, Lantana camara, Chromolaena odorata, Eupatorium adenophorum* are the most common among 37 invasive species recorded across different forest types.
- A total of 1,38,667 woody individuals above 1 cm DBH have been measured, mapped and tagged with unique numbers so far covering 64 ha following CTFS (Center for Tropical Forest Science) protocol.

Component II:
Programme for Conservation and Development of Forest Genetic Resources (FGR)

Component II:

Programme for Conservation and Development of Forest Genetic Resources (FGR)

Objectives:

- Preparation of comprehensive inventory of the FGRs of the country Preparation of priority list of FGRs with road map for their conservation and development.
- Collection and depositing of seed of important FGR species in Seed Banks.
- Evaluation and molecular characterization of commercially important FGRs
- Studying of genetic diversity and population structure of important FGRs
- Establishment of Field Gene Banks of FGR species
- Building a National FGR Information
- Developing a national level seed storage, research and referral center for seeds of forestry species.
- Development of comprehensive computerized database on FGR of India

Part-1

(FRI, AFRI, RFRI, IFP & HFRI)

- **FGR Documentation**
- Field surveys were conducted and a total of 219 FGR species have been documented from different Forest divisions in UP, Punjab, Rajasthan, Himachal Pradesh, Jharkhand, Bihar, West Bengal, Manipur, Meghalaya, Arunachal Pradesh, Mizoram and Tripura. Regeneration status has been studied for 148 species in different Forest divisions. GPS points were recorded for different species. LULC map of Haryana has been completed with 89.20 % accuracy. Eco-distribution mapping was done for 15 species and maps were upgraded for 13 species. Prediction mapping was done in 4 FGR species in Himachal Pradesh and updated for 16 species in North east. 50-70% coordinates have been completed for 7 species and 50-60% for 4 species in Himachal Pradesh. Seeds of 60 selected FGR species were collected.
- **FGR Seed and Germplasm Storage**
- Seeds were collected from 72 species. Passport data was prepared for 9 FGR species. Seeds of 18 species were processed, evaluated for germinability, desiccated to safe moisture content and sent to ICAR-NBPGR, New Delhi. Seeds of 19 species were preserved in walk in storage according to their characteristic features. Viability testing was performed in 76 species. Seeds of 17 species have been submitted to FRI by HFRI for long term storage.In vitro storage experiments are being carried out in 28 FGR species.

FGR Characterization

- Biochemical Characterization: Samples were collected and passport data was prepared for 2 species from Barmer and Jalore districts of Rajasthan. Bioactive markers have been identified for *Pterocarpus marsupium* and *Madhuca longifolia*. Extract was isolated from the bark of 4 populations of Terminalia arjuna. TTCs were estimated in 6 populations of *T. arjuna* while arjunic acid and arjungenin was estimated in 12 populations. Fruit samples of *Terminalia chebula* were collected, separated and lyophilized.
- Molecular Characterization: A total of 27 populations of selected FGR species were collected by all the participating institutes. DNA was extracted from 14 populations belonging to 5 FGR species. 196 SSRs were screened in different species. Genotyping of 15 populations of different species was completed. Genotyping data was scored for 3 populations of *Rhododendron arboreum*.

FGR Conservation

- Seeds of 6 species were collected. Seed germination trials were carried out for 18 species and their germination percent was analyzed. Stem cutting trials were attempted in 7 species for vegetative propagation. Air layering was done in 4 species. Germplasm of *Quercus semecarpifolia* and *Carpinus viminea* was planted in a nursery in Manali. Cuttings of Carpinus viminea were collected, treated and planted in Shillaru nursery. Germplasm of 2 species was collected with passport data and is maintained in the nursery for establishment of field genebank. Land has been identified in Barmer for upcoming field trials.

Highlights (FRI, AFRI, HFRI, IFP, RFRI)

- 219 FGR species documented from Forest divisions of 12 states.
- Regeneration status studied for 148 species.
- Eco-distribution mapping was done for 15 species.
- Prediction mapping was done in 20 FGR species.
- Seeds collected from 72 species. Passport data prepared for 9 FGR species.
- Viability testing was performed in 76 species.
- Genotyping of 15 populations of different species was completed and was scored for 3 populations of *Rhododendron arboreum*.

Part-2 -FGR

(IFGTB, TFRI, IWST, IFB)

Component A-Documentation of FGR

IFGTB

- Distribution map preparation based on literature was completed for 8 FGR species
- Based on the ground data collected prepared and updated distribution maps for 43 FGR species Data compilation and updation of collected germplasm for 8 FGR species was carried out Several rounds of discussion meetings were conducted and justifications for developing DBMS were submitted to ICFRE.

TFRI

- Distribution map preparation based on literature is under progress for 5 additional FGR species
- Based on the ground data collected prepared and updated distribution maps for 47 FGR species
- Documented improved germplasm available at TFRI for *Dalbergia latifolia*
- Compiled data on germplasm for 47 species and the Excel database was updated

IWST

- Based on the ground data collected distribution maps for 1 more FGR species prepare and updated for 25 species
- Distribution map preparation based on literature is under progress for 8 replaced FGR species
- Cataloguing of individual tree data of 27 species was done and updated

IFB

- Distribution map preparation based on literature is under progress for 5 FGR species
- Based on the ground data collected distribution maps for 21 specie prepared and updated
- Cataloguing of individual tree data of 24 species was done and updated

Component B- FGR Collection

IFGTB

- Field surveys were conducted to carry out population density studies and seed sources selection at, Tamil Nadu: Valparai, Siruvani, Kollihills, Sitheri Hills, Vilupuram , Pakka malai ,Ooty, Chengalpat, Kalrayan hills, Kodaikanal, Pachamalai areas. Kerala : Nelliyampathy, Agasthyamalai, Trivandrum, Palakkad, Thrissur, Peechi -Vazhani, Silent valley National Park, Munnar, Palakkad, Kottayam, Nilambur, Idukki, Kannur
- Selected seed sources/mother tree accessions for 13 FGR species in the various forest areas and

updated. Recorded field details and individual tree passport data for 13 species taken for study. Photographs of individual parts of the seed source were taken and recorded.

- Relative density studies were conducted in all the study populations visited. Average Relative density was estimated for 1 sps.
- Collected fruits of 34 species for the study
- Carried out regeneration studies for in-situ species at Nelliyampathy, Vilupuram, Konni, Kodaikanal, Palakkad, Kottayam, Idukki, Kannur .
- Species specific conservation strategy was derived for 88 species. The SSCS forms are under preparation, In-situ conservation: 26, Seed gene bank: 45, Field gene bank: 17
- For Molecular/biochemical studies, Leaf & Bark samples collected for *Myristica malabarica* (28 accessions), *Cullenia exarillata* (24 accessions), *Dysoxylum malabaricum* (18 accessions), *Mesua ferrea* (30 accessions), *Kingiodendron pinnatum* (8 accessions)

TFRI

- Field surveys were conducted at- Madhya Pradesh: Chhindwara, Mandla, Narsinghpur, Seoni, Hoshangabad, Itarsi, Raisen, Rewa, Chitrakoot, Satna, Balaghat. Sehore & Mandla (13). Chhattisgarh : Bilaspur, Dhamtari, Jagdalpur, Kanker, Katghora, Kondagaon, Surajpur, Kondapur, West Bhanupratappur, Gaurella-Pendra-Marwahi(GPM) & Kawardha (11). Maharashtra: Chandrapur, Gadchiroli, Allapalli, Sironcha, Brahmapuri, Nasik, Satara, Kolhapur, Yavatmal, Pusad, Pandharakawada, Nagpur, Jalgaon and Yawal (14)
- Species specific conservation strategy was derived for 65 species. The SSCS forms are under preparation, In-situ conservation: 10, Seed gene bank: 50, Field gene bank: 10
- Seed sources/mother tree accessions for 6 FGR species were identified at different forest areas. Photographs of individual parts of the seed source were taken and recorded 28 species in Madhya Pradesh, 29 species in Chhattisgarh, 39 species in Maharashtra.
- Relative density studies were conducted in all the study populations visited. Average Relative density was estimated for one species.
- Fruits of totally 19 species were collected from identified seed sources/ mother tree accessions.
- For Molecular/biochemical studies, Leaf samples collected from, Oroxylum indicum – 16 accessions, *Cordia macleodii*- 31 accessions, *Hardwickia binata*- 20 accessions and *Dillenia pentagyna*- 10 accessions. For Biochemical studies of 10 accession *Oroxylum indicum* were collected
- Carried out regeneration studies for in-situ species –at Kanger Valley National Park, Jagadalpur and Marwahi in Chhattisgarh, Chhindwara, Chitrakoot, Satna, Seoni and Umaria in Madhya Pradesh & Nashik, Pune in Maharshtra.

IWST

- Field surveys were conducted at-Karnataka:Sirsi, Yellapura , Karwar Kaveri WLS, (4) ,Goa: North

Goa and South Goa (2)

- Obtained permission for population survey and germplasm collection from A.P & Goa Forest Dept.
- Species specific conservation strategy was derived for 30 species. The SSCS forms are under preparation, In-situ conservation: 10, Seed gene bank: 15, Field gene bank: 5
- Selected seed sources/mother tree accessions for 22 FGR species in the various forest areas surveyed and updated. Recorded field details and individual tree passport data for 22 species. Photographs of individual parts of the seed source were taken and recorded
- Relative density studies were conducted in all the study populations visited and the values are yet to be derived.
- Fruits/seeds of 2 species were collected during survey from identified seed sources/ mother tree accessions.
- For Molecular/biochemical studies, Leaf samples collected from *Lagerstroemia macrocarpa* and *Barringtonia racemosa* for molecular and biochemical standardization

IFB

- Field surveys were conducted at- Telangana: Armoor, Nizamabad, Sathupally and Khammam (4) , Orissa: Koraput, Kalahandi North, Kalahandi South, Nabarangpur, Jeypore and Malkangiri (6)
- Species specific conservation strategy was derived for 30 species. The SSCS forms are under preparation, In-situ conservation: 5 , Seed gene bank: 20, Field gene bank: 5
- Selected seed sources/mother tree accessions for collected for 24 species. Individual tree passport data was collected and updated.
- Relative density was recorded for twenty one species in 12 forest divisions of Telangana and twenty two species in 7 forest divisions of Odisha to identify populations with above average density. Average Relative density was estimated for 24 species.
- Fruit were collected for 10 species.
- Natural populations of Givotia moluccana has been identified for regeneration studies in Pitlam, Pasra, Nagareddypet and Wazedu ranges in Telangana. Natural population of *Gyrocarpus americanus* has been identified in Madira range of Telangana.

Component C- Seed Germplasm Storage

IFGTB

- Standardised processing and extraction of seeds of 25 species collected for seed banking.
- Out of 17 species for field gene bank, standardized processing and extraction of for 7 species
- Seed germination / pretreatment studies were carried out for: Seed gene bank species 25, Field Gene bank species 7.

- Seed storage studies at -20 C upto 3 months, was carried out for 20 species.
- Viability tests- TTZ was standardized for 11 species

TFRI

- Compilation of data on Seed handling and storage techniques of 45 targeted species is in progress. A total of 35 accessions of 12 species were received. Seeds were extracted, dried, processed, and tested for moisture content and viability.
- Seed cold room became operational
- Collected accession (35) subjected to desiccation study to reduce moisture content to approx. 5% to store at -20 O C (Base collection).For accessions having sufficient quantity, additional sample storage at 5+0.5 OC (Active collection) carried out.
- Compilation of data on seed storage behaviour of present study published and resources of target species is in progress.
- Standardization of viability test (TTZ) is in progress for 10 species

IWST

- The germination of 3 tree species viz. *Albizia amara, Terminalia bellirica* and *Wrightia tinctoria* was recorded.The seeds were stored in -20^{o}C.
- Seed storage studies at -20^{o}C upto 3 months was carried out for 3 species viz. 1.*Albizia amara,* 2.*Terminalia bellirica* and *Wrightia tinctoria* Viability tests- TTZ was initiated for the above three species.

IFB

- Seed germplasm received for 10 species
- Seed germplasm of orthodox species (13 nos.) was stored at room temperature as a temporary arrangement until the availability of -20 storage facility.
- TTZ Viability tests- Yet to be done

Component D- FGR Characterization

IFGTB

- Morphological parameters of fruits and seeds were measured using Image analysis for 12 species
- The DNA was extracted from leaf samples of 24 accessions from different populations of Myristica malabarica. Standardization of DNA extraction from softwood of 5 selected in-situ species is under progress to obtain fine quality of DNA.
- Insilico research is under progress for designing of SSR primers. Through cross species amplification 20 sets of SSR primers were designed and synthesized. Among 20 sets of SSR primers, only 2 sets of SSR primers (SSR set 6 & 19) showed faint polymorphic bands in

Kingiodendron pinnatum accessions from Mundanthurai and Kolli hills. Hence, indented for transcriptome sequencing and SSR primer synthesis for the selected 5 insituspecies and is being processed through customized GeM portal.

- Secondary metabolites screening (Total Flavonoid Contents) done for 11 accessions of different populations using methanolic leaf extract of *Dysoxylum malabaricum* was carried out. Standardization of secondary metabolite screening of *Myristica malabarica* seed kernel is under progress.

TFRI

- Recorded data on morphological parameters of fruits and seeds viz., weight, length and width of fruits and seeds is being analysed through Jimage analyser software. Images of fruit/seed samples were captured for morphological characterisation.
- Genomic DNA of 31 samples of 4 populations of Madhya Pradesh of *Cordia macleodii* was extracted and quantified.
- DNA extraction and quatiification from 20 samples of Hardwickia binata of 1 population of Madhya Pradesh was carried. SSR primers were designed by collecting sequence data through NCBI database. Screening of all 29 primers was completed and PCR amplification is in process.
- 10 samples of *Dillenia pentagyna* from 1 population each from Madhya Pradesh and Maharashtra and 15 samples from 2 populations of Chhattisgarh was extracted and quantified. SSR primers were designed by collecting sequence data through NCBI database. Screening of all 22 primers was completed and PCR amplification is in process.
- DNA has been extracted and quanitified from 16 samples of *Oroxylum indicum* from 3 populations of Madhya Pradesh. Screening of 20 SSR primers was carried out for *Oroxylum indicum* and PCR amplification is in process.
- Leaves of 10 trees of *Oroxylum indicum* have been collected and processed for biochemical estimation of tannins, phenols, flavanoids and alkaloids.

IWST

- Capturing images of fruit/seed samples for morphological characterisation was performed for 11 species.
- Standardisation of DNA extraction procedure from leaf samples was completed for 3 species.
- Standardised of PCR conditions for molecular characterisation was standardized for 1 species (*Barringtonia recemoasa*) with 15 SSR primers.

IFB

- Seed images were captured for four species for characterization using image analysis software.

Component E- FGR Conservation (Field Gene bank)

IFGTB

- Raised seedlings, transplanted and hardening is in progress for: *Artocarpus heterophyllus*-10, *Artocarpus hirsutus*- 2 accessions, *Sapindus emarginatus*-7 accessions *Strychnos nux-vomica*-7 accessions, *Sweitenia mahagoni* -2 accessions *Aegle marmelos* -20 accessions
- Established III phase electrical connection in FGR Nursery. Painting and white washing work done for both FGRM Nursery and Seed Processing unit.
- Estimate for fencing has been sanctioned and the fencing work was initiated.
- Cleared 24 ha of land for field gene bank
- Indent for borewell at Tiruvannamalai has been placed
- Progeny trial of Mahogony, Progeny and clonal trial of *Neolamarckia cadamba*, Tectona grandis germplasm cum VMG were maintained

TFRI

- Seedlings of 5 species viz., *Pterocarpus marsupium, Haldina cordifolia, Mitragyna parvifolia, Buchnania cochinchinesis* and *Ailanthus excelsa* were raised and hardened for establishment of field gene bank.
- Highest seed germination was obtained in 3% GA3 in *Buchnania cochinchinensis*. In *Ailanthus excelsa*, maximum seed germination was obtained in pretreatment of 0.5% HCl.
- Digging of Borewell in the nursery area at TFRI, Jabalpur is in progress. Fencing in allotted 10 ha land for establishment of Field Gene Bank at Katni KVK is being finalized.
- Land has been requested from Madhya Pradesh Forest Development Corporation for Field Gene Bank.
- The Germplasm bank of *Pterocarpus marsupium* located in TFRI campus was maintained.

IWST

- The existing mistchamber is refabricated with new FRP sheets, cooling bad and exclusive water tank for cooling pad and foggers. The fogger line and electric control panel was changed. In the existing structure, replastering, white washing and painting was done.
- 10 hectares land will be identified in SFD/private institution land for field gene bank establishment.
- The germplasm bank of *Santalum album* is maintained at Gottipura.

IFB

- Fencing works was taken up on one side of the field gene bank at Mulugu.

Component F- Establishment of Centre of Excellence

IFGTB

- Explained and guided the PIs from IWST along with scholars to get oriented with image analysis and updation of FGR species list.
- Conducted online review meetings with networking institutes of the FGR program to discuss the progress made on 9.12.2022 and 27.1.2023.Component

Component G- Creation of National Forestry Seed Centre

- **IFGTB:** A display unit (carpellarium) for seed referral centre was created and displayed 22 species.

Fig. 33 Accessions of *Strychnos nux-vomica* from Tamil Nadu

Fig. 34 Selection of *Ailantus triphysa* seed source at Kottayam

Highlights (IFGTB, TFRI, IWST, IFB)

- 157 FGR species documented from Forest divisions of 9 states.
- Regeneration status studied for 27 species.
- Eco-distribution mapping was done for 157 species.
- Prediction mapping was done in 2 FGR species.
- Seeds collected from 96 species. Passport data prepared for 157 FGR species.
- Viability testing was performed in 20 species.
- Genotyping of 11 species was carried out.
- Raised seedlings of 7 species from different populations
- X-ray imaging equipment installed for seed analysis
- An oral presentation on "Preservation of Central India's Forest Genetic Resources through the establishment of a seed gene bank at Tropical Forest Research Institute, Jabalpur, Madhya Pradesh" made in the 1st National Conference on Plant Genetic Resource Management (NCPGRM 2022) held at National Agriculture Science Centre New Delhi organized by ISPGR, ICAR, NBPGR, CIAT, TAAS and PPVFRA from 22nd- 24th November 2022 and Received 'Best Oral Presentation Award'

Component III:

Policy studies under Centre for Forest Policy Research

Component-III:

Policy studies under Centre for Forest Policy Research

Objectives:

I. Identify the thrust areas for policy interventions for better governance of forest, wildlife and other natural resources in the country.

ii. Undertake the policy analysis of governance of natural resources and also look into the relevant legislations in a changing socio-economic scenario.

iii. Provide inputs to the Government on issues related to policy formulation & strategies for implementation.

iv. Carryout evaluation of various Government programmes/projects/policies with respect to identification of gaps in policy perspective.

S. No	Nine studies under CFPR and their status	Executing Agency	Present Status
1	Institutions of community Participation including Joint Forest Management Committees and Eco-Development Committees, linkages with Panchayati Raj Institutions, review of their working in various regions of the country and identification of successful models and shortcomings	TERI, New Delhi	Final report submitted to ICFRE & MoEF&CC
2	Policy issues in agroforestry including market mechanism, forward and backward linkages, regional availability, transit of forest produce, linkages with NDC targets, choice of species and utilization	NCCF, Noida	Final report submitted to ICFRE & MoEF&CC
3	Popularization of the use of Wood and Wood Substitutes as per the National Forest Policy and Modalities for Facilitating Industries for its Optimum Utilization	NCCF, Noida	Final report has been approved.
4	Study of grazing policies in different states and formulation of grazing policy guidelines for states	Society for Resource Planning Development and Research, Bhopal	Final report has been received.

5	Functioning of Forest Development Corporations and their role in the present Scenario	IUCN and IORA, New Delhi	Final report is awaited and the time line of the study has been extended up to June, 2023.
6	Issues in forest certification and certifying agency	GICIA, India Pvt. Ltd. Nodia	Final report is awaited.
7	Guidelines under Forest (Conservation) Act, 1980 for diversion of privately owned forests for non forestry uses	The ICFAI Law School, IFHE, Hyderabad	Inception report has been approved.
8	Public private partnerships in a broad perspective in forestry involving various sections of the society	SEEDS Technical Service Pvt Ltd., New Delhi.	Inception report is awaited

Progress:

I. Study of Grazing Policies in different States and Formulation of Grazing Policy Guidelines for States: executed by Society for Resource Planning, Development and Research (SRPDR), Bhopal.

ToRs of the study: To study the impact of grazing policies of centre/state and recommend best practices.To suggest policy prescriptions to strengthen inter-sectoral linkages between forestry agriculture and animal husbandry.Suggest mechanisms for conservation and development of fodder and pasture/grasslands in potential areas, viz, forests, culturable wastelands, community and other lands.Suggest a framework for a comprehensive grazing (cum- fodder and pasture development) policy guidelines at national level in coherence with the National Forest Policy-1988, National Livestock Policy- 2013, Agro-forestry policy and other related policies and guidelines.To study the impact of the grazing ban in the protected areas.

Status: Draft report has approved by the Director General, ICFRE, Dehradun.

II. Popularization of the use of Wood and Wood Substitutes as per the National Forest Policy and Modalities for Facilitating Industries for its Optimum Utilization: executed by Network for Certification and Conservation of Forests (NCCF), New Delhi.

ToRs of the study: To assess the present utilization and demand of wood and wood substitutes in the country including the analysis of earlier studies. To study the factors contributing to encourage the use of wood and wood substitutes as well as factors hindering their use and to suggest remedial measures. To assess and analyze the factors promoting industries for optimum utilization of wood and wood substitutes and to suggest measures for encouraging industries and promotion of optimum

utilization of wood and wood substitutes.

Status: Draft report has approved by the Director General, ICFRE, Dehradun

III. Functioning of Forest Development Corporations and their role in the present scenario: executed by IUCN (International Union for conservation of Nature) New Delhi.

ToRs of the study: To study the present role of Forest Development Corporations in the states/UTs and their economic viability To study the recent initiatives taken by these FDCs in various states/UTs, in terms of success, sustainability and profitability. To recommend programmes/activities to be taken up by the FDCs in the current scenario. To study the existing structure of the FDCs and suggest revamping wherever necessary for execution of the roles proposed for the current scenario. To study diversification perspective of FDCs in the present scenario. To study all FDC/FC existing in India.

Status: Final report is awaited and the time line of the study has been extended up to June, 2023.

IV. Issues in Forest Certification and Certifying Agencies: executed by GICIA India Pvt. Ltd., Noida, U.P.

ToRs of the Study: To analyze the existing forest certification models and suggest appropriate model for India. To assess the impacts of the costs and benefits of certification on sustainable forest management, especially with respect to forest management, trade, supply and demand of certified forest products and access to certification for stakeholders. To analyze the existing legal and policy instruments that support or discourage the use of forest certification instrument and suggest the options/means to link certification with other policy instruments for achieving sustainable forest management. To analyze the bottlenecks and changes required in the governance for realizing effective gains from forest certification. To identify the sectors and suggest a roadmap for realizing the goals of sustainability, poverty alleviation and economic growth through forest certification.

Status: Final report is awaited.

V. Guidelines under Forest (Conservation) Act, 1980 for diversion of privately owned forests for non forestry uses: executed by The ICFAI Law School, IFHE, Hyderabad

ToRs of the Study: To assess the extent of forest areas under the category of privately owned forests in the country and to analyze the demand of the individuals owning private deemed forests for bonafide/other uses. Analyse the provisions of the Forest (conservation) Act, 1980 which are in conflict with these land use requirements. Analysis of the studies conducted earlier including the recommendations prescribed. Recommendations regarding the demands and proposed amendment of the acts/rules/procedures required for conservation of such forest areas commensurate with meeting demands of private forest areas. To recommend the incentives to the forest owners keeping in view the practices in other countries and on par with the acquiring of other lands for public utility within the country

Status: Inception report has been approved.

VI. Public Private Partnerships in a broad perspective in forestry involving various sections of the society executed by SEEDS Technical Service Pvt Ltd., New Delhi

ToRs of the study: To assess the public private partnerships and contribution of various sections of the society in forestry sector in the country. To analyze the policies and instruments which aid/restrict in the public private partnerships in the forestry sector. To study the PPP models in a holistic manner on areas of partnership, terms and conditions of the contract , advantages and risks , etc., To suggest appropriate modes of partnerships for different forestry activities with various sections of society. To suggest policy changes for promotion of public private partnerships in forestry sector.

Status: Inception report is awaited

Component IV:

Capacity Building of
State Forest Departments for developing
"State REDD+ Action Plans"
under National REDD+ strategy

Component IV:

Capacity Building of State Forest Departments for developing "State REDD+ Action Plans" under National REDD+ strategy

Objectives:

- On behalf of MOEF&CC, ICFRE has developed National REDD+ strategy and the same has been approved by the Ministry. Through this programme, ICFRE will support the capacity building of the State Forest Departments for preparation of the State REDD+ Action Plans. The capacity building programme will also create awareness on REDD+ related issues, key concepts, analysis of COP decisions on REDD+ and their relevance to India.
- **A. Resource manual for capacity building of State Forest Departments:** A resource manual for capacity building of State Forest Departments for developing State REDD+ Action Plan (SRAP) in Hindi has been published and copies of the Resource Manual in Hindi will be distributed to all the State Forest Departments of Hindi speaking states. The manual has been written in a simple and easy to understand manner so that State Forest Departments can easily follow the methodology and process for developing their SRAP.
- **B. Methodology and Process followed in Organisation of the Capacity Building Programmes:** The methodology and process followed for organizing the training workshops were based on the Resource Manual: Capacity Building of State Forest Departments for Developing State REDD+ Action Plan (2020) developed by ICFRE under the project component. Following the introductory and contextual background on REDD+ mechanism and overview of preparation process of State REDD+ Action Plan, the workshop participants were divided into three working groups (1. Deforestation, 2. Forest Degradation and 3. Forest carbon Enhancement) in order to analyze and prioritize the most important drivers of deforestation and forest degradation, as well as the main barriers forest carbon enhancement activities in the state. The process involved firstly prioritization (e.g., of deforestation drivers) within each Working Group, secondly a plenary presentation of the higher priorities by each Working Group, and thirdly an overall scoring by all workshop participants of all the prioritized by the three Working Groups.
- **C. Organization of the Capacity Building Programmes of the State Forest Departments for developing State REDD+ Action Plan:** Organized the 19 capacity building programmes for State Forest Departments of Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Haryana, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Odisha, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, Andaman & Nicobar Island, Dadra & Nagar Haveli, Jammu & Kashmir Ladakh, Goa and Telangana for developing State REDD+ Action Plans.

Component V:
Operationalization of Human Resource Development Plan of ICFRE

Component V:

Operationalization of Human Resource Development Plan of ICFRE

Objectives:

- Capacity building through induction & subsequent skill upgradation training for all categories of ICFRE Personnel i.e., scientific, technical, administrative and executive.
- Seminars/workshops & conference both national and international for scientists and senior technical officers.
- Exposure visits to senior managers.
- Other HRD Initiatives like awards, online system of appraisal, increase in remuneration of support staff and periodical seminars/conference.Kashmir Ladakh, Goa and Telangana for developing State REDD+ Action Plans.

Progress:

- Under this component training programmes have been organized for Scientists/Technical Staff/Administrative Staff of ICFRE and Its Institutes under the Human Resource Development Plan. As per the approved HRD plan of council total 62 scheduled trainings have been conducted for 1461 participants through online/offline mode.

Financial year	Proposed trainings as per HRD Plan	Trainings executed using CAMPA fund	Induction Trainings executed using CAMPA fund	Number of Participants
2019-20	25	2	-	35
2020-21	23	21	4	601
2021-22	23	14	2	500
2022-23	21	18	1	325
2023-24	21	-	-	-
Total	113	55	7	1461

Fig. 35 Glimpse of trainings

Component VI:
Operationalization of Forestry Extension Strategy and Action Plan of ICFRE

Component VI:

Operationalization of Forestry Extension Strategy and Action Plan of ICFRE

Objectives:

- **Strengthening of the existing extension activities** which are already being implemented and need strengthening to get desirable results like Van Vigyan Kendras (VVKs), Demo Villages and Farmers' Mela
- **Initiating new extension** to provide outreach to ICFRE technologies to the target groups by development/establishment of Technology Demonstration Centres (TDC) and Modified Direct to Consumer Schemes

Progress:

Establishment of Technology Demonstration Centre

- Established TDC and installed bamboo & bamboo products display cabinet at ICFRE-IFP.
- Developed different exhibits, distillation assembly, 3D model of Rishi Dhanvantari, 3D models of different types of dryers, display cabinet to document harvest technique and processing of NTFPs and procured one Television and Digital Notice Board to display technologies related with NTFPs by ICFRE-TFRI, Jabalpur.
- For TDC, projector, speakers, audio visual aid, podium and other items were procured & watershed cum demonstration pond renovated by ICFRE-IFB, Hyderabad and procurement of chairs & computer table by ICFRE-HFRI, Shimla.In process: Technology

Fig. 36 Demonstration Centre being established at IWST, TFRI and IFGTB.

Documentaries: Seventeen documentaries and one mobile app have been developed by ICFRE Institutes/Centre.

- Seven documentaries on "Bamboo based products and its demonstration", "Agroforestry models", "Fungarium", "Trichocard", "Insectary", "Fly ash" and "Bamboo" by ICFRE-TFRI, Jabalpur.
- Five documentaries on "Bamboo flowering", "Wild Edible Fruits", "Extension of Vermicompost", *"Melia dubia"*, "Ecology and Land Management" by ICFRE-IFP, Ranchi.
- Two documentaries on "AFRI Contribution in the Conservation of Biodiversity" and "Traditional Agroforestry: Source of Research" by ICFRE-AFRI, Jodhpur.
- Two documentaries on "Timber Identification" and "ICFRE-IWST Research Activities" by ICFRE-IWST, Bengaluru.
- One documentary on "Bamboo Shoot and Value Addition" by ICFRE-RFRI, Jorhat.
- One mobile app on Agroforestry by ICFRE-ERC, Prayagraj.

Maintenance of VVKs including networking with KVKs (VVK-R)

Raising of seedlings of different species in VVKs carried out by ICFRE-HFRI, Shimla.

- VVK Longani, Dharampur, Mandi, H.P:

- Maintained demonstration nursery of medicinal plants (20 species) at Shivdwala by carrying out regular weeding, hoeing and watering. Raised and maintained the forestry species viz. Kachnar (2100), Taur (900), Teak (280), Chandan (400) Shisham (500), Amla (80), etc. and seed sowing of *Phyllanthus emblica* (1500 No.) carried out.
- Procured/collected seeds of different tree species viz. *Grewia optiva* (1kg), *Pyrus pashia* (5kg), *Acacia catechu* (1kg), *Terminalia chebula* (20 kg) and *Phyllanthus emblica* (12kg). Processed and dried the seeds for further sowing in the nursery beds.
- Seedlings of *Valeriana jatamansi* (100 No.) were transplanted to poly bags and *Morus alba* cuttings were planted in the nursery beds.

- VVK Jagatsukh, Manali, H.P.:

- Maintained the QPM stock of medicinal plants viz., *Picrorhiza kurroa*: (3300 no.), *Podophyllum hexandrum*(2300 no.'s), *Angelica glauca* (1800 no.'s) and *Trillium govanianum*(1900 no.'s) at VVK, Manali, H.P.
- Revenue worth Rs. 5000.00 has been earned by selling the medicinal plant seedlings viz. *Picrorhiza kurroa* (175), *Angelica glauca* (50), *Thymus* (50), *Acorus calamus* (50), *Valeriana jatamansi* (50), *Podophyllum hexandrum* (50), *Bistorta officinalis* (50).

- VVK, Janipur. Jammu, UT:

- Maintained 10 different Poplar clones (about 5000 plants) at demonstration nursery Nagbani Jammu by carrying out regular weeding, hoeing and watering etc. Prepared nursery beds and planted cuttings of 10 Poplar clones PIP(150), G-48(680), PIP-202(450), PIP-221(1018), PIP-119(270), PIP-216(120), PIP-113(140), UDAI (160), ST-124(272),S7C20(352) and mixed (904) planted and maintained cuttings (about 4570 no.'s) in nursery beds at Nagbani Jammu.
- Distributed/sold about 1500 poplar seeding to farmers and earned a revenue to the tune of Rs. 3000/- .
- Maintained demonstration plot of medicinal plants species (20 species) at Nagbani nursery, VVK, Jammu, UT.
- Collected seeds of Amla, Harad, Bahera, and Arjun for sowing in the nursery beds.
- Carried out general maintenance of VVK, Janipura Jammu.

- VVK, Badamibhag, Leh, Ladakh UT:

- Maintained different demonstration plot of medicinal plants species and Juniper (500 no.'s) raised at VVK Badamibhag, Leh by carrying out regular weeding, hoeing, watering etc.

- Networking with KVK:

- To carry out collaborative work with KVK, 550 numbers seedlings of 10 Poplar clones were supplied to KVK Sambha, Jammu, UT for establishing demonstration plot in farmer's fields.
- Established demonstration plot of 10 Poplar clones (400 plants) in farmers' field at Trewa Arnia, RS Pura, Jammu in collaborations with KVK Jammu. Recorded initial growth data and maintained the demonstration plot.

Conducted 39 Trainings/Workshops under VVKs by ICFRE Institutes and Centres

ICFRE-HFRI, Shimla conducted following 03 training programmes:

- Training programme on "Cultivation of Important Temperate Medicinal Plants: An option for Enhancing the Income of Local Communities" in collaboration with KVK Rohru and Tridev medicinal plant society Chirgaon at Taganu, Chirgaon, Rohru district, Shimla. About 40 members of mahila mandal, youth club, farmers etc. participated in training programme.
- Training programme on "Cultivation of important temperate medicinal plants" was organized in which About 30 farmers of Kullu region were trained at VVK Manali.
- Training programme on "Nursery and Plantation Techniques of *Juniperus polycarpos*" at KVK-Recongpeo.

ICFRE-AFRI, Jodhpur conducted following 02 training programmes:

- Three days VVK training programme at KVK Rajkot (Gujarat) from 1st to 3rd Nov, 2022 for 47 farmers and forest field functionaries.
- Three day training under VVK- Bikaner and Udaipur was organized in collaboration with KVK, CAZRI, Jodhpur at AFRI Jodhpur from 21st to 23rd Dec 2022. A total of 50 beneficiaries including farmers and forest field functionaries were participated in the training.

ICFRE-IFGTB conducted following 03 training programmes:

- "Vegetative Propagation techniques" of SFD`s.
- Red Sanders Cultivation for farmers.
- Agroforestry models for farmers.

ICFRE-IWST Bengaluru conducted following 10 trainings/workshops:

- Training program on Sandalwood based agroforestry models in collaboration with KVK Chamarajanagar, Karnataka. About 100 farmers of Chamarajanagar District attended the program
- Training on Sandalwood based agroforestry models in collaboration with KVK Hiriyur, (Tumkur) . About 150 farmers benefited from the program
- Training on Sandalwood based agroforestry models in collaboration with KVK Bidar. About 100 farmers benefited from the program
- Training on Sandalwood based agroforestry models in collaboration with KVK Kalaburgi. About 124 farmers benefited from the program
- Training on Sandalwood based agroforestry models in collaboration with KVK Kalikiri, Chitoor District, Andhra Pradesh. About 95 farmers benefited from the program
- Training program on "Sandalwood based on Agroforestry Models" for farmers in Collaboration with KVK Nellore district, Andhra Pradesh under CAMPA Extension. More than 80 farmers participated in the program
- A workshop jointly organized with Velankani Information Systems Limited, Bangalore and Quercus Space, Bangalore on integration of wood and wood based products in green building in HYBRID MODE. About 140 stakeholders participated.
- Sensitization program on Forestry and Wood Science for about 23 Audit officers from Regional Training Centre of Indian Audit and Accounts Department (IA&AD), Bengaluru.
- Training Program on Bamboo cultivation and livelihood at Kortagere, Tumkur. About 125 tribals from HakiPikki community and farmers attended the training.
- Training program on "Sandalwood based on Agroforestry Models and Spike Disease" jointly with Karnataka Forest Department, Chikkamangaluru and Akhila Karnataka Sandalwood Growers

Association. More than 80 farmers participated in the program

ICFRE-TFRI, Jabalpur conducted following 06 trainings:

- Training Program on "Agroforestry Models for Maharashtra State" was organized at Melghat, Maharashtra for 70 forest officials and farmers.
- Training programme on "Agroforestry and Bio fertilizer" was organized for 60 forest officials and farmers of Mandla, Jabalpur, Dindori, Kundam, divisions.
- Training Program on "Sustainable Harvesting Methods of NTFPs" was conducted for 54 participants of JFMCs & SFDs of Chhindi Range, Chhindwara district.
- Training Program on "Nursery Techniques of Important Forestry species" was conducted for 58 officials of SFDs of Seoni (MP).
- Training Program on "Nursery Techniques of Important Forestry species" was conducted for 29 officials of SFDs of Nagpur (MH).
- Hands on training on organic farming to the youths and women on plant medicinal plants such as neem tulsi, giloy, mint, curry leaves, ashwagandha, etc. within household premises.

ICFRE-IFP Ranchi conducted following 05 training programmes:

- Four trainings on "Improving livelihood through Non-Timber Forest Products (NTFP)", "Non-Timber Forest Produce Collection and Value addition", "Production of *Cinnamomum tamala* and its value addition" and "Promoting cultivation of Medicinal and Aromatic plants and development of Medicinal Plant Nursery" were organized by VVK ERS, Sukna.
- One Training on "Lac Production & Processing" was organized by VVK Jharkhand in collaboration with VVK, Balumath, Latehar for 346 farmers.

Fig. 37 Training on "Lac Production & Processing" on 21.03.2023 by ICFRE-IFP, Ranchi

ICFRE-RFRI, Jorhat conducted following 07 trainings:

- Training on Value Addition of Bamboo Shoot under Van Vigyan Kendra (VVK), Mizoram.
- Training on Low Cost Vermicomposting Techniques and Livelihood Generation at FRCLE for beneficiaries of different parts of South Tripura District .
- Training cum workshop programme on "Establishment of Herbal Home Gardens and Traditional Health Care" at FRCLE, Gandhigram, campus.
- Training cum workshop programme on "Skill Development on Bamboo Utility Products" at Kalibazar, Bamutia, West Tripura.
- Training on "Bamboo and Rattan Architecture" for 20 participants by ICFRE-BRC, Aizwal.
- Training on "Bamboo & Rattan Handicraft and Jewllery Making" for 20 participants by ICFRE-BRC, Aizwal.
- Training on "Bamboo & Rattan based Products Development" for 20 participants by ICFRE-BRC, Aizwal.

ICFRE-FRI, Dehradun conducted training on "Agroforestry and land management" for 41 farmers under VVK-KVK networking at KVK, Dhanouri Haridwar (Uttarakhand) .

ICFRE-IFB, Hyderabad conducted following 02 training programmes:

- Training on Conservation Techniques for Red Sanders for 30 farmers in VVK at IFB, Hyderabad.
- Training on Sandalwood Cultivation & Management Techniques for 26 farmers in VVK at FCRI, Mulugu.

Other Activities under VVKs:

- Purchased equipments viz. agarbatti, dhoopbatti making machine and essential oil distillation unit by ICFRE-TFRI, Jabalpur.

Establishment of nursery shed for model nursery by ICFRE-IFB, Hyderabad.

Demo Village (DV):

Conducted Five trainings/workshops under Demo Villages:

- Awareness program cum-workshop on "Agro-forestry" at DV Badagaon for 40 villagers and training and demonstration programme on "Grafting Technique of Horticultural Plants" for 15 villagers by ICFRE-HFRI, Shimla.
- Training on Bamboo Cultivation, Seasoning, Preservation and Utilization for farmers at Demo Village Gottipura, Hosakote Bangalore Rural Dist. for 50 farmers by ICFRE-IWST, Bengaluru.
- Training cum demonstration on Mushroom cultivation for farmers by ICFRE-TFRI, Jabalpur.
- Training on "Income generation through honey bee keeping" by ICFRE-IFP, Ranchi.

Other Activities conducted under DVs:

- Established vermi-bed and distributed honey box to villagers of DV Kutam by ICFRE-IFP, Ranchi.

  Collected/procured seeds of Khirak (1kg) and Kachnar (1kg) for sowing in demo nursery by ICFRE-HFRI, Shimla.

Tree Growers Melas

Tree Growers Mela was organized by ICFRE-AFRI, Jodhpur. A workshop was also organized on raising high quality seedling and nursery management, sustainable development of agroforestry, use of biochar, improved varieties of millets, its value addition and marketing. More than 400 farmers, environmentalist and tree growers attended the event. In this mela 20 stalls were exhibited on value added forest produce, medicinal plants and products, bio-fertilizer organic compost etc.

Tree Growers Mela was organized in Magh Mela-2023 by ICFRE-ERC, Prayagraj. Around 50,000 visitors visited the exhibition stall.

Extension Normal/Other Activities

Prakriti: A Scientist-Student Connect Initiative (24 Activities)

- Hands on training on vegetative propagation at KV, Miran Sahib, Jammu by ICFRE-HFRI, Shimla.
- Awareness programme on Rain Water Harvesting at KV, Ghumarwin, Disit. Bilaspur by ICFRE-HFRI, Shimla.
- Awareness programme on 'No to Single use plastic at JNV, Kothipura, Bilaspur by ICFRE-HFRI, Shimla.
- Exposure Visit of 82 students from GSSS, Kot Beja, and GSSS, Patta, Distt. Solan by ICFRE-HFRI, Shimla.
- Competitions on paintings and quiz for 124 students of 12 KVs/JNVs and development of Butterfly garden at KV IMA is under progress by ICFRE-FRI, Dehradun.
- Biodiversity & Nature Walk Campaigns and training on basics molecular techniques was organized for students by ICFRE-IFGTB, Coimbatore.
- Awareness programme was organized for 130 students of KV, Vijayanagaram by ICFRE-CEC, Visakhapatnam.
- Hands-on training was organized for 120 students of Nausenbaugh KV No. 1 by ICFRE-CEC, Visakhapatnam.
- Eight Environmental Awareness Programmes were organized at different Jawahar Navodaya Vidyalaya and Kendriya Vidyalaya across Jharkhand by ICFRE-IFP, Ranchi.
- Four Programmes under Prakriti at Jawahar Novodaya Vidyalaya, Dhing, Nagaon, Navodaya Vidyalaya, Dibruragh, Navodaya Vidyalaya, Golaghat, Assam and at Kendriya Vidyalaya, Miao, Changlang, Arunachal Pradesh were organized by ICFRE-RFRI, Jorhat.
- Exposure Visit of 38 students of KV-Mizoram University organised by ICFRE-BRC, Aizwal.
- Lecture & Presentation on Bamboo & Rattan Diversity, its cultivation and utilization to 50 students of JNV, Thenzawl and 50 students of JNV, Khawzawl organised by ICFRE-BRC, Aizwal.

- Exposure Visit of 59 students of KV- Zemabawk, Aizwal organised by ICFRE-BRC, Aizwal.

Participation in Melas/Exhibitions

- Participated in Krishi Mela, Northeast Expo and in "International Cultural Jamboree 2022 – Science Mela" by ICFRE-IWST, Bengaluru.
- Participated in IFFCO-organized farmer's meet at ICFRE-IFB, Hyderabad.
- Participated in "Farmers' Fair" and "1st Bodoland International Knowledge Festival, 2023" by ICFRE-RFRI, Jorhat.

Publication (Six brochures/pamphlets & one leaflet)

- Six brochures/pamphlets on "Insect pest of Forest Nurseries plantations & their management in Telangana", "*Syzygium alternifolium*- A medicinally important, endemic & endangered tree species from Eastern Ghats and Insect pest of Medicinal Plants and their Management", "An important wood boring insect pest (*Xylotrechus smei*) in Red Sanders; "Identification of Red Sanders and Bijasal seedlings in nursery using Morphological features", "*Decalepis hamiltonii* – An important NTFP climber species" and "Management of Acid Soils for Sustainable Plant Production" under VVK by ICFRE-IFB, Hyderabad.
- One leaflet on "Sandalwood Cultivation" in English and Kannada by ICFRE-IWST, Bengaluru.

Celebration of Important Days/Azadi Ka Amrit Mahotsav

- Women's Day 2023 and environmental important days under AKAM, Mission LiFE etc. by ICFRE-IFGTB, Coimbatore.
- Fit India Run 3.0, Women Empowerment programme, celebrated Birsa Munda Anniversary and International Forestry Day etc. by TFRI, Jabalpur.
- Celebrated various environmental important days under AKAM, Mission LiFE etc. by ICFRE Institutes & Centres

Modified Direct to Consumer Scheme

- Four Agroforestry demonstration plot established for Melia dubia at Sambhalkha, Ambala (Harayana), Birampur, Garhshankar (Punjab) with a spacing of 4x4m, 4x5m and 5x5m in 1.872 ha and at Baro, Prayagraj (Uttar Pradesh) with area coverage of 1 ha. A total 756 seedlings were planted in demo plots. The survival percentage of demo plots were recorded 23% at Ambala, Haryana, 47% at Hoshiarpur , Punjab and 50% at Prayagraj, Uttar Pradesh by ICFRE-FRI, Dehradun.
- Distribution of Mycorrhizal (VAM=AM fungi) inoculums (consortium) to farmers during VVK training held at KVK-Dhanouri, Haridwar (Uttarakhand) by ICFRE-FRI, Dehradun.
- Five thousand quality seedlings of Khejri (5000 plants) and Rohida (5000 plants) and clonal seedlings of Shisham (10,000 plants) were raised by ICFRE-AFRI, Jodhpur.

- Awareness-cum-Hands on training on 'Value Addition of Moringa" for 30 participants of women Self Help Groups of Chhindwara District on 30.12.2022. Developed Moringa leaves based value added products viz. biscuits, papad, chocolates and published Booklet on value added products of moringa by ICFRE-TFRI, Jabalpur.
- Demonstration plantation of *Melia dubia* at Bhonda, Daladali (Ranchi) and Kutam (Torpa, Khunti) and of Mehagony at Chitarpur, Ramgarh maintained by ICFRE-IFP, Ranchi.

Highlights

- Established 11 new Van Vigyan Kendras (VVKs) (Karnataka; Uttar Pradesh, Himachal Pradesh, Tamil Nadu; Meghalaya; Rajasthan; Chhattisgarh; West Bengal; Telangana & Bihar).
- Established 05 Demo Villages (Himachal Pradesh; Jharkhand; Karnataka; Rajasthan and Assam).
- Established 04 Technology Demonstration Centres HFRI;IFP;FRI; RFRI) & 01 Photogallery at FRI and 01 Marine Interpretation Unit at ICFRE-CEC, Visakhapatnam.
- Prepared 49 documentary films and Developed 01 mobile app on 'Agroforestry'.
- Organized 12 Tree Growers Melas/Kisan Melas.
- Conducted 99 trainings under VVKs, DVs and MDTC.
- Published 40 pamphlets, brochures, technical bulletins etc.
- Established 20 demo plots/models of different species (*Commiphora wightii*; *Melia dubia; Neolamarckia Cadamba*) Windbreak Clonal Plants at Tamil Nadu; Agroforestry model at Karnataka; Six demo plots of *Calophyllum inophyllum, Gmelina arborea,* Tamarind, Teak (T.C.), *Cadamba*, Pricision Silvicultural Technique with Teak and Casuarina, Tree Fodder Species, Medicinal Plants at Talamalai, Tamil Nadu; Four agroforestry demo plots of *Melia dubia* at Ambala, Haryana; Garhshankar, Punjab and Prayagraj and Poplar clones at Trewa Arnia, RS Pura, Jammu.
- Manufactured and sold 430 reactions of ArborEasy DNA isolation kit, improved VAM Production unit for producing 2000 kg of VAM/year and distributed Mycorrhizal (VAM=AM fungi) inoculums (consortium).
- Vacuum Pressure Impregnation Unit installed at RFRI for preservative treatment of Bamboo and has been given for lease to an Entrepreneur and now it has been running successfully. Now, treated bamboo is available at affordable price.
- Over 6 lakh QPM of various forestry species were raised.

Research Publications, books, bulletins from the scheme "Strengthening Forestry Research for Ecological sustainability and Productivity Enhancement"

Research Publications, books, bulletins from the scheme "Strengthening Forestry Research for Ecological sustainability and Productivity Enhancement"

- **Research papers presented in conferences, seminars, symposia etc.**
- A paper titled "Chemi-mechanical processing of cellulose nanofibers from bamboo and development of natural fiber-based nanocomposites" was presented in an International e-Conference on "Nanomaterials & Nanoengineering" held during February 24-26, 2022 at National Physical Laboratory, New Delhi (India)
- Almas Khannam and Tresa Hamalton (2021) Biotechnological tools for production of quality planting material of *Santalum album* L. In: Virtual International Conference 'Bengaluru Tech Summit 2021 held from 17 - 19 November 2021 at IWST, Bangalore, Pp-36.
- Balasubramanian Aiyar, Sandhya M.C, Shamili Krishnaraj and Mathish Nambiar-Veetil (2020). Composite transgenics as a tool for functional analysis of genes in trees. In Abstracts of the Virtual workshop on "Clonal propagation of tree species" Organised by IWST, Bangalore on 7th October 2020. pp32.
- Behera, D., Menon, D., Wilson, V., Das, P., & Ayyappan, N. (2021). Integration of Sentinel-1 and Sentinel 2 for the estimation of biomass in a tropical wet evergreen forest. In: 11th International Conference on Ecological Informatics (ICEI 2020+1). pp. Online, Thiruvananthapuram, India, 9-13 November 2021.
- Bhalla Piyush, Chitme H.R., Lal Mohan, Tripathi Y.C., and Varshney V.K. (2022). Chemical and biological investigation of *Cupressus torulosa* needles essential oil. In: International symposium on essential oils held on 4-7 September at Wroclaw, Poland. Piyush Bhalla was also awarded 'Young Scientist Fellowship' for registration fee to attend the symposium.
- Bhalla Piyush, Lal Mohan, Tripathi Y.C., Varshney V.K. and Singh A.K. (2022). *Cupressus torulosa* needles essential oil: Chemical composition and its biological activity In: International Conference on Biodiversity & Bioprospecting organized by Department of Plant Resources, Ministry of Forest & Environment, Govt. of Nepal from June 22-24, 2022 at Kathmandu (Nepal).
- Bhasker T, R., Dev, S. A., Balakrishnan, S. and Modhumita G. (2022). Development of neutral and adaptive genomic markers for management of *Santalum album* Linn.', paper presented at the Environmental Sciences, Forestry & Wildlife section, 34th Kerala Science Congress, Thiruvananthapuram, Kerala, India, 10-12 February, 2022.
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- Borpuzari, P.P; Singh, M.K. and Bhuyan, T. (2020); Agroforestry of *Gmelina arborea*: An economically important tree species, International Plant Physiology Virtual Conference "Prospects of Plant Physiology for Climate Proofing Agriculture December, 6-7, 2020; pp 182
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- Chauhan Kiran, Tripathi Y.C., Singh A.K., and Varshney V.K. (2022). Chemical examination and value addition of seed oil of *Prinsepia utilis* Royle from Uttarakhand. In: 15th and 16th Uttarakhand State Science & Technology Congress held at Graphic Era Deemed to be University, Dehradun from June 22- 24, 2022.
- Deepa M. delivered oral presentation on "Screening for establishing bioefficacy of ethnoinsecticidal plants for the development of formulations". 8-10 Dec. 2022. 3rd National symposium, Entomology -2022, PJTSAU, Rajendranagar, Hyd.
- Dr Rekha R Warrier presented a paper on Smallholder teak agro forestry plantations: scope and prospects in India' during the National Webinar on "Augmenting Teak Timber in India: A way forward" held on 21st and 22nd March 2022 (online mode) at IWST, Bengaluru.
- K Chandraprakash, Pankaj Singh, MSagar and G Sandeep. 2021. A Study of Important Medicinal Plants of Kowdipally Forest Area Medak Telangana in Abstarct book of NATIONAL CONFERENCE- "VALUE ADDITION AND MARKETING OF NTFPs", TFRI, Jabalpur Pp. 87.
- K. Bhole, N. D. Shivakumar, S. S. Chauhan, S. Tonannavar & Rajath S. Synthesis and characterizati on of nanocellulose based green composites. Poster presented in "Recent Advances in Cellulose Nanotechnology Research" held in Norway 5-6 Oct. 2022.
- K. Shanthi, T. Karthick, Thangaraj, A. Balasubramanian, K.C. Madhuvanthi, K. Jayabharathi, Modhumita Ghosh Dasgupta (2020). Optimization of vegetative propagation of sandal through root suckers. In: Virtual Workshop on 'Clonal propagation of tree species held at IWST, Bangalore on 7-10-2020.
- Kartik, A.G and Durai M V (2022). Past distribution of Indian sandalwood population in Karnataka and its glory. In: 8th International Conference on Environment and Ecology (ICEE2022), "Make India clean as well as cleaning up technologies, organized by the International Foundation for Ecology and Environment, Kolkata, and Department of Environmental Science, Bharathiar University held on 22-24 August, 2022 in Coimbatore, Tamil Nadu.
- Kartik, A.G and Durai M V (2022). Sandalwood and Mulberry based farming for sustainable development and high economic returns. In: National conference on Sericulture based multi-disciplinary approaches for climate Resilience, Sustainability and Livelihood, organized by the University of Agricultural Sciences, Bengaluru held on 26 and 27 August 2022 at College of Sericulture Chintamani, Chikkaballapur Dist. Karnataka (Oral presentation).
- Khanna Radhika, Tripathi Y.C., Chitme H.R. and Varshney V.K. (2022). Anti-inflammatory potential of needles of *Cupressus torulosa* D. Don ex Lamb In: International Conference on Biodiversity & Bioprospecting organized by Department of Plant Resources, Ministry of Forest & Environment, Govt. of Nepal from June 22-24, 2022 at Kathmandu (Nepal).
- Madhuvanthi K.C, Muthulakshmi E., Suma Arun Dev, Ulaganathan, K. and Ghosh Dasgupta, M. (2022). MicroRNA-mediated post-transcriptional regulation of sesquiterpene pathway genes in Santalum album. Poster presented in 20th IUFRO Tree Biotech & 2nd Forest Tree Molecular Biology and Biotechnology Conference 7-9 July, 2022, Harbin, China.

- Mayavel, A., Krishnan, S., Sivarathinavel, R.A., Ajith Kumar, A. and Nagarajan, B. 2020. Effect of grafting season and clone for deploying commercial propagation of tamarind (Tamarindus indica). In: Virtual Workshop on Clonal Propagation of Tree Species. Organized by: Institute of Wood Science and Technology, Bengaluru, 7th October 2020, pp. 18.
- Menon, D., Behera, D., Ayyappan, N. & Aravajy, S. (2021). Understanding tropical phenology of the Western Ghats: Combining citizen science and expert based approach. In: 11th International Conference on Ecological Informatics (ICEI 2020+1) Online, Thiruvananthapuram, India, 9-13 November 2021.
- Mohan C*, Neelu Singh, SakshiDwivedi, Rambhajan Singh and GulshanChakravarty (2022). Laboratory evaluation of Madhucalongifolia seed oil against key defoliator pests of teak. In "National Symposium on Entomology 2022: Innovation & Entrepreneurship" held during 08-10, December, 2022, Professor JayasankarTelangana State Agricultural University, Hyderabad, Telangana.
- Muthu Kumar A and Sandhya, G. M. (2021). Consortium of bio-fertilizer – a benefit for growth performance of Melia dubia seedlings. National Conference on "Clonal Forestry in Eco-restoration (CFER-2021)", 10-11, November, 2021, Prayagraj
- One paper has been communicated for publication in the conference proceedings of 'Value addition, marketing of NTFPs organized by TFRI, Jabalpur on 'Value addition to Dillenia indica L. fruit -a potential Non-Timber Forest Product of North East India prepared and sent during Jan, 2022
- One paper has been communicated for publication in the conference proceedings of 'Value addition, marketing of NTFPs organized by TFRI, Jabalpur on 'Value addition to Dillenia indica L. fruit -a potential Non-Timber Forest Product of North East India' prepared and sent during Jan, 2022 RFRI
- Paper presented on "Properties of Nano-Wood Composite (NWC) prepared from Populus deltoides impregnated with nano Zinc Oxide fortified PVAc resin" in an International e-Conference on Nanomaterials and Nanoengineering, APA Nanoforum-2022 held during 22-26 Feb, 2022 at National Physical Laboratory, New Delhi (India).
- Paper presented on "Properties of Nano-Wood Composite (NWC) prepared from Populus deltoides impregnated with nano Zinc Oxide fortified PVAc resin" in an International e-Conference on Nanomaterials and Nanoengineering, APA Nanoforum-2022 held during 22-26 Feb, 2022 at National Physical Laboratory, New Delhi (India).
- Phytochemical screening of red tamarind clones in Tamil Nadu. 2021. Mayavel, A., Chitra, P., Senthil Kumar, N., Nagarajan, B. presented at IHC- NEXT Generation Horticulture 2021 Tamil Nadu Agricultural University
- Piyush Bhalla, H.R. Chitme, Mohan Lal, Y.C. Tripathi, and V.K. Varshney (2022). Chemical and biological investigation of Cupressus torulosa needles essential oil. In: International symposium on essential oils held on 4-7 September at Wroclaw, Poland.
- Priya Nagaraik and Shukla S.R. "Physico-mechanical properties and characterization of nano-

wood composite prepared from nano-Zinc oxide fortified furfuryl alcohol" A poster presented in an International conference on Advance Polymeric Materials (APM-2023), organized by CIPET, Bangalore.

- Priyanka S., Pattanaik S. and Padmaja G. (2022). Genetic polymorphism revealed by RAPD and ISSR markers in different accessions of Pterocarpus santalinus L. Poster presented in International Conference on Frontier Areas of Science and Technology (ICFAST 2022).
- Research paper on" Development of Nutraceutical Bars from *Madhuca longifolia* (Mahua) flowers was presented as Poster presentation in National Seminar on "Securing Human Health though the use of Medicinal Plants" organized by MFP-PARC, Bhopal. Best poster presentation was awarded during the event. Authors were Dr. Vishakha Kumbhare, Smruti Shukla and Revanth V.
- Richa Bansal and K. K. Pandey: Beeswax nano-emulsion incorporated with zinc oxide nanoparticles – a sustainable wood coating for UV protection. Paper presented in International Conference on Advances in Smart Materials and Emerging Technologies (ASMET 2021) (20-21Dec. 2021) organized by: Indira Gandhi Delhi Technical University for Women, Delhi, India. This paper won "Best Paper Presentation Award" (1st Prize).
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- Sreenivasan, K. Krishnan, S. Soosai Raj, J. and Mayavel, A. Quality Planting Stock Production of *Gmelina arborea* Roxb. Virtual Workshop on "Clonal Propagation of Tree Species" 7th October 2020, organized by Institute of Wood Science and Technology (IWST), Bangalore. Pp.3.
- Sudha,S., Maheswari,P and Shanthi,A. 2022. Microsatellite DNA marker study in *Gmelina arborea*-an agroforestry tree species. In proceeding of the International conference on " Unifying Biology through Diversity (ICUBD-2022) , American college, Madurai. Pp.16.
- Thakur Nisha, Tripathi Y.C., Jishtu Vaneet, Singh A.K., and Varshney V.K. (2022). Variability in content and chemical composition of essential oils of Neolitsea pallens leaves collected from different locations of Himalaya in: International Conference on Biodiversity & Bioprospecting organized by Department of Plant Resources, Ministry of Forest & Environment, Govt. of Nepal from June 22-24, 2022 at Kathmandu (Nepal).
- Tresa Hamalton (2020). DNA barcoding for species discrimination -insights into Santalum species discrimination. In: Sandalwood Workshop 2020 organised by University of Adelaide on 5th, August 2020.
- Vipin Parkash, Karthikeyan, A., Megha, Gaur A., 2021. Effect of IFGTB developed biofertilizers on

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- A paper titled "Modeling potential hotspots of invasive *Prosopis juliflora* (Swartz) DC. In India", Ecological Informatics 64(7):101386. DOI: 0.1016/j.ecoinf.2021.101386.
- A. Karthikeyan, R. Kalaiselvi and V. Sujithra (2021). Vegetative propagation technique for *Pterocarpus santalinus* L.f. Indian Forester.147(3): 316-317.
- Almas Khannam, Tresa Hamalton, Somashekar P.V., Chandrakala D (2021) Hydroponic acclimatization of micropropagated Bamboo plantlets. Indian Journal of Tropical Biodiversity, 29(1): 54-59.
- Anamika Jangra, Sandeep Maikhuri, Santan Barthwal, Shailesh Pandey, G. Singh, Rajendra K. Meena, Rama Kant and Maneesh S. Bhandari. 2023. Distribution of *Salvadora oleoides* Decne. in Arid regions of Northwestern India- an overview. Indian Forester. ISSN 0019-4816. NAAS: 5.06. UGC: List B. 149(1): 99-102. DOI: 10.36808/if/2023/v149i1/159754
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- Barua, K.N., Dutta, N.B., Hazarika, P., Hazarika, P., Borah.P., Saikia, N.J. and Kalita, A. (2022), Variation of *Litsea cubeba* (Lour.) Pers. Essential oil from North East India emphasis on identification of industrially adoptable elite genotypes, Journal of Non Timber Forest Products, 29(2), 65-69
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- Bohra N.K., Kumar S., Soni A. and Giri V. (2021). *Salvadora persica* (tooth brush tree) – A Important Tree with Multidimensional Uses. Int. J. Adv. Res. Biol. Sci. 8(10): 149-153.
- Buvaneswaran, C., Anurag, R. and Nagarnambi, M. 2021. Modern Silvicultural Practices and Productivity of Teak. In.: Yasodha, R., Galeano, E. and Win, T. T. (Eds.). The Teak Genome. Springer Nature, Switzerland. pp 27-44 ISBN: 978-3-030-79310-4
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Published books/technical bulletins, manuscript, brouchers and other publications

- Technical Bulletins on Propagation and Management of different species of Bamboos were published in English and Hindi language.
- Article on "Bamboo based multipurpose windbreak- An effective measure for reduction of wind disaster in Tripura"
- A brochure on management of tissue culture teak in plantations in Tamil was prepared, released during the Tree growers Mela during September 2021.Microwave processing of bamboo, Wood is Good, 1(2): 73-75, 2021

- Book published on "Tree Blossoms of northeast India".
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- A Digital Brochures on bamboo Hindi and English prepared by FRI Dehradun. IWST, Bengaluru has published a technical bulletin on *Dendrocalamus stocksii* in local language (Kannada) for the benefit of various end users.

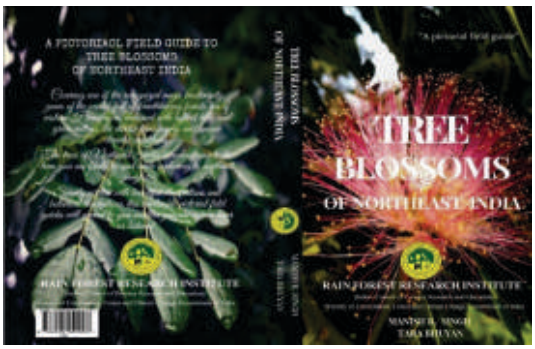

Fig. 38 Book on "Tree Blossoms of northeast India"

- AFRI published two booklets on sandal titled:
- 1. Farmers' guide for white sandalwood cultivation (English)
- 2. किसानों के लिए सफ़ेद चन्दन की खेती हेतु मार्गदर्शिका (हिन्दी)
- Two posters on Invasive Alien Species has been prepared.
- Red Sanders (Lal Chandan) A Green gold (English & Hindi) by AFRI
- An extension brochure 'Cultivation guide for Red sanders' by IFB
- An extension pamphlet 'An important wood boring insect pest (*Xylotrechus smei*) in Red sanders: Identification and management measures' by IFB
- An extension pamphlet 'Identification of Red sanders and Bijasal seedlings in nursery using morphological features' by IFB.
- An extension poster 'Electrical Resistance Tomography (ERT): A Novel Technology in Forestry' by IWST.
- Leaflets in Hindi and English prepared for distribution among stakeholders

  Nursery technique for seedlings production of *Oroxylum indicum* (Sonpatha)

  Nursery technique for seedlings production of *Uraria picta* (Prishnaparni)
- M. K. Singh, V. Sharma, P. Kardong & N. Gayary (2022). Forest Seed Identification- A Pictorial Guide for Northeast India. RFRI, Jorhat, Assam.
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Videography

- Under AICRP-3, a video was prepared on estimation of heartwood using ERT in standing trees of sandalwood.
- Under AICRP-4, a video on Cultivation practices of Eucalyptus clones in dry lands is being prepared for creation on awareness among the farmers of Tamil Nadu. Basic video shoot has been completed.
- Under AICRP-23, Indigenous Traditional Knowledge were collected and documented from different locations in Tamil Nadu and Kerala through questionnaire, photos and videos.

Patent/Trademarks (filed/awarded)

- A patent on "End grain drying of green turned timber" was filed under AICRP-5.
- Patent filed on 'Improved wood coating by IIT-R and ICFRE jointly' under AICRP-6.
- Patent filed under AICRP-16:
- A novel formulation for the management of type-2 diabetes mellitus and complications associated with diabetes
- Formulation and method of making a topical herbal gel formulation for the treatment of pain.
- Herbal hair colouring composition and method for preparation
- A process for recovery of natural dye from Soymida febrifuga bark.
- IFP, Ranchi lab certified as: ISO 90001:2015 under AICRP-22

The shortfalls in achieving the envisaged targets of all the components of the scheme along with detailed justification:

- Funds shortage particularly under Recurring Head is affecting activities in some of the projects and institutes.
- Few plantations could not be established in 2020-2021 due to COVID therefore, there growth parameters measurement has been delayed by one year.
- IFP, Ranchi lab certified as: ISO 90001:2015 under AICRP-22

Fig 39 Germination of Bambusa tulda in nursery bed

Fig 40 Germinating seeds of Butea monosperma

Fig 41 Inoculation of biofertilizers

Fig 42 Kisan Mela at AFRI, Jodhpur on 17.03.2023 by ICFRE-AFRI, Jodhpur

Fig 43 Mature fruit of Cullenia exarillata

Layout & Design : Amol k. Raut (FRI)

Indian Council of Forestry Research and Education,
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