

2.1 Ecosystem Conservation and Management

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	3	10	12
Externally Aided	7	20	8
Total	10	30	20

2.1.1 Climate Change

Carbon, water and energy dynamics in Himalayan *Pinus roxburghii* (chir pine) forest ecosystem (FRI)

Temporal dynamics of carbon, water and energy in chir pine forest ecosystem were investigated. The study showed huge fluctuations in components of carbon, water and energy which were directly affected by variations in microclimate of the forest ecosystem. The Leaf Area Index (LAI) and soil heat flux (SHF) exhibited inverse relationship. Canopy photosynthesis and transpiration was significantly affected by opening and closing of stomata i.e. stomatal conductance which was affected by air temperature, solar radiation and soil moisture content. The energy components namely net radiation; sensible heat and latent heat showed positive correlation with air temperature and sunshine hours. Soil CO₂ efflux was found to be higher during rainy season which was significantly impacted by soil temperature and moisture. In addition, increased evapotranspiration was observed during summer season. The major driving forces for change in microclimate were identified as air temperature, precipitation and solar radiation which lead to alter action of functioning of chir pine ecosystem.

Screening tree species for intra-specific variation in carbon sequestration potential under elevated CO₂ (IFGTB)

The study aims to assess intra-specific variation in growth and morphology in response to the elevated CO₂ level under ambient and simulated temperature regimes. On the basis of rooting ability for further multiplication, 33 clones of teak have been short listed for studying intra-specific variation for carbon sequestration potential under elevated CO₂ levels in the open top chambers.

Carbon sequestration through afforestation at Rourkela Steel Plant, Odisha (TFRI)

Carbon stock and annual carbon sequestration in vegetation, litter and soil in 1013 ha of plantations raised by Rourkela



Plantation raised at RSP

Steel Plant (RSP) were quantified. Raised four hectare plantation of 12 tree species having higher carbon sequestration potential at RSP and measured growth characteristics and survival rate of the planted trees. Allometric regression equations have been developed for biomass estimation of *Tectona grandis* (teak) ($y=0.0248x^2-0.1887x$; $R^2=0.963$), *Azadirachta indica* (neem) ($y=0.0097x^2-0.1267x$; $R^2=0.985$), *Phyllanthus emblica* (Amla) ($y=0.0041x^2-0.035x$; $R^2=0.977$), *Pongamia pinnata* (karanj) ($y=0.0146x^2-0.12x$; $R^2=0.99$), *Butea monosperma* (palash) ($y=0.0034x^2-0.0085x$; $R^2=0.982$). Carbon in trees, under storey, litter, deadwood and soil have also been estimated. Maximum carbon was found in *Tectona grandis* (teak) (13.56t/ha), followed by *Alstonia scholaris* (Saptarni) (6.04t/ha) and *Cassia siamea* (Kassod) trees (5.60t/ha). The tree plantations raised at RSP were found to sequester 4942 tonnes carbon per hectare. In the soil of RSP, 32.19 t C/ha was observed.



Measuring growth data of plantations raised at RSP

Atmospheric CO₂ concentration was measured at different locations of RSP in different seasons. It was observed that CO₂ levels in post monsoon are generally higher as compared to pre monsoon. This project will lead to estimation of biomass carbon for important tree species, Soil Organic Carbon (SOC) and carbon sequestration potential of plantation ecosystems.

Developed allometric regression equations and quantified carbon in trees, underground storey, litter, deadwood and soil. Maximum carbon was found in *Tectona grandis* (teak) (30 t), followed by *Alstonia scholaris* (Saptaparni) (8.94 t) and *Cassia siamea* (Kassod) trees (7.26 t). The total carbon content in 1040 trees found in the selected quadrats belonging to 39 species has been calculated to be 78.02 t. In the soil of RSP, 32.19 t C/ha was observed. Atmospheric CO₂ was measured at different locations of RSP in different seasons. Carbon in shrubs and herbs in the plantation area and natural forest was quantified after rainy season in the month of August when herbaceous biomass is found maximum and was recorded as 0.12 t/ha. Litter and deadwood was collected in 0.5m x 0.5 m size quadrats laid out in the tree quadrats and carbon in the form of deadwood and litter was recorded as 1.33 t/ha. This project will lead to estimate the Soil Organic Carbon (SOC) and carbon sequestration by different tree species in RSP.

Impact of forest cover change on stream flows of the Narmada River Basin using Macroscale Hydrological Model (TFRI)

Basin boundary and watersheds were delineated and channels were derived in Geographical Information System (GIS). Soil, land use and meteorological, river discharge and sediment data etc were procured. Geographic latitude and longitude of all gauging stations and Groundwater observation well were acquired. Major Dam locations in Narmada basin were demarcated and their level data were acquired. India Meteorological Department (IMD) Pune's newly developed

gridded climatological data (daily rainfall and temperature) was procured. Processing of acquired data mentioned above is completed. In addition, scanning, geo-referencing of soil maps of National Bureau of Soil Science and Land Use Planning (NBSS and LUP) were done. Soil parameters were estimated. This project will lead to understand effect of forest cover change on stream flows of the Narmada River Basin.

Climate change mitigation and adaptation strategies in western Rajasthan (AFRI)

People of western Rajasthan have evolved varying mechanism to cope up with climatic harshness and adversities. This project is funded under Mitigating Poverty in Western Rajasthan (MPOWER), which has been implemented in six blocks, one each in Jaisalmer, Barmer, Jodhpur, Pali, Jalore and Sirohi district of western Rajasthan. It is for identification of activities that enhanced livelihood and adaptations to climate change among the villagers of the selected villages in western Rajasthan; selecting best practice supporting mitigation (i.e., carbon sequestration in soil) of climate change in these villages; and documentation on level of sensitization and adoption of best practices for better adaptation and mitigation to climate change and improvement in people's livelihood for its further replication at large scale. Data from 407 households in Baitu (Barmer) block have been collected through different types of questionnaires and soil samples collected from different land uses for estimating soil carbon storage. There were 5.27 members per family/household. Numbers of days employed in agriculture and animal husbandry by a household were 113 days and 355 days respectively. Numbers of animals per household were 8.48, out of which 7.22 numbers is for goat/sheep. Cow dung, fuelwood, crop residue, LPG and kerosene are used for cooking/energy generation. Consumption of energy sources are 1.55 kg and 1.74 kg per day Cow dung, 9.53 kg and 12.6 kg per day fuelwood, 2.43 kg and 4.11 kg per day crop residue, and 3.86 kg and 7.01 kg per month LPG and 0.17 liter and 0.25 liter per month during summer and winter season, respectively.

Data generation in this project will help in estimating amount of carbon sequestered in soil and reduction in CO₂ emission and will come up with improved adaptation measures to climate change.

Carbon stock, vegetation and soil mapping for Rajasthan forests (AFRI)

In earlier concluded projects we have studied about 15% forest blocks of Rajasthan and generated valuable informations on types of forests, site characteristics, vegetation diversity and composition, carbon stock in five major components of forests, regeneration status, drainage characteristics, erosion, and soil physical and chemical parameters. To make this information easily available to different agencies in a user

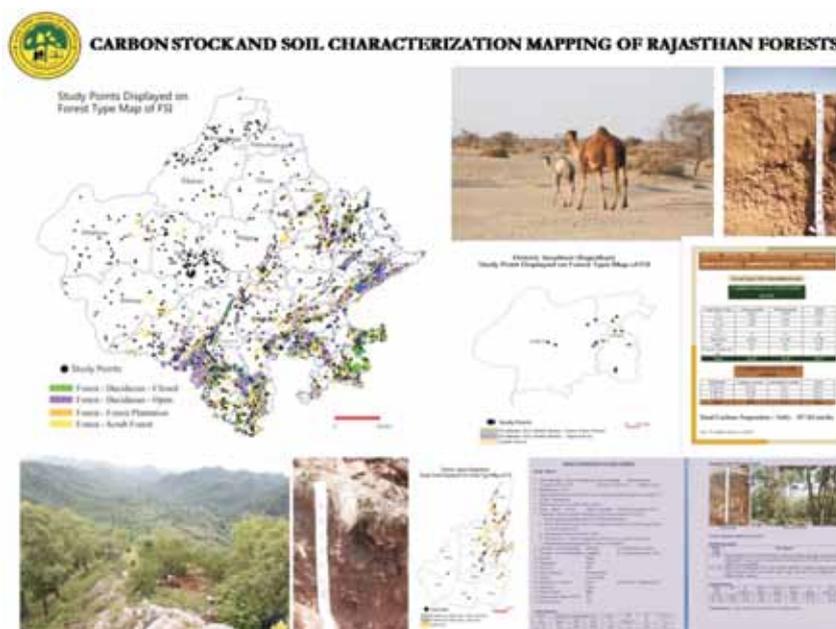


friendly manner it was required to present them in the form of digitized maps of various kinds. This project on mapping was initiated so that the users can click on the studied forest blocks to know the vegetation composition, carbon stock, soil type, nutrient status etc. for the reference year/period.

District wise digitized maps have been prepared on Geographic Information System (GIS) platform and the database has been linked with the studied points. It is a source of baseline information in the present climate change scenario. Users can visualize different parameters on site,

vegetation and soil with relevant photographs of soil profile and vegetation. Carbon stock and soil characterization maps of Rajasthan forests have been developed separately. Digitized maps on Forest carbon stock, Forest soil types and Forest soil nutrient status of Rajasthan is a pioneering work in the state. The maps developed are useful to the researchers, forest managers and policy makers and also will help to formulate appropriate forests management strategies. The maps are available in soft copy and can be viewed in any PC using 'Google Earth'.

Digitized maps prepared to display various soil parameters, vegetation composition, site characteristics and carbon stock in different forest blocks of Rajasthan



Carbon Stock and Soil Characterization Mapping of Rajasthan Forests

Long-term Study to Assess the Effect of Global Warming and Trials to Rehabilitate Degraded Site in High Altitude Transition Zone in Himachal Pradesh (HFRI)

The floristic composition studies conducted in high altitude transition zones between 3400 to 4000 m at Dhel Thatch (Kullu), Kalpa Kanda, Kinner Kailash and Naardu Kanda (Kinnaur) and Satrundi Saach Pass (Chamba) in Himachal Pradesh to monitor changes in their composition over a period of time. Floristic surveys till date recorded more than 100 plant taxa (data collection is still in progress) including many RET species, based upon the CAMP (Conservation Assessment Management Prioritisation) Shimla report (2010). Some notable threatened/RET species include *Aconitum heterophyllum* (atis), *Fritillaria roylei* (kakoli), *Rheum australe* (Indian rhubarb), *Malaxis muscifera* (Fly Bearing Malaxis), *Podophyllum hexandrum* (Ban kakri), *Saussurea obvallata* (Brahma Kamal). The dominant families being Asteraceae, Poaceae, Fabaceae, Lamiaceae and Polygonaceae; the number of dicots far exceeds the monocots and gymnosperms. The survey also revealed the presence of species like *Aconitum*



Studies and capacity building programmes on high altitude transition zone flora

heterophyllum (CR) (atis), *Aconitum violaceum* (CR) (Dudhia-bis, Mitha telia), *Dactylorhiza hatagirea* (CR) (Salam Panja), *Malaxis muscifera* (EN) (Fly Bearing Malaxis), *Meconopsis aculeata* (EN) (Vanita, Kanta), *Rheum australe* (EN) (Indian rhubarb), *Saussurea obvallata* (CR) (Brahma Kamal), those are of high conservation of significance.



The collected germplasm of threatened medicinal plants from the HATZ sites is being maintained in nursery beds at the Western Himalayan Temperate Arboretum (WHTA) at Potters Hill, near Shimla for *ex situ* conservation.

Nursery trials were conducted at Shongtog and Chitkul nurseries in Kinnaur district. The plants taken up for nursery trials are *Betula utilis* (Bhoj patra), *Quercus baloot* (baloot), *Rhododendron campanulatum* (Burans) and *Syringa emodi*

(Himalayan Lilac). The only two species that responded with germination upto 55 to 68 per cent were *Betula utilis* (Bhoj patra) and *Quercus baloot* (baloot) respectively under nursery conditions. Last year onwards trials on root and shoot cuttings were also initiated with *B. utilis* (Bhoj patra) and *R. campanulatum* (Burans). *Betula utilis* (Bhoj patra) and *Quercus baloot* (baloot) sowing carried out in Kinnaur were planted in the arboretum.

2.1.2 Ecology & Environment

Reclamation of degraded land & biodiversity conservation at NCL, Singrauli, Madhya Pradesh (FRI)

Forest Research Institute, Dehradun worked on development of Eco-restoration model and conservation of biodiversity in coal mined overburden dumps at Nighai and Krishnshilla of Singrauli Coalfields. Soil quality of mined areas was improved by spread of top soil and mulching material. Plan species were planted through, seed broadcasting, seed mixed soil balls, root stock, culm, branch cutting and seedling. *Dalbergia sissoo* (Shisham), *Gmelina arborea* (Gamhar), *Albizia lebeck* (Saras), *Pongamia pinnata* (Karani), *Bauhinia variegata* (Kachnar), *Emblca officinalis* (Amla), *Neolamarckia cadamba* (Kadamb), *Pithecellobium dulce* (Jangal Jalebi) were found to be the most successful species with respect to survival and growth. Top soil spread in mined out areas has resulted a dense and diverse vegetative ground cover as compared to the site without top soil spread, indicated the importance of use of top soil in mined degraded areas. The restoration model developed in coal mined area at Nighai is being replicated in other coal mined out areas of NCL, Singrauli.

Technical advisory for ecological restoration on overburdened dumps/mined out areas (FRI)

Technical knowhow for ecological restoration on nine project sites at Dhanbad, Jharkhand was extended to Bharat Coking Coal Limited (BCCL). Action plans for ecological restoration of the nine overburdened (OB) dumps were prepared and are currently being executed. Among trees, the growth of *Aegle marmelos* (Bel), *Albizia procera* (Safed siris), *Alstonia scholaris* (Saptaparni), *Bauhinia variegata* (Kachnar), *Dalbergia sissoo* (Shisham), *Heterophragma adenophyllum* (Marodphali), *Tectona grandis* (teak) etc. were found promising after the end of first year of restoration. Soil physico-chemical and biological properties from all the nine project sites are analysed. The bulk density of the soil in ranged between 1.24 to 1.61 gm/cm³, water holding capacity (WHC) varied from 30.72 to 45.12%, pH ranged between 6.09 to 8.05, EC varied from 104.26 to 671.87 μS/cm, soil organic carbon varied from

1.25 to 2.31%, the available Nitrogen varied from 145.6 to 369.6 kg/ha, the available calcium varied from 39.05 to 99.23 kg/ha. Occurrence of faunal population including mammals, reptiles, birds, butterflies, insects etc. have also been recorded from the restored sites.

Assessment of Carbon stock and Carbon sequestration potential of major land uses in Nagaland and Upper Assam (RFRI)

In Upper Assam and Nagaland, studies on soil and vegetation carbon stock were conducted. Data on carbon stock is being generated to prepare the carbon map of the area. This is part of a nation-wide programme to map carbon under Agriculture, Forestry and Other Land Uses (AFOLU).



View of various land uses in Nagaland and Upper Assam

Phytoremediation of soil for productivity enhancement through land disposal of effluent (AFRI)

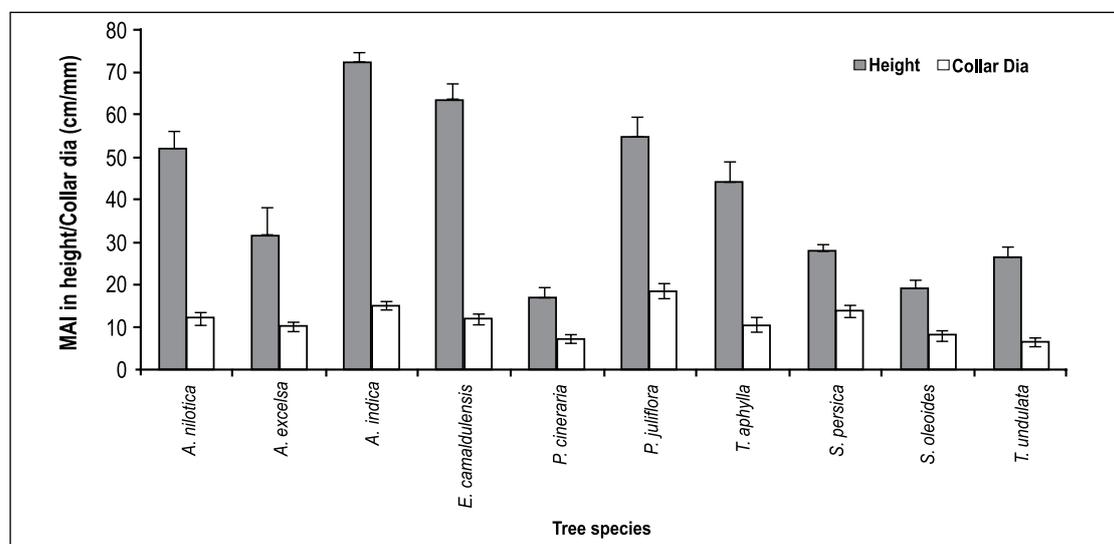
This project was initiated with objectives (i) to assess the most efficient species for soil improvement and phytoremediation; (ii) to monitor changes in soil health and phytoremediation



ability of different species; and (iii) to utilize industrial treated effluent as source of irrigation in afforestation with overall improvement in soil and environmental quality. Experiments in lysimeter tanks (non-weighting type) with 7 tree species and for different irrigation levels with treated effluent (1/2 and 3/4 ET) and canal water (1/2 and 3/4 ET) on 10 tree species were conducted.

Lysimeter experiment on seven tree species i.e., *Azadirachta indica* (Neem), *Eucalyptus camaldulensis* (Safeda), *Prosopis cineraria* (Khejri), *P. juliflora* (Vilayati Babul), *Tamarix aphylla* (Farash), *Salvadora persica* (Khara Jaal) and *S. oleoides* (Meetha Jaal) with four levels of irrigation were conducted. Mean annual increment in height (49.5 cm per year), collar diameter (12.0 mm per year) and crown diameter (31.5

cm per year) were highest in *E. camaldulensis* (Safeda), *Salvadora persica* (Khara Jaal) and *Azadirachta indica* (Neem), respectively. Soil sample collected from 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm indicated a decrease in NH_4-N (13.09 to 10.47 mg kg^{-1}), available PO_4-P (8.16 to 6.6.75 mg kg^{-1}), K (128.92 to 88.14 mg kg^{-1}), EC (0.90 to 0.72 Sm^{-1}) and increase in NO_3-N (3.53 to 4.00 mg kg^{-1}) while moving down in soil layers. Lowest amount of NH_4-N (11.60 mg kg^{-1}) was in *A. indica* (Neem), NO_3-N (3.31 mg kg^{-1}) was in *E. camaldulensis* (Safeda), PO_4-P (6.22 mg kg^{-1}) was in *P. juliflora* (Vilayati Babul), K (99.62 mg kg^{-1}) was in *S. persica* (Khara Jaal), Among the irrigation levels, concentrations of most of the soil variables were higher under effluent irrigation though soil pH, K and EC did not differ significantly ($P > 0.05$).



Mean Annual Increments (MAI) in height and collar diameter of different species irrigated with treated effluents.

In another field experiment conducted on ten forestry tree species i.e., *Acacia nilotica* (Desi Babul), *Ailanthus excelsa* (Ardu), *Azadirachta indica* (Neem), *Eucalyptus camaldulensis* (Safeda), *Prosopis cineraria* (Khejri), *Prosopis juliflora* (Vilayati Babul), *Tamarix aphylla* (Farash), *Tecomella undulata* (Rohida), *Salvadora oleoides* (Meetha Jaal) and *S. persica* (Khara Jaal) planted at 3 m x 4 m spacing with three replications., four irrigation levels are given (i) effluent water at 1/2 evapotranspiration (ET), (ii) effluent water at 3/4 ET, (iii) normal water at 1/2 ET, and (iv) normal water at 3/4 ET. The irrigation is based on cumulative pan evaporation at one month interval. Height and collar diameter of the plants indicated highest height increment of 72.1 cm per year in *A. indica* (Neem) and collar diameter of 18.6 mm per year in *P. juliflora* (Vilayati Babul) and *T. undulate* (Rohida) respectively. Among the irrigation levels, height and collar diameter increments were highest in tree irrigated with effluent at 3/4 ET and 1/2 ET, respectively.

Treated effluent can be utilized in raising tree plantation with some amendments to enhance environmental quality and green cover in suburban areas.

Natural regeneration studies of important tree species of Nallamala, Seshachalam Hills and Kaundinya Wildlife Sanctuary of Eastern Ghats of Andhra Pradesh (IFB)

Natural regeneration studies of important tree species of Nallamala, Seshachalam Hills and Kaundinya wildlife sanctuary were also conducted so far a total 53 numbers of quadrats have been laid out across Nallamala, Seshachalam hills and Kaundinya wildlife sanctuary for assessment of natural regeneration of important tree species and collected the data and soil samples. About 19 local communities from the different regions were sampled for knowing the priorities of important tree species and their perception about the natural regeneration. Thirteen soil samples from Nallamala, Seshachalam hills and Kaundinya wildlife sanctuary of Eastern Ghats of Andhra Pradesh have been analysed for EC, pH, organic carbon, available NPK and micronutrients like Cu, Fe, Mn, Zn.



2.1.3 Biodiversity

Floral Biodiversity studies in Bihar (FRI)

To assess the status of vegetation, quantitative and qualitative study eleven districts (West Champaran, Aurangabad, Banka, Nawada, Nalanda, Kaimur, Rohtas, Munger, Lakhisarai, Jamui and Gaya) of Bihar was carried out. Emphasis was given to record all woody species in the study area. Study reveals that there are endemic species in the West Champaran District such as *Leucas helicterifolia* (Thumbai) and *Carum villosum* which requires immediate attention for conservation. Interesting finding of the study are several new records from the West Champaran district viz., *Erathenum montanum* (wild castor.), *Mallotus ferrugineus* (Mallotus, Rusty Kamala), *Olxax nana*, etc. Tree outside forest (TOF)

and Medicinal plants along with their local names were also reported from the allotted districts. Total number of plant species recorded from the West Champaran, Aurangabad, Banka, Nawada, Nalanda, Kaimur, Rohtas, Munger and Lakhisarai, Jamui, Gaya and Udaipur Wildlife Sanctuary were

537, 126, 156, 168, 106, 158, 168, 212, 128, 172 and 194 respectively.

Enhancement and conservation of biodiversity (FRI)

In order to enhance biodiversity status in already restored mines site at Tetulmari, of Bharat Coking Coal Limited (BCCL), Dhanbad, a number of ameliorative measures such soil moisture conservation, enhancing soil fertility status of the site etc. were applied to make habitat suitable for regeneration, establishment and growth of native and planted species. About 2,560 saplings of different plant were also planted at the sites. Phytosociological analysis was also conducted and the data were compared with the natural adjoining forest. Soil samples to assess the nutrient status were collected and analysed. Carbon sequestration potential of mined areas after restoration was found to be increasing over the period.

Mycological investigations on diversity and ecological status of *bambusicolous* macro-fungi in upper Assam (RFRI)

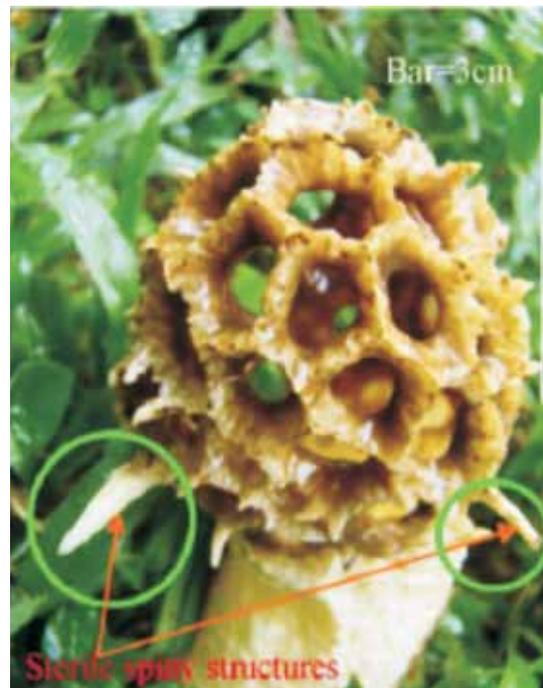
Host-fungus relationship was worked out for *Bambusicolous* macro-fungi in Upper Assam, and two ectomycorrhizal associations were found out with *Cantharellus* and *Boletus* species. *Lysurus habungianus*, a new species of fungus was reported from Assam.



Scrub forest at Nalanda district in Bihar



Firmiana colorata at Rajgir (Nalanda)



Lysurus habungianus G. Gogoi & V. Parkash, sp. nov. MycoBank No. MB 812277

Studies on ecological and ethnomycological aspects of wild mushrooms of Meghalaya (RFRI)

these, 112 species were first records for Meghalaya while 16 species were first records from India.

A total of 148 mushroom species were collected from Meghalaya, of which, 137 species were identified. Among



Cortinarius caninus



Amanita bisporigera



Amanita magniverrucata



Laccaria affinis

Assessment, Documentation and Characterization of Lichen Diversity in Mizoram (RFRI)

are rich in lichen flora represented by crustose, foliose and fruticose growth forms . Follicolous lichens (lichens growing on leaves) were particularly abundant on the leaves of understory plants of closed canopy forests.

Around 100 species of lichens have been documented from Mizoram. Study revealed that sites above 1000 m altitude



Lichen *Caloplaca* sp. growing over a rock



Habit of Fruticose lichen *Hypotrachyna* sp.



Lichen *Letrouitii transgressa* growing on a bark



Coccocarpia palmicola and *Heterodermia* on a tree trunk at an altitude of 1300 m.



Lichen *Collema subconveniens* growing on a rock. The sample is collected from Mamit district



Ecological assessment of floral diversity in MPCA of Chhattisgarh with special emphasis on species of medicinal importance and conservation priority (TFRI)

Seven MPCAs of 200 ha each in Sindavand (N. Kondagaon), Keregaon (Dhamtari), Kelo, (Dharamjaigarh)Navadih (Balrampur), Dudhitangar (Korba), Pahadjamali (Kathghora) and Churnai (Sarguja) were studies.

Compartment history and grid map of the Medicinal Plant Conservation Area (MPCA) was collected from the respective forest divisions of Chhattisgarh. The preliminary list of species

recorded in one season for each MPCA was prepared. In so far as the protection status is concerned, 5 MPCa were fenced 3 were not fenced, however, all MPCAs were very well protected by respective JFM committees. Regeneration status in all MPCAs varies from good to excellent. The findings of this project will be useful to assess floral diversity of MPCAs with special reference to species of medicinal importance and conservation priority . Details of vegetation structure, important species, species that need conservation efforts in MPCAs are given in table:

Name and location of MPCA	Sindavand, N. Kondagaon, Keshkal compt 2811,C/1, SCI Nalajhar	Keregaon Dhamtari Keregaon compt. 106	Kelo Dharamjaigarh Lailunga compt. 187/188	Navadih Balrampur Rajpur Compt. RF 58	Dudhitangar Korba Balco compt. P943	Pahadjamali Kathghora Pali compt. P117/119	Churnai Sarguja Matharinga Compt. P2124
Number of species recorded	Trees: 47 Shrubs and lianas:12 Herbs:78	Trees: 55 Shrubs and lianas:15 Herbs:68	Trees: 34 Shrubs and lianas: 6 Herbs: 54	Trees: 48 Shrubs and lianas: 9 Herbs: 98	Trees: 45 Shrubs and lianas: 13 Herbs:45	Trees: 59 Shrubs and lianas:10 Herbs:113	Trees: 59 Shrubs and lianas:18 Herbs:74
Important species of MPCA recorded	<i>Strychnos nux-vomica</i> , <i>Stereospermum suaveolens</i> , <i>Cordia macleodii</i> , <i>Terminalia bellirica</i> , <i>Oroxylum indicum</i> , <i>Pterocarpus marsupium</i> , and <i>Buchanania lanzan</i>	<i>Ougeinia dalbergioides</i> , <i>Pterocarpus marsupium</i> , <i>Saccopetalum tomentosum</i> , <i>Dillenia pentagyna</i> , <i>Buchanania lanzan</i> , and <i>Terminalia chebula</i>	<i>Elaeodendron glaucum</i> , <i>Boswellia serrata</i> , <i>Pterocarpus marsupium</i> , <i>Garuga pinnata</i> , and <i>Terminalia chebula</i> ,	<i>Ougeinia dalbergioides</i> , <i>Pterocarpus marsupium</i> , <i>Saccopetalum tomentosum</i> , <i>Dillenia pentagyna</i> , <i>Buchanania lanzan</i> , and <i>Terminalia chebula</i>	<i>Stereospermum suaveolens</i> , <i>Boswellia serrata</i> , <i>Ougeinia dalbergioides</i> , <i>Pterocarpus marsupium</i> , and <i>Dillenia pentagyna</i> ,	<i>Garuga pinnata</i> , <i>Pterocarpus marsupium</i> , <i>Dillenia pentagyna</i> , <i>Stereospermum suaveolens</i> , <i>Dalbergia paniculata</i> , <i>Stereospermum suaveolens</i> , and <i>Terminalia chebula</i>	<i>Cholchospermum religiosum</i> , <i>Ochna obtuse</i> , <i>Sterculia urens</i> , <i>Pterocarpus marsupium</i> , <i>Cordia dichotoma</i> , <i>Stereospermum suaveolens</i> and <i>Ougeinia dalbergioides</i>
Some medicinal plant of conservation priority	<i>Costus speciosus</i> , <i>Eulophia herbacea</i> , <i>Eulophia nuda</i> , <i>Curcuma angustifolia</i> , <i>Chlorophytum tuberosum</i> , <i>Curculigo orchioides</i> , <i>Smilax zeylanica</i> , <i>Curculigo orchioides</i> , <i>Pueria tuberosa</i> <i>Smilax macrophylla</i> , <i>Smilax zeylanica</i> , <i>Celastrus paniculata</i> , <i>Gloriosa superba</i> , <i>Citrullus colocynthis</i> and <i>Ceropegia candelabrum</i> ,	<i>Embelia ribes</i> <i>Costus speciosus</i> , <i>Eulophia nuda</i> , <i>Chlorophytum tuberosum</i> , <i>Curculigo orchioides</i> , <i>Smilax zeylanica</i> , <i>Celastrus paniculatus</i> , <i>Gloriosa superba</i> , <i>Citrullus colocynthis</i> and <i>Ceropegia candelabrum</i>	<i>Embelia ribes</i> <i>Exacum pedunculatum</i> , <i>Curculigo orchioides</i> , <i>Acalypha lanceolata</i> , <i>Vernonia anthelmintica</i> , <i>Habenaria digitata</i> , and <i>Curculigo orchioides</i>	<i>Embelia ribes</i> <i>Chlorophytum tuberosum</i> , <i>Asparagus racemosus</i> , <i>Dioscorea hispida</i> , <i>Curculigo orchioides</i> , <i>Dioscorea bulbifera</i> , <i>Celastrus paniculatus</i> , and <i>Smilax zeylanica</i>	<i>Embelia ribes</i> , <i>Dioscorea hispida</i> <i>Dioscorea oppositifolia</i> <i>Smilax zeylanica</i> <i>Curculigo orchioides</i> <i>Chlorophytum tuberosum</i> <i>Asparagus racemosus</i> <i>Uraria picta</i> <i>Celastrus paniculatus</i> , and <i>Psoralea corylifolia</i>	<i>Embelia ribes</i> <i>Sauromatum venosum</i> , <i>Chlorophytum tuberosum</i> , <i>Costus speciosus</i> , <i>Curculigo orchioides</i> <i>Chlorophytum tuberosum</i> <i>Eulophia nuda</i> , <i>Urginea indica</i> , <i>Dioscorea hispida</i> , <i>Curcuma angustifolia</i> , and <i>Oenanthe javanica</i>	<i>Embelia ribes</i> <i>Celastrus paniculatus</i> , <i>Chlorophytum tuberosum</i> , <i>Citrullus colocynthis</i> , <i>Dioscorea hispida</i> , <i>Oenanthe javanica</i> , <i>Peucedanum nagpurense</i> , <i>Pueraria tuberosa</i> , and <i>Costus speciosa</i>

Diversity of insect pollinators and their role in fruit/pod production of *Acacia Senegal* (Kher), *Capparis deciduas* (Karel) and *Prosopis cineraria* (Khejri) in Rajasthan (AFRI)

Insects play an important role in pollination. AFRI Jodhpur conducted study on diversity of insect pollinators and

their role in fruit/pod production of *Acacia Senegal* (Kher), *Capparis decidua* (Karel) and *Prosopis cineraria* (Khejri) in Rajasthan. In *Acacia senegal*, flowering was observed in the end of July and flowers were creamy-white in colour. Hymenopterans (*A. dorsata*, *A. florea*, *Vespa* spp., *Xylocopa* spp., ants, *Polites* spp., *Megachile* spp.), Coleopterans (*Mylabris pustulata*, *Oxycetonia* spp.), Hemipteran (*Bagrada*



spp.), Lepidopteran (*Colotis fausta*, *Colotis etrida*, *Catopsilia* spp., *Eurema* spp., *Papilio* spp.) and Diptera (Syrphids) were important group of insects pollinators recorded on *Acacia Senegal*. Foraging behaviour of insect pollinators visiting the flowers of *C. decidua* in February - March and April- May were also observed. The insect pollinators recorded were Hymenopterans (*A. dorsata*, *A. florea*, *Vespa* spp., ants, *Xylocopa* spp.), Lepidopteran (*Pieris* spp., *Colotis* spp., *Danus* spp. *Eurema* spp. *Cephora* spp., *Ixias* spp.) and Diptera (Syrphids). Flowering was observed in second fortnight of February in *Prosopis cineraria*. Insect pollinators recorded during blooming period were Hymenopterans (*A. dorsata*, *A. florea*, *Vespa* spp., Halictids, megachilids, *Trigona* sp. ants *Xylocopa* spp., *Vespa* spp.), Diptera (Syrphids), Lepidopteran (*Pieris* spp., *Colotis* spp., *Eurema* spp.).

The foraging insects were found maximum between 10.00h to 12.00h. There was a sudden decline in the number of insect visiting the flowers from 12.00h to 14.00h. However foraging activity increased again around 16.00h.

Project will be beneficial in finding out role of insect pollinators in fruit/pod production of Khejri, Kair and Kumat.

Distribution patterns and food plant resources of butterflies along altitudinal gradients in Western Himalayan Sub-Alpine Forests (HFRI)

The Present study carried out during 2013-16 provided an array of butterfly diversity of Sub-alpine forests of Himachal Pradesh. A total of 70 butterfly species belonging to 48 genera, 16 subfamilies representing all 5 families were identified. Identified species belong to Hesperridae (3 species, 3 genera), Papilionidae (5 species, 3 genera), Pieridae (15 species, 9 genera), Lycaenidae (14 species, 10 genera) and Nymphalidae (33 species, 23 genera). Maximum numbers of the species were collected from Chanshal (Rohru). One hundred six (106) new host/food plant species of butterflies were identified. Fifty two species of butterflies were recorded for the first time from sub alpine forests of Himachal Pradesh and Geo-referencing and GIS mapping was accomplished.



Dark Clouded Yellow / *Colias Fieldii* (Menetries)

Risk Assessment of *Lantana camara* (Lantana) using spatial distribution modelling approach in Latehar district (IFP)

The project aims at generation of probability distribution map of *Lantana camara* (Lantana) in the Latehar district. The project is of three years duration and at the end of first year of the project, components wise progress of the main activity is as under:

- Acquisition and processing of satellite data from open source. The base data preparation activity including acquisition of Landsat TM/ETM data for the year October 2000, 2010 and 2014 from USGS site has been downloaded and its geo-referencing is validated with

reference to SOI topo sheet at 1:50,000 scale. This data will be used for preparation LULC map of the study area. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) dataset has been downloaded and subsequently aspect, slope and elevation map of the study area has been created. The WorldClim data of 30 arc-seconds resolution with a spatial resolution of about 1 km² of Zone 28 has been downloaded and subsequently map for the 19 bioclimatic variables with reference to study area has been created.

- Further, processing of imageries, in Quantum GIS, preparation of continuous input data for different geo-statistical models will be carried out in second year. Multi co-linearity test among the bioclimatic

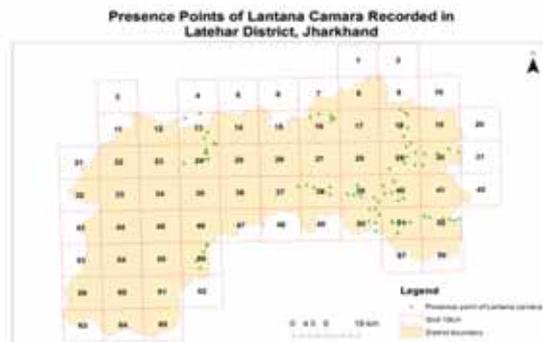


and geographical variables will be carried out in open source statistical software 'R' using Pearson Correlation Coefficient.

Field survey for ground data collection of Lantana and its associate species (IFP)

- First phase of field survey in randomly selected 13 grids (6 quadrates of size 1m x 1m in each grid) out of total 65 grids (10km x 10km) has been done in Latehar districts and occurrence data for *lanata camara* and associated species is recorded.

- Further, all these processed spatial data and attribute data collected through field survey will be used as input data for the model running under MAXENT, GARP and Bioclim environment and for generation of probability distribution map of *Lantana camara* (Lantana) during the second year of study.
- Field survey for data collection will continue in second year of the project for further collection of data on occurrence of *Lantana camara* (Lantana) and its associated forestry tree species as well as data for the LULC validation.



Presence points collected in Latehar



Distribution of *Lantana camara* in Latehar

Documentation of insect fauna and flora of mangrove ecosystems in Odisha (TFRI)

Studies on flora and insect fauna of mangrove ecosystems of Bhitarkanika and Dangmal Forest Block of Kanika Forest

Range and West Orasahi Forest Block of Rajnagar Forest Range, Bhitarkanika National Park (Odisha) were conducted for documentation of flora and insect fauna. Six species of true mangroves, two species of mangrove associates and one species of back mangrove were documented from the



Rhizophora stylosa (Rai)



Cerbera odollam (Panamas)



Strychnos nux-vomica



Xylocarpus mekongensis

*Danaus melanippus**Hypolimnas bolina**Papilio polytes**Tirumala limniace*

study area. *Strychnos nux-vomica* L. (Nux-vomica) (Family Loganiaceae) is a new record in Bhitarkanika mangrove forests. Twenty one (21) species of butterflies, seven species of moths, three species of dragon flies, one species of damsel fly, honey bee, ant, grasshopper and stick insect

were documented. *Hibiscus tiliaceus* L. (Bania) (Family Malvaceae) – recorded as a new host plant for leaf roller, *Sylepta derogata* Fabricius (Lepidoptera: Pyralidae). This project will lead to information on mangrove species and insect fauna existing in Bhitarkanika National Park, Odisha.

2.1.4 Forest Botany

Documentation and conservation strategies of rare, endangered and threatened species (FRI)

Population status of rare and threatened species such as *Ilex pseudo-odorata*, *Sophora mollis* (Peeli Sakina), *Pittosporum eriocarpum* (English: Doon Cheesewood, Hindi : Agani) *Indoptadenia oudhensis* (Hindi : Gainti), *Mahonia jaunsarensis*, *Itea nutans* (Hindi: Garkath), *Trachycarpus takil* (Hindi: Thakil Palm), *Incarvillea emodi* (Himalayan Incarvillea), *Catamixis baccharoides* (Baccharis Catamixis) and *Cythea spinosa* (Kabra) was carried out. Belt transect method was used for the quantification of species. It was observed that population of these species is very less and regeneration is poor. Efforts were made for ex-situ conservation of these species. Seed and stem cutting of above species were collected and planted in polybags in the Botanical Garden for ex-situ conservation.

The institute provided treatments and advisory for protection of trees at Bodhgaya (Bihar), Jyotisar (Haryana) and Rashtrapati Bhavan, New Delhi. Two training programmes on conservation

of rare and threatened plants under the project were organized at Regional Research Centre at Khirsu (Pauri Garhwal) for Forest staff, students, villagers etc.

Digitization of Herbarium (Dehradun Herbarium) (FRI)

The voluminous task of digitizing invaluable herbarium specimens of DD Herbarium of FRI Dehradun was initiated in year 2008. First phase has now been completed with digitization of one specimen per species. Some of the significant achievements of the project are (i) all the type specimens digitized with labeled data and documented in "Digital Herbarium specimen database" of FRI, (ii) total number of families in "Digital herbarium specimen database" is 200 in accordance with Bentham and Hooker system of classification, (iii) total number of recorded genera in "Digital Herbarium specimen database" is 5,089 in accordance with "Genera Plantarum" and later described genera (iv) total recorded number of species in "Digital Herbarium specimen database" is 33,987 and (v) total number of specimens in "Digital Herbarium specimen database" is 55,915.



Catamixis baccharoides

Incarvillea emodi

Trachycarpus takil

Some rare and endangered plant species of Uttarakhand taken up for inventorization, characterization and conservation strategies

Digital Herbarium System

Search Result

Species found

Ranunculaceae >> Aconitum >> Aconitum heterophyllum Wall

Sub Species	-	Variety	-
Synonym	Aconitum atees Royle	Common Name	Indian Atees
Altitude	2400-4500 m	Flower Color	Blue
Habit	Herb	English/Trade Name	Azonite
Vernacular /Local Name	Ativisa	Habitat	Alpine meadows, riverbeds
Distribution	Himalayan region of India, Pakistan and Nepal	No. of Specimen	78



E-page of 'Digital Herbarium specimen database

2.1.5 Tribals and Traditional Knowledge System

Study on indigenous knowledge and documentation of extent of utilization of herbs in folk-medicines prevalent in tribal pockets of Madhya Pradesh (TFRI)

The study was conducted to document folk-medicines prevalent in tribal pockets of Chhatarpur, Panna, Satna, Jabalpur, Seoni, Chhindwada and Hoshangabad districts of Madhya Pradesh. The information was recorded from 116 Vaidyarajs on various plant parts and their formulations in cure of various ailments. Plant parts such as roots, rhizomes,

tubers, stem, leaves, fruits and seeds utilized in folk medicines in tribal areas were documented. The distribution was documented in different clusters on herbs, shrubs, climbers and trees, which were found to be threatened, vulnerable and overexploited for their uses in pharmacy, indigenous use and periodical collection for export from forest areas. Market survey was conducted to study the fluctuations in prices over a period of time. This project will provide indigenous knowledge on use of medicinal plants by tribal of Madhya Pradesh.



2.2 Forest Productivity

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	4	10	12
Externally Aided	1	15	2
Total	5	25	14

2.2.1 Silviculture

Impact of Assisted Natural Regeneration of *Shorea robusta* (Sal) – in Shiwalik Circle of Uttarakhand" (FRI)

The ANR compartments were administered with basic silvicultural operations during the inception of ANR, however, to accelerate the regeneration potential, further silvicultural operations are required. Light ground thinning is required by removal of shrubs, weeds and inferior trees/saplings in some of the ranges. Light thinning should be carried out when the saplings reach at the diameter class of 5-10 cm. Such type of thinning is required in Timli, Langa, Chorpur and Asarori ranges for proper and sound development of silviculturally available trees of sal. It is also advisable to provide 60-70% of shade to the seedlings below 5 cm of diameter. In case of woody stage, the canopy is to be opened in such a way that dominates left were spaced 12-15m apart. In areas where regeneration has reached the established stage, the top canopy has to be opened further. It is necessary to provide nursing or nurse crop for retention of light crowned miscellaneous species of Sal regeneration. Removal of mature and over mature trees along with the shrub cutting in the moist Sal will definitely enhance regeneration particularly the seedlings, as they cannot tolerate competition in the early phase of life. So to reduce the competition moderate shrub cutting is advisable.

Study on Impact of Ban on Green Felling on Biophysical status of forests in context to production prescribed in Working Plans vis-a-vis actual production from the chir forests of Uttarakhand in terms of Supreme Court's order (FRI)

Uttarakhand Forest Development Corporation entrusted above project to FRI for study of ban on green felling in chirpine forests in terms of Supreme Court Order. The data on past and present production of chir from chir working circles of Uttarakhand was collected from the working plans

of Uttarakhand. Data on crop growth was collected from the sample plots of chir. The data were submitted to UKFDC in the inception report. The field data on different parameters like biophysical conditions, growth, regeneration, ecology, litter, soil etc. are being collected from felled and un-felled coupes of chir working circles of Uttarakhand. The data is being analysed.

Propagation of *Santalum album* (sandalwood) in Punjab (IWST)

Demonstration plots of *Santalum album* (Sandalwood) were established in one ha each at Mohali, Roper, Mathewada (Ludhiana) and two ha in Bhatoli (Hoshiarpur) in Punjab. Modern nursery was established at Bhatoli (Hoshiarpur) for raising 50,000 Sandalwood quality planting stock annually. Training was imparted to the farmers and forest officials on Sandalwood seed handling, nursery and plantation management. A technical bulletin on Sandalwood prospects in Punjab was prepared for Punjab Forest Department.



Sandalwood nursery established in Bhatoli, Hoshiarpur with IWST technical support



Distribution, assessment and growth of *Santalum album* L. (Sandalwood) in Karnataka (IWST)

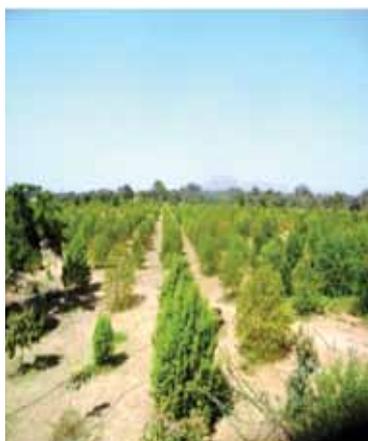
Eleven forest divisions and thirteen ranges in Karnataka having *Santalum album* L. (Sandalwood) population under Karnataka Forest Department were identified. Thangli Sandal Reserve (47 ha area) under Kadur Forest Range (Chikamagalur division), excellent growth of Sandalwood (about 1300 plants/ha) has been observed. The growth rate was 13.68 % to 274.17 % in Sandalwood plantations. Stem wood varied from 49.78 Kg/ha (3 years plantation) to 13178.20 Kg/ha (19 years plantation). Benefit cost ratio (B:C) was 1.93 % and Internal Rate of Returns (IRR) 29 % showed better results when Sandalwood cultivated in combination with redgram and citrus compared to Sandalwood alone having showing B:C ratio of 2.58 % and IRR 26 %.

Evaluation of existing plantations, establishment of agro forestry trials and capacity building to promote *Santalum album* (Sandalwood) cultivation in Gujarat and Rajasthan (AFRI)

This project was started in January 2017 under 15-points programme of ICFRE. The objective of the project was to evaluate the existing plantation of *Santalum album* (Sandalwood) established in Gujarat to identify best cultural practices and to develop and demonstrate best plantation model for the farmers. Survey was conducted in different agro climatic zones of Gujarat to get information about various

Santalum album (Sandalwood) plantations established by farmers. In Central Gujarat, climate is semi-arid to dry sub humid with an average rainfall of 1000-1500 mm annually. Shri Nitin Bhai Patel of Kheda village Anand used *Casurina equisetifolia* (Casurina) plants as host with spacing of 4 m x 4 m host with host at 0.45 cm distance. 1250 plants of Sandal were plated in 2014 with drip irrigation. Height and girth of the plants were 4-4.5 meter and 25-30 cm, respectively. At Nanu bhai's Farm in Anand district, 550 Sandal seedlings were planted in year 2011 with *Moringa oleifera* (Senjana) as the host. The height ranged from 2-4 m and collar girth from 15-30 cm.

In North Gujarat, climate is arid to semi arid with an annual rainfall of 635-875 mm. In Kherva village, Mehsana at Tulsibhai Patel field, Citrus species were planted as host and spacing was 5 m x 3 m and 8 m x 3 m. Replacement of causality of host was done with *Alstonia seholaris* (Saptaparni) and Guava. Height of sandal wood plants was 3-4.5 m and collar diameter was 36-43 cm. In Satlasna taluka, 15 km from Kheralu in Mehsana district at Narendra Chavda's Farm, Sandal with different hosts were planted in 2013 at 6 m x 6 m spacing. In this farm, Sandal with pomegranate host attained height of 3-4 m and collar diameter of 15-24 cm. In another plot with *Citrus limetta* (mosambi) host sandal plant attained height of 2-3 m and collar diameter of 15 cm to 24 cm. In association with mango (variety kesar) sandal plants attained average height of 2 to 3 m and collar diameter of 18-25 cm.



(a) Sandal with *Mangifera indica*



(b) Sandal with *Casuarina equisetifolia*



(c) Sandal with *Citrus limettas*

Sandal with different host tree species

Bamboo propagation (IWST)

Demo plots of 4 species of *D. asper*, *B.balcooa*, *D.hamiltonii* and *B.tulda* (Bamboo) in 4 ha in Bhatoli and Talwara were established and a vegetative propagation center of bamboo was set up in Bhatoli (Hoshiarpur) for future propagation of bamboo in Punjab.



Bamboo nursery at IWST



Enhancing productivity of Clonal Seed Orchards (IWST)

Tectona grandis (Teak) clonal seed orchard (CSO) at Janganmatti, Dharwad, *Syzigium cuminii* (Jamun, Jumbul, Jambolan) and *Tamrindus indica* (Imli) CSO at Nallal and Gottipura in Hoskote range were selected. Experiments were laid out to induce flowering and fruit setting through various cultural operations such as girdling, shoot pruning, root pruning and branch girdling on low-flowering and non-flowering clones. It was found that stem girdling (3/4th inch) plus root pruning (50%) enhanced the flowering to an extent of 26.64%, 32.35% and 28.60% in case of *T. grandis* (Teak), *S. cumini* (Jamun, Jumbul, Jambolan) and *T. indica* (Imli) respectively.

Assessing the impact of pruning of *Diospyros melanoxylon* (Tendu) bushes on its yield, quality and natural regeneration of tree species in Maharashtra (TFRI)

The project was conceptualized to evaluate harvest practices for collection of tendu leaves with reference to

their sustainability, natural regeneration of tree species and quality of leaves in Gondia and Gadchiroli forest divisions of Maharashtra. Selected seven each of pruned and unpruned sites, laid out twenty one quadrats, marked each tendu bush falling in the quadrat and collected baseline information. Gall infested, diseased and defoliated tendu leaves were found more in unpruned sites while healthy leaves were found to an extent of 60.33% in pruned sites. Specific Leaf Area (SLA), considered as quality of leaves was found higher (7.52 mm²/mg) in pruned bushes compared to non-pruned bushes (6.39 mm²/mg). Available nutrients in the soil were found in low to medium range, while organic carbon was found in high range in the selected sites of Maharashtra. Gall attack on tendu leaves was caused by the insect *Trioza obsoleta* and leaf blight disease by *Pestalotia diospyri*. Conducted control fire experiment to examine its effect on the productivity and quality of tendu leaves at Koshamtondi site of Gondia division. The results of this project are of immense importance to Forest Department for better production of tendu leaves and to collect quality leaves.



Tagging tendu bushes with unique ID Number



Control fire experiment conducted at Koshamtondi

Determination of nursery requirements and initial planting performance of *Diploknema butyracea* (Roxb.) H. J. Lam (Cheura) and *Myrica esculenta* Buch. Ham. (Kaphal) under mid-hill conditions of Himachal Himalayas (HFRI)

Germination studies with various pre-sowing treatments on seeds collected from different seed sources of *Myrica esculenta* Buch. Ham. (Kaphal) were carried out during the previous three years. The per cent filled seeds varied from year to year and source to source.

The germinated seeds (2000 no.) transplanted in polybags were field planted at two locations (Model Nursery Baragaon, Shimla and Dharampur, Solan) and 50 per cent survival was recorded for 9 months old plantation. The efforts to raise kaphal through vegetative propagation did not produce results. The germination of *Diploknema butyracea* (Roxb.) H. J. Lam (Cheura) seed from Champawat district of Uttarakhand



Kaphal Outplanting in the field



Demonstration of Kaphal Production in nursery

during 2015 was 60 per cent with 50 per cent survival after 9 months. The Cheura plantation raised at Thakurdwara near Nalagarh in Himachal Pradesh showed initial survival but being frost sensitive and damage by porcupine 30 per cent survival has been recorded. A training programme on 'Mass Production of Kaphal Stock in the Nursery' for the benefit of local farmers was also organized.

2.2.2 Social Forestry, Agro-forestry/ Farm Forestry

Development of model of some important medicinal plants with *Melia dubia* (Malabar Neem) and *Emblia officinalis* (Amla) in degraded land of Punjab and Uttarakhand (FRI)

Melia dubia (Malabar Neem) and *Emblia officinalis* (Amla) are fast growing species and show a remarkable performance even in rainfed conditions. An experiment of both species in combination with medicinal plants like *Rauvolfia serpentina* (Sarpagandha) and *Withania somnifera* (Ashwagandha) was conducted in degraded lands at Naukragrath in Haridwar district of Uttarakhand and Handesra in Mohali (SAS Nagar) district of Punjab state. The geometry of plantation of both species was kept in Randomized Block Design with spacing of 6 x 4m and medicinal plants as understory crops were planted in blocks at 60 x 60 cm spacing along with seasonal agriculture crops like Masoor and Groundnut.

Economics of *Melia* and *Aonla* plantation with agricultural crops and medicinal plants, the estimated maximum B : C ratio in 8 years rotation were found to be (2.73) in promising model-2 (*Aonla*-*Sarpagandha*-*Masoor*) followed by model-1 (*Melia*-*Sarpagandha*-*Masoor*) (2.64), model-4 (*Aonla*-*Ashwagandha*-*Groundnut*-*Mustard*) (2.46) and model-3 (*Melia*-*Ashwagandha*-*Groundnut*-*Wheat*) (2.36) respectively. The estimated net returns were found to be from model-1 (Rs.12,53,714), model-2 (Rs. 13,24,640), model-3 (Rs.12,35,564) and model-4 (Rs.13,16,990) in 8 years rotation respectively. This *M. dubia* and *E. officinalis* based (Agri-Silvi-Medicinal) agroforestry system can suggested for improving the soil fertility and conserving soil moisture content thereby enhancing the soil productivity along with

growth of tree species and provide income generation to the farmers in short rotation from dry areas.

Evaluation of windbreaks for enhancing water use efficiency, crop productivity and climate change resilience in farmlands in semiarid regions of Tamil Nadu (IFGTB)

This project aims to evaluate efficacy of superior windbreak clones of *Casuarina junghuhniana*. (*Casuarina*) i) IFGTB-WBC-1, ii) IFGTB-WBC-2, iii) IFGTB-WBC-3, iv) IFGTB-WBC-4 and v) IFGTB-WBC-5 of IFGTB in windbreak agroforestry towards enhancing water use efficiency in agro-ecosystem of semiarid regions in Tamil Nadu. The project will also study the effect of windbreaks on productivity of agriculture crops. Ten windbreak clones were selected from germplasm assemblage in IFGTB for evaluation under this project. During this year, Two farm field trials with windbreak clones of IFGTB have been established in Coimbatore and another in Trichy district. Observation on growth and establishment is in progress.

Establishment of Small Bamboo Nursery (NABM funded ICFRE-BTSG Project) (IFGTB)

Successfully established a small bamboo nursery for production of planting stocks of important bamboo species for supply to farmers under National Agroforestry and Bamboo Mission funded project. Brought a new bamboo species *Thyrsostachys oliveri* (edible-seeded bamboo) to Tamil Nadu by receiving planting stocks from Nowagaon Bamboo Growers Society in Tripura. These planting stocks will be used for further multiplication and popularization among farmers in this region.



Under the project on “Productivity studies on commonly cultivated bamboo species in different agro climatic zones of Tamil Nadu” a database of around 653 bamboo growers, covering 32 districts of Tamil Nadu, containing details of their bamboo holdings was compiled and maintained. Details of bamboo growers was collected by contacting Forest Extension officers of Tamil Nadu Forest Department, Deputy Directors of Horticulture of Tamil Nadu Horticulture Department and the office bearers of Tamil Nadu Tree Growers Association of 32 districts in Tamil Nadu. Details of 716 bamboo plantations under management of Tamil Nadu Forest Department, including natural bamboo bearing areas was collected from Working Plans of 17 territorial divisions of Tamil Nadu, compiled & maintained.

Field surveys were carried out by visiting around 149 bamboo growers in Coimbatore, Tirupur, Erode, Salem, Dharmapuri, Karur, Virudhunagar, Madurai, Dindugal, Tirunelveli, Villupuram, Cuddalore, Thiruvannamalai, Thuthukodi, Nagapattinam, Namakkal, Theni, Thiruvavur, Trichy, Vellore, Pudukkottai and Kanyakumari districts of Tamil Nadu. Details on their socio economic profile along with information on bamboo growing stock viz., details of their landholdings, educational qualifications, extent of bamboo and extent of other crops cultivated along with source of bamboo planting stock, bamboo species planted etc has been compiled. This is the first baseline data on bamboo growers in Tamil Nadu and in another first, the productivity of bamboo plantations from an agro-forestry plantation in Tamil Nadu was also documented.

In the absence of standard methods to assess productivity from intensively cultivated clonal bamboo plantations in farmers fields, developed a methodology of dividing the plantations into blocks and collecting growth parameters from 10 clumps per block. Sampling intensity of 3% of bamboo clumps has been recommended for assessing productivity of clonal bamboo plantations in farmer’s fields.

Knowledge generated under the project were presented as “Overview of bamboo policy & schemes of Government of India” during the session on “Policy & Legal aspects in bamboo sector” and on “Experiences and key learnings of bamboo planting in Tamil Nadu under various schemes” during the session on “Raw material and strategies for enhancement” during the “National Seminar on Bamboo sector in India” organized by Uravu Indigenous Science and Technology Study Centre, Kalpetta, Kerala and Habitat Forum (INHAF), Pune, Maharashtra during 11 and 12 March 2017.

Empowering tribal communities through lac cultivation in Madhya Pradesh (TFRI)

Identified the major causes of low yield of lac crop on the traditional hosts existing in the farmer’s field. The technique for improvement of crop production was demonstrated.

Farmers are not aware how to maintain the lac crop during hot summer days. Demonstrations were conducted to keep the lac crop healthy during summer. Discussed marketing issue of lac and its processing with the Balaghat based lac merchant, who are ready to purchase the raw material from the farmers. Motivated and interacted with farmers who are hesitant to adopt lac cultivation on their lac host trees due to some religious superstition. The farmers who have adopted the system get additional income of Rs.72,200 with an input of Rs.35,150 per 100 trees of *Butea monosperma* (palash) within first year and second year onwards they will earn 92,940 net income. The lac cultivation was revived in the selected villages and established broodlac farm for the sustainable supply. This project will help tribal communities to get better economic returns through lac cultivation.

Study on the effects of tree on soil fertility and crop production in Rajasthan (AFRI)

Survey was conducted to study exiting agroforestry models in 21 districts of Rajasthan. Different agroforestry models on farmer’s land were studied in Nagaur, Sikar, Churu, Ganganagar, Bikaner, Barmer, Karauli and Dausa covering eight agroclimatic zones in kharif season. Improved as well as traditional agri-horti and agri-silvi models like grafted *Zizyphus mauritiana* (Ber), Kinnow mandarin, *Punica granatum* (Anar), *Mangifera indica* (Aam), and *Prosopis cineraria* (Khejri), *Acacia tortilis* (umbrella thorn), *A. nilotica* (Babool), *Ailanthus excels* (Mahanimb), *Azadirachta indica* (Neem) and *Dalbergia sissoo* (*Shisham*) were found integrated with agricultural crops. Crop yield recorded and soil samples were collected from exiting irrigated agroforestry systems in Ganganagar, Bikaner, Karauli and Dausa in Rabi season. Collected information on tree growth, crop production and cost of cultivation were tabulated and their analysis is under process. Collected soil samples were analysed for their physico-chemical characteristics. Most dominant agroforestry systems were *P. cineraria* (Khejri) based in arid region and *A. nilotica* (Babool) based in semi-arid region.

Establishment of demonstration plots of *Operculina turpethum* (Nisoth) and *Oroxylum indicum* (Sheonak) to know optimum spacing (IFP)

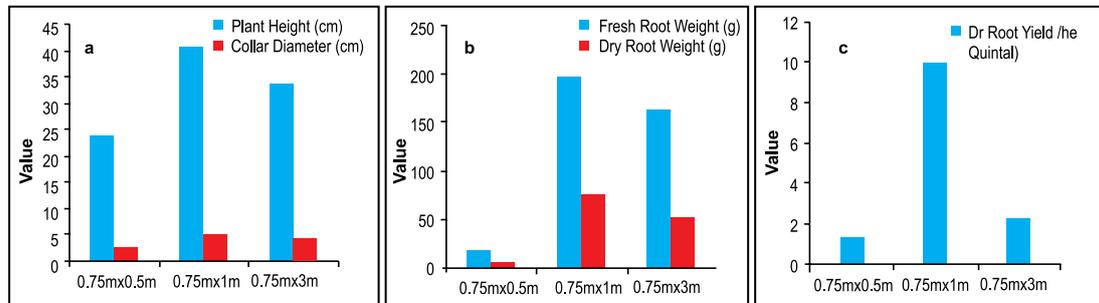
Oroxylum indicum (Sheonak) and *Operculina turpethum* (Nisoth) are very important medicinal plants used by pharmaceutical and ayurvedic companies in many formulations. Some of the preparations made by these two species are Trivritaadi ghrita, Dasamula, Abhyarishta, chandraprabha vati, Brahma Rasayana and Dantadyarista. Due to less availability of raw material from the forest, Dabur, India Ltd. was willing for commercial cultivation and high density plantations of these species, package of which was not standardized up to the date. By keeping in view the above problem the present project was funded by Dabur, India Ltd.



To get maximum yield per unit area for commercial purpose, high density spacing trial of both species was carried out and data was analyzed after nine month growth. Experiment was laid down using three different spacing with seven replications.

3 m using randomized block design with seven replications. The spacing 0.75 m x 1 m resulted in maximum values for all the growth parameters in *Oroxylum indicum* and yielded 10 quintals root dry weight per hectare. The spacing 0.75 m x 0.5 m showed the lowest values for these parameters.

Experimental trial was laid down using three different types of spacing, viz., 0.75 m x 0.5 m, 0.75 m x 1 m and 0.75 m x



Effect of spacing on growth performance of *Oroxylum indicum* (Sheonak): (a) Plant height and collar diameter, (b) Fresh and dry weight of root and (c) yield of dry root per hectare.

In case of *O. turpenthum* (Nisoth), 30 cm x 30 cm, 30 cm x 45 cm and 30 cm x 60 cm spacing did not influence growth parameters significantly. The minimum spacing 30 cm x 30 cm revealed maximum 20.2 quintal dry root yield per hectare.

Vegetative propagation procedure was standardized for *Operculia turpethum* (Nisoth) using three different types of shoot cutting thickness in the month of May, using in a randomized block design with seven replications and 25 cuttings per treatment per replication. The cutting thickness > 4mm produced significantly the highest plantlets.

Salient findings and recommendations of the project are as follow:

1. Spacing of 0.75 m x 1 m is recommended for commercial cultivation of *Oroxylum indicum* (Sheonak) and spacing 30 cm x 30 cm for *Operculia turpethum* (Nisoth).
2. Cutting with thickness more than 4 mm is recommended for *Operculia turpethum* (Nisoth) as a vegetative propagation method for large scale cultivation.
3. By observing growth performance of both species, the environment of Chhota Nagpur Plateau is found suitable for commercial cultivation of both the species.



Field demonstration of *Oroxylum indicum* (Sheonak) (a) and its roots (b) and *Operculia turpethum* (Nisoth) (c) and its roots (d).



Intensive organic farming system based on Paddy+Bach *Acorus calamus* (Bach) trees and fish in Agroforestry system (IFB)

A pilot project on Paddy+Bach + (RET) species (Babul + Sandal or babul + red sanders), *Sesbania grandiflora*

(Gaach-munga) system with fish as an Intensive organic farming system was developed and established initially in 20 acres and spread it over to 50 acres in the current year with the assistance from Telangana State Medicinal Plant Board (TSMPB).

2.2.3 Forest Soils & Land Reclamation

Effect of altitude and season on soil microbiology and biochemistry (FRI)

Sites were selected at different altitudes viz. < 500m, 1000 m and > 1500 m at Tehri Garhwal, Dehradun and Pauri Garhwal district of Uttarakhand. Soil samples were collected from Pine, Deodar, Sal, Oak and miscellaneous forest at different altitudes in winter season. Soil Samples were collected in summer and rainy seasons from Bhogpur, Itarna, Cantonment Board forest Chakrata, Charba, Saklana Range, Kotdwara Panyali range, Gumkhal, Fatehpur, Lansdowne. The samples were analyzed for soil pH, Organic carbon, available Nitrogen, Phosphorus Potassium. Soil bacteria were isolated and MPN were determined in soil samples following standard method. Dehydrogenase and Phosphomonoesterase i.e., acid and alkaline phosphatase activity were also measured. Some of the isolated bacteria were put to various cultural and biochemical test for identification purpose. Studies on soil enzyme activities will also be conducted which would endow information on the biochemical processes occurring in soil.

Assessment of soil organic carbon under different land uses in Tamil Nadu (IFGTB)

Soil samples (120 nos.) were collected from the reserve forests of the North-Eastern zone and Cauvery-delta zones. Soil samples (72 Nos.) from Kalathur, Madukkur, Irugur and Kondal soil series were collected from different land uses viz., agriculture, agro-forestry and plantation in the Cauvery delta zone for estimation of carbon stock. Soil samples collected at four depths of 0-30, 30-50, 50-80 and 80-100 cm were analyzed to estimate the carbon content. The per cent of coarse fragments (>2 mm size) was calculated for each layer based on visual observation of the area occupied by coarse fragments. The samples were fractionated into three aggregate size classes viz., macroaggregates (250-2000 μ m), microaggregates (53-250 μ m) and silt and clay sized fraction (<53 μ m) and carbon was estimated in each fraction. Soil organic carbon storage was found to be highest under forest land use, followed by agro-forestry and plantation and the clay + silt sized fraction (<53 μ m) retained the highest amount of organic carbon at 0-30 cm soil depth in the Cauvery delta agro-climatic zone. Most suitable land use for enhancing



Soil sample collection in Thorn forest



Soil profile for assessing carbon

storage of soil organic carbon was identified and best management practices was identified.

Studies on soil profile attributes under Forest and Jhum land areas of some selected sites of Nagaland (RFRI)

A total of 70 soil profiles were studied under 8 land uses covering 5 forest types i.e Subtropical semi evergreen forest, Tropical wet evergreen forest, Montane wet temperate forest, Subtropical pine forest, Tropical moist deciduous forest. Significant differences were recorded for bulk density, pH, cation exchange capacity, available nitrogen and phosphorus, while no significant differences were observed for organic carbon and available potassium. Highest amount of carbon was found to be sequestered in the soils of Montane wet temperate forest type of Nagaland. Negative correlation was observed between species richness and availability of potassium.



Adaptation and mitigation measures in relation to shortening of jhum cycle vis-à-vis soil nutrient status and productivity in different traditional systems of Nagaland (RFRI)

Due to increasing population and decreasing land area the jhum cycle (number of years the land is used for crop cultivation and then left fallow until the next cropping) has been reduced from 15–25 years to 2–3 years resulting into low soil nutrients and crop productivity. It was observed that the indigenous knowledge of tribal communities have evolved to develop land use systems in Nagaland by adopting agroforestry and enriched fallow management systems such as alder based fallow management in Kohima, cultivation of nitrogen fixing legumes as cover crops during fallow period and subsequent crop cultivation in Kohima and Mokokchung. This traditional practice of fallow management under short jhum cycles can improve soil fertility and crop productivity. Further management of fallow land through these practices is

an adaptation strategy for decreasing land availability, reduces the felling of natural forest for jhumming and increasing soil fertility of jhum fields. However, less forest felling and burning reduces emission of carbon dioxide which can be linked to the climate change mitigation strategies. Combined with soil erosion control measures, these cropping systems improve soil fertility, crop productivity, help insure food security, improves income generation and sustain the natural biodiversity of the forests. As a part of microbial diversity estimation 14 pure cultures of plant growth promoting bacteria (PGPR) have been identified using 16S rRNA partial sequencing which are given below:

Enterobacter sp., *Pseudomonas koreensis*, *Arthrobacter sp.*, *Arthrobacter scleromae*, *Serratia sp.*, *Pseudomonas aeruginosa*, *Lelliottia amnigena*, *Pseudomonas fluorescens*, *Cupriavidus basilensis*, *Azospirillum lipoferum*, *Bacillus subtilis*, *Pseudomonas fluorescens*, and *Azospirillum oryzae*.



Pure cultures of bacteria isolated from jhum land soils of Nagaland

Enhancing fodder productivity through silvipastoral system on degraded land of India (AFRI)

Colophospermum mopane (mopane) : *Cenchrus ciliaris* (dhaman grass) Silvipastoral trial.

In Rajasthan large area (0.38 mha) suffers from problems of salinity and alkalinity; and its rehabilitation through bio-corrective measures is required to make effective use for providing agricultural sustainability and resilience against climate change. There are very few glycophytic plant species, which can perform on arid salty areas. Our research conducted on loamy sand saline alkali soil in hot arid part of Rajasthan, India during 2003–08 revealed that exotic glycophytic tree species *Colophospermum mopane* (mopane) proved to be ideal species maintaining high survival (89 %) and growth after five years of establishment; and it was the only species where roots penetrated the CaCO_3 nodulated kanker pan further enhancing its utility. Substantial site improvement, reduction in soil pH and electrical conductivity and improvement in organic carbon content was also observed during the study period. Despite of exotic, it did not suppress the growth of indigenous salt tolerant grasses mainly *Sporobolous diander*,

Chloris virgata (feather fingergrass) and *Dactyloctenium scindicum*, *D. aegyptium* (crowfoot grass) but their palatability is low. Hence, the investigation was undertaken to introduce on salt tolerant but highly palatable grass species *Cenchrus ciliaris* and evaluate its growth and yield with other grasses in the inter row spaces with *C. mopane* available at a spacing of 3 X 4 m. There were six blocks of 9 plants in three replications. Thus there were 18 blocks of 9 trees between which soil was raised as mound of 3'x4'x25 cm size- referred as soil structure. Seed sowing of *C. ciliaris* CAZRI 75 was done on soil slope in inter-row spaces of *C. mopane* in 2013. Seed sowing was done at 30 cm distance in the lines 40 cm apart from each other on soil structures. Green grass yield for *C. ciliaris* was measured by laying quadrates of 1x1 m randomly on soil structures; while for other grasses quadrates were laid out in vicinity of trees in the experimental area.

Growth and yield data of various grasses with *C. mopane* revealed that maximum green fodder yield was obtained in *S. diander* (471–720g/m²) while the minimum in *Brachiaria ramosa* (Browntop millet) (130–205 g/m²). The most significant finding is the fact that *C. ciliaris* CAZRI 75 (highly palatable grass) could established on soil slope in



the inter row spaces of *C. mopane* plantation to convert it into a silvipastoral system. Generally, *C. ciliaris* does not grow and establish on salt affected soils. The Growth of *C. ciliaris* was in the medium range (130- 208 g/m²) as compared to performance of other grasses (less palatable). *Cyperus* sp. is a sedge (cyperaceae) and very highly palatable.

The grass growth and yield parameters of various grass species in the area are given below as :-

Sporobolus diander (ht65-130 cm, 17.3-30.0 clumps/m² & green yield (471-720g/m²), ash 18.0%

Chloris virgata (ht35-80 cm, 17-22 clumps/m² & green yield 244-270 g m² ash 20.3%

Dactyloctenium scindicum (ht40.4-80.1 cm, 17.3-20.3 clumps/m² green yield 185-450 g/m² ash 17.8%

D. aegyptium (ht22-50 cm, clumps 15-17/m² & green yield 170- 210 g/m² ash 18.5%

Brachiaria ramosa(ht43.4-98.4 cm, clumps 7.3-10.3/m² & green yield 130- 205 g/m² ash 7.5%

Cenchrus ciliaris(ht52.1-109.6 cm, clumps 6.7-10.3/m² & green yield 130- 208 g/m² ash 8.0%

Cyperus sp. (20-70 cm, 5.7- 13clumps/m² & green yield 200-250 g/m² ash 6.50%

The palatability range is *C. ciliaris* > *Brachiaria ramosa* > *Dactyloctenium scindicum* > *D. aegyptium* > *Sporobolus diander* > *Chloris virgata*.



Cenchrus ciliaris 75 with *Colophospermum mopane*



Other grasses with *Colophospermum mopane*

Grass growth and yield

Tree growth in the year 2016 the annual incremental growth in *C. mopane* was 8.35 % (Height) and 7.41% for crown diameter in trees with grass treatment which is higher as compared to growth in control trees (increment of 7.3% in height and 8.64% in crown diameter). Same trend was observed in the year 2014-15 indicating the better moisture availability even with grasses

The second trial was on succulent halophytic shrub *Suaeda nudiflora* (Unt morad) with agriculture crop.



Suaeda nudiflora under waterlogged condition

Suaeda nudiflora (Unt morad), a member of family Chenopodiaceae, is an evergreen highly salt tolerant shrub with numerous slender, erect branches, endemic to coastal regions around the world. In India and Pakistan, the foliage of *S. nudiflora* (Unt morad) has been used traditionally as a vegetable and forage/fodder especially for camels. It is found on mud flats along sea coast or in saline soils in Bharoach, Cambay, north Gujarat (Kharaghoda), Saurashtra and Kutch region of Gujarat state.

Suaeda nudiflora (Unt morad): *Pennisetum typhoides* (Pear millet, Bajra) trial

S. nudiflora seedlings planted in August 2013 at a spacing of 4m x 5 m on double ridge mounds were established well. However due to very hot summer in 2016 there was some casualties and the mean percent survival in October 2016 (64.5%) after 34 months compared to 70.3% in Oct 2015.

Due to good monsoon rains, plants attained significant growth. Mean height increment was 30.5 % over mean height (190.52 to 146.5 cm), 16.9% for in crown diameter (149.0 to 128.0cm) and 137% in the mean collar diameter (71.52 to 48.12 mm) registering 484.4% increase over October 15 values.



Bajara emergence in the inter row slopes



Bajara crop in the inter row slopes

In the year 2016 Bajra variety HHB-67 (IMP) was sown on 14 July 2016 in the inter row slopes between *S. nudiflora*. Very good germination was observed after 5-7 days. It rained after two weeks (43.3 mm) on 30.7.16 and very heavily on 8-9 August 2016 (206 mm) which resulted in water logging in many lanes affecting the survival of Bajara crop. Bajra survived the water logging in few lanes showing its potential to grow on improved salty soil.

Vegetation status of the area was evaluated on the plant bunds in September 2016 showed the presence of 17 plant species were recorded which is equal to last year. Out of 17 species 10 were grasses two more than last year, *Aristida* did not appear even in this year.

Findings suggest that these silvipastoral systems could provide an alternative to improve pastoralism in the arid salt affected region, giving a greater buffer capacity and allowing for sustainable production even in critical years.



2.3 Genetic Improvement

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	9	31	21
Externally Aided	4	49	11
Total	13	80	32

2.3.1 Conservation of Forest Genetic Resources

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

With the objective of identifying stable and unique morphological characters in Teak, various natural populations in Tamil Nadu and Kerala were surveyed. The Seed Production Area (SPA) and Permanent Preservation Plot (PPP) in Kerala and Tamil Nadu were characterised. A large number of characters were observed in farmers' plantation in Tamil Nadu. The tree stem form, leaf, branching habits and reproductive characters were found to be discriminating characters. A draft report for DUS testing has been prepared. In case of *Melia dubia* (Malai Vembu), studies were conducted in Panampally, Karur, Nellore, Tirupati, Thithimathi, Hosekote, Annur and Chennai for developing DUS descriptors and DUS test guidelines. Variation in morphological characters in leaf, stem, bark and reproductive structures were studied. Studies were also conducted in clonal trials for quantifying the uniformity and stability of the selected morphological traits.

DUS centre for *Eucalyptus* (Safeda) and *Casuarina* (Jungli saru) (IFGTB)

The Germplasm banks of *Eucalyptus* at Forest Campus and Thuvankurichi were assessed for DUS characters. The example clones were identified for all the morphological characters for developing database of clones and DUS character matrix. In *Casuarina*, DUS Centre has assembled with around 100 clones of *Casuarina equisetifolia*, *C. junghuhniana* and their hybrids in Forest Campus, Coimbatore which constitute the example clones used for developing DUS testing guidelines for *Casuarina*. This reference germplasm collection is periodically maintained for expression of all characters mentioned as descriptors in the guidelines.

Characters are assessed annually in at least four trees of a clone for developing Clone vs DUS character matrix. A separate block of 25 trees for the clone IFGTB-CJ-9 has been established and being periodically assessed for which application for registration has been filed.

Conservation, improvement and bio-resource development of Sandalwood (IWST)

In Indian *Santalum album* L. (Sandalwood), core samples were collected from 31 populations spread across 14 states to study variability in heartwood formation in different age classes. Oil content ranged from 0.2 to 1.0 % in age class of 9-12yrs and maximum of 4 % oil content in 30 years old trees. Growth parameters like height, clear bole height and girth were recorded from *Santalum album* (Sandalwood) plantations at Hagalwadi, Hiriyyur, and Madhugiri in Karnataka. Average growth of trees in border rows was 4 cms higher compared to core trees in the block. In a 16 year old plantation in which trees were harvested, in 10 trees heartwood had not yet developed.

Studies on variation in reserpine content in some high yielding genotypes of *in vitro* and seedling raised *Rauvolfia serpentina* Benth (Sarpagandha) (TFRI)

Studies on variation in reserpine content in some high yielding genotypes of *in vitro* and seedling raised *Rauvolfia serpentina* Benth (Sarpagandha) was carried out. Five genotypes of *Rauvolfia serpentina* (Sarpagandha) were evaluated for their ability to respond under *in vitro* conditions and their regeneration procedure was standardized for economical yield. Among the genotypes tested, GO-MN genotype collected from Maina locality of Goa invariably emerged as the best genotype to produce maximum sprouting (84%), shoot number of 9.66 fold and 81% of rooting. Besides, GO-MN genotype



In vitro propagation and field trial of *Rauvolfia serpentina* plants, (a-b) Maximum shoot initiation and regeneration in GO-MN genotype, (c-d) maximum shoot number and rooting in GO-MN genotype and (e-f) hardening and field transfer of *in vitro* and seedling raised plants of *R. serpentina*

registered a maximum caulogenic response, organ formation and root development in leaflet explants. The variation in *in vitro* and seedling raised plantlets was evaluated in terms of root yield and reserpine content. The highest content of 0.1% of reserpine was obtained in OR-AG genotype raised

through *in vitro* procedure and reserpine content of 0.09% in seedling raised plants of this genotype. Similarly, highest root yield 26.61 g/plant was obtained in *in vitro* raised plantlets of GO-MN genotype as compared to the seedling raised plants (24.84g) of same genotype.

2.3.2 Tree Improvement

Selection of Superior Quality Germplasm of *Oroxylum indicum* (Shyonak) - an endangered species (FRI)

This study aims at preparing state wise availability of *Oroxylum indicum* (Shyonak) in Forest Areas of Uttarakhand, Uttar Pradesh, Haryana and Punjab for serving as baseline documentation for future conservation and potential utilization of *Oroxylum indicum* (Shyonak). Two states namely Uttarakhand, and Uttar Pradesh, have been surveyed so far. The study also involves documenting phytoassociates of the species and germplasm collection from different GPS location and their qualitative and quantitative analysis. Survey works in others selected state is continuing.

Availability of *Oroxylum indicum* (Shyonak) was assessed through surveys in Uttarakhand and Uttar Pradesh. Germplasm

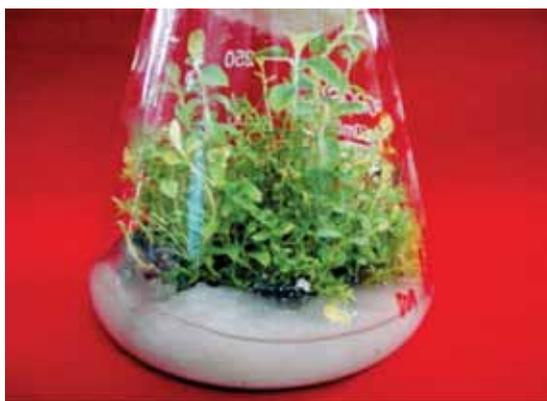
collection is being done from different GPS location. Distribution of select temperate medicinal plants has been examined and superior genotypes are being collected in Uttarakhand

Evaluation of recombinants from F₁ and F₂ generations of *Corymbia* (Syn. *Eucalyptus*) (FRI)

Ten recombinants of *Corymbia citrodora* Hook. (Lemon Gum) × *C. torelliana* were selected, classified on morphological basis and subjected to multiplication through micro and macro propagation. Initial rate of macro-propagation varied between 10% and 55%. For micropropagation, aseptic cultures were established in respect of seven recombinants viz. E2, E14, X2, X4, X8, X9 and X11.



Variation in leaf characteristics of recombinants from *Corymbia*



Aseptic culture of a recombinant from *Corymbia*

Germplasm assemblage and improvement of *Leucaena leucocephala* (subabul, soundal) for industrial biomass productivity (IFGTB)

Leucaena (subabul, soundal) is an important pulpwood species preferred by farmers for short harvest cycles and industries for high pulp yield. The existing germplasm of *Leucaena* was originally introduced for fodder production and hence has a shrubby tree form with high seed production. A new set of germplasm has been assembled from different locations within the country and from University of Hawaii, USA and deployed in multilocation testing. Assessment for growth, axis persistence and fecundity at two years age revealed that a few accessions from Hawaii possessing faster growth, longer axis persistence and lower seed production compared to the local germplasm. Ten outstanding individuals from the selected germplasm accessions were selected for clonal propagation and field testing. Clones that fulfill the selection criteria of high pulpwood production with low seed production will be released for commercial planting and also involved as parents for production of hybrid progeny.



Variation in growth and form among *Leucaena* accessions compared to local (right)

Genetic improvement of *Casuarina* (Savukku, Jungli Saru, Jaun, Katradi) for growth and pulp yield through intra and intespecific hybridization (IFGTB)

As part of the long term breeding programme for *Casuarina* (Savukku, Jungli Saru, Jaun, Katradi), hybridization between *Casuarina equisetifolia* and *C. junghuhniana* has been carried out to develop hybrid clones with fast growth and high pulp yield. The parent clones were selected from the second generation breeding population based on their superiority for the desired characters. Two clonal tests were established with the parent clones which will also serve as hybridization orchards once the trees start flowering. A min-potted orchard was also established with selected parents and control pollination experiments were conducted taking advantage of early flowering in reproductively matured shoots. Seeds harvested from control pollinated fruits will be raised to produce hybrid progeny which will be deployed in multilocation field tests to select hybrid trees with fast growth and high pulp yield. Putative hybrid clones were also selected from breeding populations for clonal propagation and testing.



Casuarina trial at Chellanchery, Cuddalore District, Tamil Nadu



Selection and Multi-location Testing of *Gmelina arborea* (Gamhar) Clones for Growth, Form and Wood Traits (IFGTB)

Survey conducted in different parts of Tamil Nadu and Kerala and selected 70 Candidate Plus Trees (CPT) of *Gmelina arborea* (Gamhar) based on growth superiority, clear bole and pest and disease resistance. The CPTs were marked with GPS. The data on bio-metric, phenology and reproductive characters have been recorded from selected CPTs. Established vegetative multiplication garden with 51 clones. Outstanding progenies were selected at Neyveli progeny trail and trees were felled for coppice shoot production. Established clonal trail with 25 clones planted in a spacing of 5 x 5 m. The field trials were established in randomized block design with 4 replications and 3 ramets per replication had been maintained at Lingamalai, Trichirapalli, Tamil Nadu. The clonal trails will help in selecting superior clones of *G. arborea* for commercial cultivation and also serve as base genetic resource for future tree improvement programme.



Clonal plantation of *Gmelina arborea* at Lingamalai, Trichi (Tamil Nadu)

Rapid improvement of *Casuarina* (jungle saru) and *Leucaena* (subabul) to enhance pulpwood production from farm forestry plantations (IFGTB)

This project is implemented through collaboration between Indian Paper Manufacturers Association and IFGTB. Provenance trials of *Casuarina equisetifolia* (jungle saru) and seed source trials of *Leucaena leucocephala* (subabul) were established with 5 major paper industries (IP-APPM, Andhra Pradesh, BILT, Maharashtra, JK Paper, Odisha, WCPM, Karnataka and TNPL, Tamil Nadu). Data received from the industries were analysed and submitted the interim report to the funding agency.

Screening of International Germplasm of *Casuarina equisetifolia* (jungle saru) for Enhancing Productivity and Rural Livelihood in Tamil Nadu (IFGTB)

Data recorded at six months age from two field trials of *Casuarina equisetifolia* (jungle saru) were analysed and

submitted the report on results obtained to the funding agency. Provenance 18586 China ranked first with reference to height growth and it was found to be at par with 11 other provenances. Provenances 17577 PNG, 18144 Kenya, 18160 Malaysia, 18134 Kenya, 18267 China and 18122 Egypt also recorded superior values. Provenance 18135 Kenya was at the bottom.

Selection and vegetative propagation of superior clones of *Pterocarpus santalinus* L. (Red Sanders) for mass multiplication and large scale planting (IFGTB)

Fifteen trees were selected for their superiority in terms of growth and tree form were selected at two locations viz., Maramalai Nagar in Tamil Nadu (plantation) and Tirupati, Andhra Pradesh (natural population). At Maramalai Nagar 4 trees were selected and 11 trees from Tirupati were selected using check tree and point grading method. Branch cuttings were vegetatively multiplied through rooting of cuttings and explants collected for micro propagation through tissue culture. Wood core samples were collected using increment borer and wood density, heartwood and sap wood content were determined for selected trees. Leaf samples were collected from all the selected trees and DNA was isolated. 40 ISSR markers were used for screening for polymorphism. As the number of amplicons generated with these primers is low, further screening will be taken up. The work is in progress on optimizing the polymorphic banding pattern of other primers and thereby scoring and constructing a phylogenetic tree and development of fingerprints specific for the germplasm assembled.



Heartwood determination using Increment borer in Red Sanders plantation at Malanthur (Tamil Nadu)

Induction of early flowering in *Eucalyptus* (IFGTB)

Grafting offers a cost effective solution for early flowering so that desired crossings could be carried out at lower heights. Five grafts each of 5 clones produced earlier were grounded and were maintained at the vegetative propagation complex. Another, 190 grafts of 18 clones of *Eucalyptus* was produced. The grafts are under the healing process and were maintained. Planting stock of different targeted clones is being produced in phases.



Evaluation of genetic resources of *Melia dubia* (Malabar Neem, Malai veppu) (IFGTB)

The Institute has established and is managing about 12 ha area of provenance resource stands, progeny trials, seed orchards and evaluation trials to develop new high-yielding clones /seeds of *Melia* (Malabar Neem, Malai veppu). Pest and disease problems of the species in nursery and natural plantations were recorded and control measures are being developed. Germplasm from different regions is being tested as multilocation trials. A VMG has been established at IFGTB from which clones are being vegetatively propagated for clonal trials. Four clonal trials were established in Tirupathy, Dharwad, Chennai and Trichy. A Field Gene Bank of *Melia dubia* is being maintained in the Vegetative Propagation Complex.

Production of multi-parent populations of eucalypts for salinity tolerance (IFGTB)

Eucalyptus clones with salinity tolerance ability were identified to generate multiple intercrosses to combine volume production and salt tolerance after appropriate field tests. Superior performing clones of eucalypts were induced to flower early by grafting method to facilitate intercross generation.

Screening water stress tolerant clones of Eucalypts (IFGTB)

Under this project, an infrastructure was up-graded to conduct phenomics studies for water stress response of *Eucalyptus* clones. Equipments including water potential meter, chlorophyll content meter and tensiometers were procured for the study and the protocol for imposition of water stress was optimized. A total of 88 clones from the first and second generation *Eucalyptus* breeding program were coppiced for vegetative propagation and stress tolerance studies.

Selection of clones of *Acacia auriculiformis* (Australian babul, Bengali babul, Katti savakku and Pencil maram) with desirable stem form and wood properties for short rotation timber production (IFGTB)

Three clonal trials of *Acacia auriculiformis* (Australian babul, Bengali babul, Katti savakku and Pencil maram) established

during 2014 were evaluated for growth and form traits. Ten out of 63 clones were found to perform better in terms of growth and form. One clone (Clone No. 27) was found to perform better than seedlings and the benchmark clone (MPM hybrid clones) in terms of early growth in all locations. The selected clones have been proposed for release through the variety releasing procedure of ICFRE. Mass multiplication of the selected clones has been taken up for promoting their deployment for pulpwood and timber production.

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

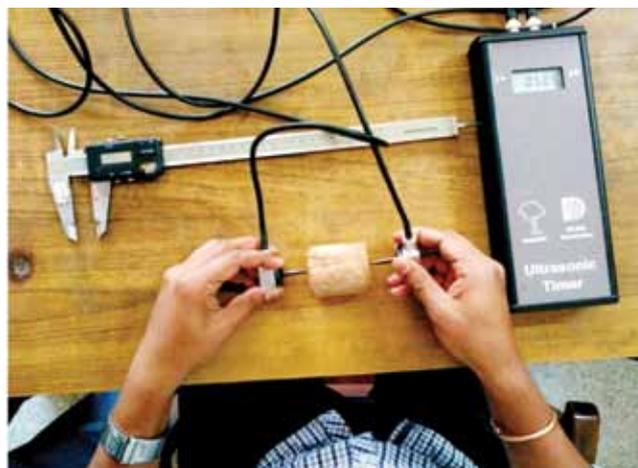
The First generation (FG) breeding populations were evaluated for their growth performance and best performing trees were identified and seeds were collected from 150 plus trees. Seedlots from 50 families of Thailand origin were also collected as infusion population. The seedlots of Thailand populations have been raised for establishment of preliminary adoptability testing. The Second generation (SG) progeny trials established at Chennai, Karunya, Udumalpet, Nellore, Karikudi, Arimalam, Marakkanam, Coimbatore, Pudukottai, Thiyagadurgam and Kandiyyur were evaluated and selected 344 plus trees. The selected trees were felled and coppice shoots were collected from all the plus trees clonally propagated and assembled in an *in-situ* multiplication garden for subsequent multiplication and establishment of clonal trials.

Assessment of wood quality variability in tree species (IWST)

Natural variability in morphological and wood quality related traits was assessed using non-destructive tools in different aged plantations of *Melia dubia* (Malabar Neem, Malai veppu), Poplar and *Eucalyptus* Spp. at different locations in Punjab in order to identify superior trees based on wood traits. A plantation of *M. dubia* located in Bhainda Zoological Park was identified as the potential seed production area. Similarly, superior trees of *M. dubia* were identified based on growth, wood density and wood stiffness from 11-year-old plantation at Pallanpur Forest, Siswa range, Mohali; line



Wood samples



Testing of wood samples



plantations in Bir Sanour, Rajpura (Patiala), and Goniana Range (Bhatinda), which are generally used for seed collection. These trees can be selected as the base population for initiating tree improvement programme. These selection criteria can easily be adopted in tree improvement programme of the *Melia dubia* and other species.

Wood traits in validation population comprising of *Eucalyptus* hybrid (155 clones; 3 ramets per clone, total 1209 samples) from three locations were assessed. A significant variation in air dry density (range 511 kg/m³ to 778 kg/m³) and dynamic modulus of elasticity (ranging from 3.80 GPa to 15.05 GPa) was observed across the locations. Preliminary analysis suggests no significant correlation between wood density and acoustic velocity across the locations and possibilities of screws of superior clones.

Bamboo genetic evaluation, improvement and propagation (RFRI)

Sixteen superior clumps of four species of bamboo [2 from *Dendrocalamus hamiltonii* (Kako) and 3 *Bambusa nutans* (Mokal), 7 from *B. tulda* (Jati) and 4 from *B. balcooa* (Bholuka)] were selected from the gene bank and were used for propagation through culm and branch cuttings. Growth performances of cuttings were found satisfactory in *B. balcooa*, *B. nutans* and *D. hamiltonii*. However, in case of *B. tulda* performance is very poor. A rhizome bank of *Dendrocalamus hamiltonii*, *Bambusa balcooa*, *B. nutans* and *B. tulda* was established.

Studies on effect of introduction of honey bee on seed production of teak seed orchards (TFRI)

A stock culture of honey bee, *Apis mellifera* was maintained at TFRI, Jabalpur. The colonies of *A. mellifera* were introduced in Teak Seed Orchard (TSO) at Ghisi, Behrai and Seoni just before the flowering season in the locality. The experimental field was visited periodically and honey bee colonies were introduced. Total 800 trees were marked and observations on flowering and fruiting status were recorded. Seeds were collected during the months of February–March, and subjected to detailed qualitative and quantitative observations like seed weight and size. Seeds were collected and data on number of seeds, seed weight and size were recorded. Based on the fruiting status and number of seeds, the introduction of honey bees has positive impact on seed production. The findings of this project will be useful for better production of quality seeds of known genotypes and production of honey as an income generation activity.

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

Surveys were conducted in Palanpur, Deesa and Gandhinagar areas of Gujarat. Sixty six new CPTs were identified and marked. Data from unreplicated progeny trial at Deesa were collected and tabulated. Seeds of 51 individual CPTs were

collected and depulped. Seeds from individual clone from CSO at Deesa were also collected. Similarly, seed from individual tree of good families were also collected from progeny trial. Seeds from these collections were germinated in the nursery and seedlings were raised. 1650 seedlings from 20 CPTs and more than 2000 seedling of local provenance were provided to FRI, Dehradun for establishing genetic test trials. Seeds from individual trees of 33 families and 20 clones were also provided to FRI, Dehradun.

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

A. Survey and selection of plus trees and establishment of progeny trials of *Dalbergia latifolia* (Kala Shisham)

A progeny trial of *Dalbergia latifolia* (Kala Shisham), a vulnerable species was established at TFRI, Jabalpur. The progeny trial was established in Randomized Block Design in three replications. Nine plants per plot were planted at a spacing of 2m x 2m. Regular soil working and irrigation is being carried out. Plant height, collar diameter and survival % of plants was noted down after three months. The plants are growing well with 95% survival. Trees were selected and collection of half-sib seeds was carried out from two locations in Maharashtra. viz., from the seed plot located at Azra range, Kolhapur Forest Division and Allapalli range, Chandrapur Forest Division. The morphological data on total height, clear bole height, GBH, crown diameter, number of primary branches, status of flowering and fruiting was noted down. Physical parameters of pods, viz., pod length and number of seeds present were noted in 3 replications. 100 seed weight was noted down. This project will help in selection of superior trees and assemblage of germplasm of *D. latifolia*.

B. To refine existing micro-propagation protocols of *Dalbergia latifolia* for production of improved planting stock

A number of experiments were conducted for *in vitro* rooting of shoots of *Dalbergia latifolia* (Kala Shisham). In the first experiment various auxins viz., Indole Acetic Acid (IAA), Naphthyl Acetic Acid (NAA) and Indole Butyric Acid (IBA) and Coumarin in different concentrations (1, 2 and 4 mg l⁻¹) was tried for rooting on half strength MS medium. *In vitro* rooting was obtained on 2 mg l⁻¹ IBA supplemented medium. In the second experiment various strengths of MS medium were tested. Rooting was obtained on half strength MS medium. The third experiment was a pulse treatment experiment in which shoots were pulse treated on MS medium supplemented with 1mg l⁻¹ NAA and 1mg l⁻¹ IBA for 48 hours and 72 hours. Rooting was obtained in shoots which were pulse treated for 48 hours. *In vitro* shoot cultures were multiplied and maintained on MS medium supplemented with 0.5 μM BA. This project will help in refining the micro-propagation of this species.



Establishment of progeny trial of *Dalbergia latifolia* (Kala Shisham) at TFRI Jabalpur

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

Progeny trials of *Tecomella undulata* (Roheda) have been established at Jodhpur and Jhunjhunu districts of Rajasthan. Plantation maintained and growth data were collected. Preliminary data showed an average height of 1.08 m and collar diameter of 1.21 cm for progeny established at Jodhpur. The progeny of CPT No.36 from Pali district gave the best growth attaining the height of 1.59 m and collar diameter of 2.4 cm. At Jhunjhunu, average height was 42.5 cm and collar diameter was 0.48 cm. The progeny of CPT No.25 from Churu district gave the best growth where height was 75.5 cm and collar diameter was 0.78 cm. Leaf DNA samples collected from 40 CPTs and 120 individuals representing 12 populations of *Tecomella undulata* collected from Churu, Sikar, Nagaur, Bikaner, Pali, Jalore districts in Rajasthan for carrying out genetic diversity analysis. Total 50 ISSR primers were screened, out of which 25 primers resulted in distinct and reproducible bands. ISSR data were scored as presence (1) and absence (0) of bands. The data thus obtained in the form of binary matrix was analysed by UPGMA method of hierarchical clustering among different populations. Clustering pattern of CPTs showed two major clusters based on genetic diversity. These two major clusters were made up of five and four minor sub clusters. Clustering pattern of the population's showed one and seven minor sub clusters. Thus elements of geographical distinction were resolved through ISSR markers.

Selection & Screening of Superior and Insect-Pest Resistant Clones of *Salix* for their Cultivation and Conservation in the Cold Deserts of Himachal Pradesh and Jammu & Kashmir (HFRI)

Survey to identify the natural population of *Salix* in the Spiti part (Kaza, Kibber, Key, Shego, Lalung, Lari and Poh) of Distt. Lahaul and Spiti was carried out. As far as the Kinnaur part is concerned, areas to identify the natural population of *Salix* were scanned at Sumra, Hurling, Samdoh, Shalkhar, Chango and Nako.



Local flora with special reference to *Salix* was also studied



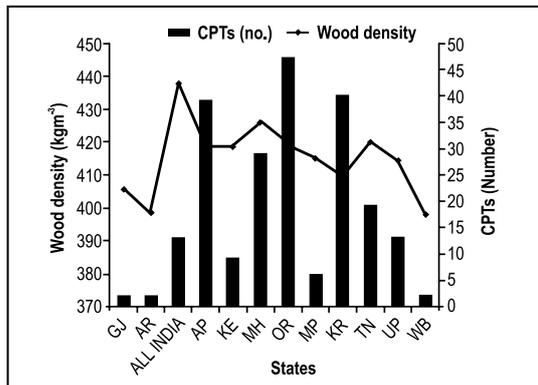
Assessment of genetic structure, linkage disequilibrium and marker-wood trait association in *Tectona grandis* L.f. (Teak) using molecular markers (TFRI & IFP)

Surveyed National Teak Germplasm Bank (NTGB), Chandrapur. Leaf samples from 217 Candidate Plus Trees (CPTs) of teak were collected and subjected to DNA extraction. Extracted genomic DNA was further subjected to purification using phenol chloroform extraction procedure. DNA quantification was carried out by Spectro-photometric method. Dilutions of the DNA samples (50ng/3ul) were prepared for PCR reactions. Samples of the extracted genomic DNA of 217 CPTs were provided to IFP, Ranchi. Total 52 microsatellite primers were screened with selected set of DNA samples and after critical perusal 28 primers were selected for final implication. Genotyping of 120 CPTs was carried out using 11 SSR primers. Pilodyn penetration value was recorded for 218 CPTs. This project will help is assessment of genetic structure, linkage disequilibrium and marker-wood trait association in CPTs of teak at NTGB, Chandrapur.

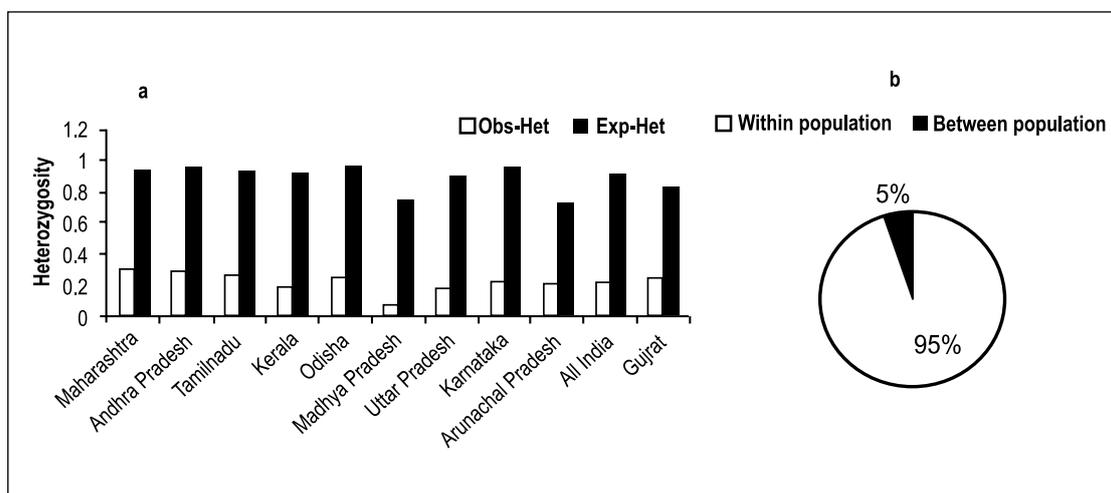
Screening of superior planting stock of *Tectona grandis* L.f. (teak) at seedling stage by DNA based methods is in progress. Twenty eight microsatellite primers and two key genes locus cinnamyl alcohol dehydrogenase (CAD), cinnamoyl Co-A reductase (CCR) and their transcription factors (MYB1 and MYB2) were used to characterized 216 teak candidate plus trees (CPTs) selected for superior wood density and maintained at National Germplasm Bank, Chandrapur, Maharashtra (collected from 11 states). The highest wood density was recorded in CPTs of Orissa and the lowest in CPTs of Arunachal Pradesh and West Bengal.

The microsatellite marker analysis reveals existence of ten population in the assembled teak CPTs. The CPTs from all states exhibited deficit in heterozygosity, i. e. difference between observed heterozygosity and expected heterozygosity and allocated, on the basis of AMOVA, the largest proportion of genetic diversity to within population and the least genetic diversity proportion between populations. The deficit in heterozygosity relates to selective felling of superior genotypes from the population for commercial exploitation. Further, the high proportion of genetic diversity within population indicates predominant outcrossing nature of species and gene flow across the populations. This also confirms the movement of teak germplasm by way of gene flow or anthropogenic activities.

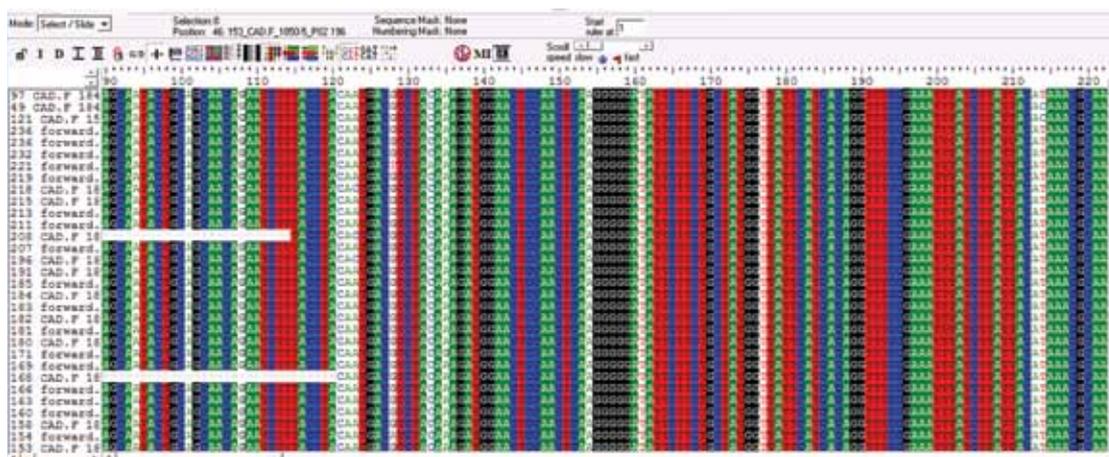
Discovery of variability (Indels and SNPs) in sequenced CAD, a key enzyme in lignin synthesis pathway, in teak has been done for the first time. Amplification and sequencing of a new teak gene with homologies to pectinesterase/ pectinesterase inhibitor 51 in other species has been achieved. The gene is responsible for synthesis and regulation of pectin in cell wall. The sequenced data of only CAD gene is available and approx 670bp long showing 95% sequence homology with the EST of CAD1 of teak. 100 sequenced data were aligned using clustalX and Bioedit. The variability (SNP) discovery is in progress in these sequences. The work on amplification, sequencing and



Variation in wood density and number of teak CPTs of different states maintained in NTGB, Chandrapur. GJ=Gujarat, AR=Arunachal Pradesh, All India =collection from non-teak growing states, KE= Kerala, MH=Maharashtra, OR= Orissa, MP=Madhya Pradesh, KR= Karnataka, TN=Tamil Nadu Up = Uttar Pradesh, WB=West Bengal.



Deficit in heterozygosity in CPTs across states (a) and genetic diversity partitioning within and between population (b).



Alignment of sequenced data of CAD of 100 teak CPTs using Bioedit software. The colors exhibit different domain of homology/ variability in the aligned teak CPTs.

SNP discovery on the other genes incorporated in the project proposal is in progress.

Identification and release of superior clones (IFP)

The Planting Material of 76 different half sib families have been collected from different places in country (42 from FRI, Dehradun, 18 from North Bengal, 6 from IWST Bangalore and 10 from IFGTB, Coimbatore). Different parameters of seed have been studied to evaluate genetic diversity and variances

among different family, seed length, seed width and 100 seed weight were studied. It was observed that the seeds from South Indian origin having larger seed size, seed weight while of seeds from north Bengal having smallest size and weight. Assessment of genetic diversity and stability in traits, multi-location through field trials was done by recording data at six month interval. The highest growth was recorded in Bihar in comparison to Jharkhand. The genetic diversity assessment by using SSR (Microsatellite) markers is under progress.

2.3.3 Vegetative Propagation

Commercial production of quality planting material of bamboo (FRI)

Aseptic cultures of superior genotypes were established and multiplied *in vitro*. Presently 400 culture bottles of BB-585, 250 culture bottles of BT-480, 150 culture bottles of *Bambusa nutans* (bamboo) are being maintained. Fresh cultures of *Dendrocalamus asper* (Giant bamboo) and *Bambusa tulda* (Bengal bamboo, Jati) are being developed. Micro-propagated plantlets (10-25 cm size) of selected clonal materials have been supplied to nursery for macro-proliferation:

Dendrocalamus asper (accession no. DAS 1) – 800

Bambusa tulda (accession no. BT-480): 1400

B. balcooa (accession no. BB-585): 2000

Cultures of accession no. *B. balcooa* 585 (40 bottles worth Rs 50,000) were sold to Devleela Biotech, Raipur Chhattisgarh for further multiplication.

At FRI, 114 m² area of tissue culture facility was upgraded. At RFRI Jorhat, existing tissue culture laboratory was revamped, upgraded along with increase in production capacity. Existing tissue culture laboratory at TFRI Jabalpur is also being upgraded.

Multiplication of Ringal

Vegetative propagation technologies were developed for *Arundinaria* spp. (hill bamboos or Ringal). The rooted propagules were separated through macroproliferation for out planting and supply to stakeholders. As a result of the project, the fast eroding ringal has been multiplied for establishment of nurseries at Mazra (Mussorie) and Devalsari (Jaunpur range) to meet the afforestation needs of the State Forest Department. Capacity building of artisans and villagers coupled with awareness programme will provide long term benefit towards conservation.



Development of tissue culture protocol

Vegetative material was collected from male and female trees of *Ginkgo biloba* (Bal kumari) from Nainital and F.R.I. campus. Surface sterilization of nodal and leaf explants was standardized. Optimal media formulations are being standardized. Different concentration and combinations of plant growth regulators and additives were standardized for shoot bud induction and callus formation. Green callus was induced in leaf as well as stem node. Efforts are being made to induce shoot buds in callus. Success has been achieved to initiate shoots from nodal explants. Stem cuttings were rooted using different concentrations of IBA, IAA and NAA.

Vegetative Multiplication of clones to be suggested to farmers and SFDs (IFGTB)

Clones developed by IFGTB were propagated vegetatively in the form of mini-cuttings harvested from juvenile stock plants maintained in a naturally ventilated green house. Such stock plants have the potential to produce higher amount of cuttings when compared to conventional stock plants grown in field. A pragmatic approach was developed to supply high yielding hybrids of *Casuarina equisetifolia*, *C. junghuhniana* and eucalypts clones to the farmers and forest development corporations. Propagules were made ready in 60cc root trainers and were lifted in vehicles with stands designed to carry large number of hycotrays.

Rooting and *in-vitro* propagation (IWST)

Studies were carried out to understand the effect of growth hormones (IBA, IAA and NAA) and their concentrations on sprouting and rooting for *Melia dubia* (Malabar Neem, Hebbevu), *Grevillea robusta* (Silver oak), *Anthocephalus chinensis* (Kadamba) and *Ailanthus excelsa* (Peethari). Rooting was observed in semi lignified brown cuttings treated with 1500 to 2500ppm IBA in all the species except *G. robusta*. Studies on effect of elevated CO₂ on growth revealed that 600ppm was optimum for growth of seedlings. Spacing and fertilizer trial for all the four species were established with survival of 60 to 80%.

In vitro propagation of *Bambusa balcooa* (Bamboo) and *Thyrostachys oliveri* was carried out using different explants. In nodal shoot segments, shoot multiplication was 85% and 83% and rooting was 85% and 10% in *B. balcooa* and *T. oliveri*, respectively. During hardening, survival was high in *B. balcooa* and was unsuccessful in *T. oliveri*. The plants obtained for *B. balcooa* have been planted in the field.

At RFRI, Jorhat *in vitro* propagation of *Vanda coerulea* (Vandaka), a rare and endangered species was regenerated through *in vitro* propagation. In another work more than 10 thousand plantlets of bamboo species were generated using micropropagation and macroproliferation techniques.



Micropropagated plants hardened in nursery and field planting

2.3.4 Biotechnology

Genetic diversity and adaptability through morphological and molecular markers in *Dalbergia sissoo* (Shisham) Roxb. (FRI)

Under the project, a series of germplasm has been collected and assembled in the gene bank. The existing clones have been coppiced and being propagated for multiplication so that trials could be established in the coming season.

The isolation of DNA for various clones / genotypes is being worked out and is in progress. Once the DNA for all the clones/ genotypes is isolated, genetic diversity for various clones / genotypes would be analyzed. The same is expected to assist in understanding the pattern of diversity of existing and newly introduced populations.



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

Bamboos are distinct and fascinating plants, with a wide range of values and uses. *D. hamiltonii* (Calcutta bamboo), is one of the priority bamboo species recommended by NBM for plantations in India due to their commercial and economical viability. The work was carried out to characterize of natural populations of *D. hamiltonii* (Calcutta bamboo), for its genetic diversity and genetic structure which will be helpful in designing effective conservation strategies, better management and efficient utilization of the species. Total 535 samples belonging to 19 populations have been collected across the range of distribution. Work of sample collection, DNA extraction and quantification has been completed for all the samples. Sixty eight microsatellite markers which have been developed previously in other bamboo species (Nayak & Rout, 2005 and Bhandawat *et al.*, 2014) were tested for cross amplification in *D. hamiltonii*. Annealing temperature was optimized through gradient PCR and positively amplified primers were further tested for polymorphism by subjecting them to PCR amplification in about 20 different samples and resolved in 4 % high resolution agarose (Sigma Aldrich) gel. Out of 68 primers 21 were found polymorphic and 17 used for genotyping of the samples through PCR. Amplified DNA fragments were resolved in 4 % high resolution agarose and scored as 0 (absent) and 1 (present) and arranged in binary matrix. Initial data analyzed and revealed low to moderate level of genetic diversity in natural populations of *D. hamiltonii*.

Biotechnological interventions for valorization of biomass waste residues into antioxidants (FRI)

Chemo-enzymatic extraction of the bark and spent leaves of *Eucalyptus* hybrid and spent biomass of *Cymbopogon citratus* (Lemon grass), *C. nardus* (Citronella grass) and *C. martini* (Palmarosa grass) was carried out. Inclusion of ligno-cellulosic enzymes in extraction medium resulted into enhanced recovery of antioxidant phenolics from these biomass residues.

Multiplication, Conservation and Promotion of Ringal cultivation for socio-economic upliftment of hilly rurals in Uttarakhand (FRI)

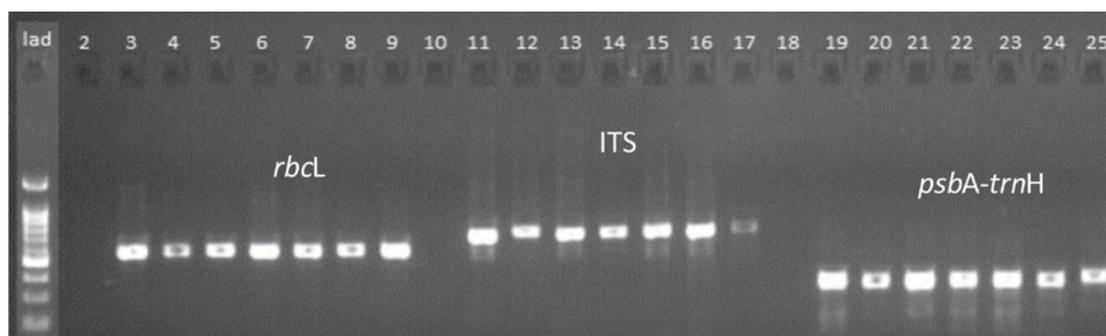
Developed technologies for vegetative propagation and for *in situ* conservation. The rooted propagules were separated through macroproliferation for out planting and dissemination. Fast eroding Ringal has been multiplied enormously for establishment of nurseries. One nursery has been established at Mazra (Mussorrie) and another at Devalsari (Jaunpur range). These nurseries are catering Forest department who are multiplying Ringal for afforestation. At the same time capacity building of artisans and villagers and awareness and education program for long term benefits of conservation were taken into account.

Development of candidate gene based DNA markers in *Eucalypts* for linkage and QTL mapping (IFGTB)

This project aims at developing high throughput markers for linkage and QTL mapping. A total of 766 genes expressed during wood formation were selected for exome sequencing. A total of 54182 probes of 120 bp length were designed for in-solution capture with 30X tilling. Target capture and exome sequencing was conducted in 32 *Eucalyptus* hybrid genotypes. Further, a computational pipeline was developed to document SSRs from short read length sequences generated from Illumina platform. The sequence data obtained from target capture and exome sequencing was mined for the presence of SSRs in *Eucalyptus* parents and hybrid progenies and 1112 SSRs were documented. A total of 349 potential polymorphic SSRs were recorded across parents and hybrids, which included 105 simple and 244 compound SSRs.

Barcoding in *Pterocarpus* species (IFGTB)

Pterocarpus santalinus (Red sanders, Sivappuchandanam), *P. marsupium* (Vengai, Malabar kino, Indian kino tree or vijayasar) and *P. indicus* (Malay paduak) are commercially important tree species exploited for its medicinal properties and timber. In order to develop DNA barcoding approaches in these species, the candidate barcoding genes viz, *rbcl*, ITS, *psbA-trnH* were sequenced and the average sequence length is ranged between 300 bp-800 bp.



Evaluation of *rbcl*, ITS and *psbA-trnH* candidate genes for DNA barcoding of *Pterocarpus marsupium*.



High density genetic linkage maps for QTL localization and validation for rooting ability and wood property traits in *Eucalyptus* (IFGTB)

In the first phase of the program, genetic linkage map was developed for *E. tereticornis* × *E. camaldulensis* and *E. grandis* × *E. tereticornis* using SSR, ISSR and SRAP markers. To increase the density of the linkage map for QTL localization efforts are undertaken to generate more number co-dominant markers such as SSR and SNP markers.

Phenotyping of wood property traits in inter-specific hybrids of *Eucalyptus* (IFGTB)

Under this project, the protocol for analysis of fibre morphology was optimized and the fibre analysis for length, width, cell wall thickness, perimeter and lumen diameter was determined in 70 inter-specific hybrids of Eucalypts. Additionally, protocol was optimized and validated for large – scale chemical analysis of total lignin content in wood samples.

Incorporating resistance in *Eucalyptus* to *Leptocybe invasa* through expression of insect specific dsRNA (IFGTB)

Leptocybe invasa is a major pest of *Eucalyptus* plantations. In an effort towards generating transgenic *Eucalyptus* that could tolerate the insect pest *Leptocybe invasa*, a chimeric multigene silencing construct was designed, synthesized and cloned into a plant transformation vector.

Isolation and Characterization of CCR gene in *Casuarina equisetifolia* (IFGTB)

Casuarina equisetifolia (Coast she-oak) is a major raw material for the paper and pulping industries. In order to isolate and characterize lignin biosynthesis genes like *CCR* (Cinnamoyl coA reductase), whole transcriptome sequencing of the wood tissues of *C. equisetifolia* clone CE-119 was carried out. The

Illumina-compatible sequencing library was constructed with fragment size ranging between 300 bp to 700 bp and the raw transcriptome data consisting of 87.53 % high quality reads with average read length of 150bp. Transcriptome sequence assembly yielded a total of 26985 transcripts with a total size of ~16.4 Mb.

Secondary metabolite production through hairy root cultures (IFGTB)

Development of protocols for hairy root culture for medicinal trees has been initiated for species where the root is the major constituent used. Four tree species, *Aegle marmelos* (Bael), *Oroxylum indicum* (Syonkha), *Gmelina arborea* (Ghamar) and *Premna integrifolia* (Agnimantha) have been selected. These species are maintained in the tissue culture laboratory. Optimized extraction parameters for enhanced yield of phenolics and flavonoids in the species through linear and interaction effects. Hairy root transformation in *Aegle marmelos*, *Oroxylum indicum* and *Gmelina arborea* is attempted.

In another study at IWST, Bengaluru protocol for DNA extraction from wood samples of three important timber species, *Dalbergia latifolia* (Rosewood), *Tectona grandis* (Teak) and *Lagerstoemia lanceolata* (Nandi) have been standardised. The technique is useful for developing DNA based techniques for wood identification and timber forensics applications.

Development of tissue culture protocols for important forestry species (TFRI)

For developing tissue culture protocols of commercially important species viz., *Buchanania lanzan* (Chironji), *Madhuca indica* (Mahua) and *Tamarindus indica* (Tamarind, Imli), experiments were being carried out to standardize sterilization treatment, nutrient medium and plant growth regulators for shoot multiplication with encouraging results.

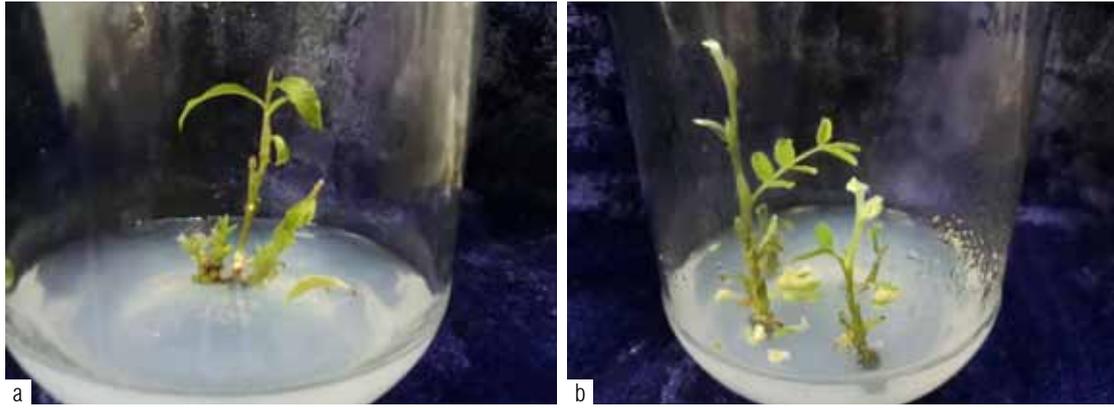


a



b

Nodal segment inoculated on MS medium supplemented with 3mg l⁻¹ BA (a) *Buchanania lanzan* (Chironji), (b) *Madhuca indica* (Mahua).



In vitro shoot multiplication in (a) *Buchanania lanzan* (Chironji), (b) *Tamarindus indica* (Tamarind).

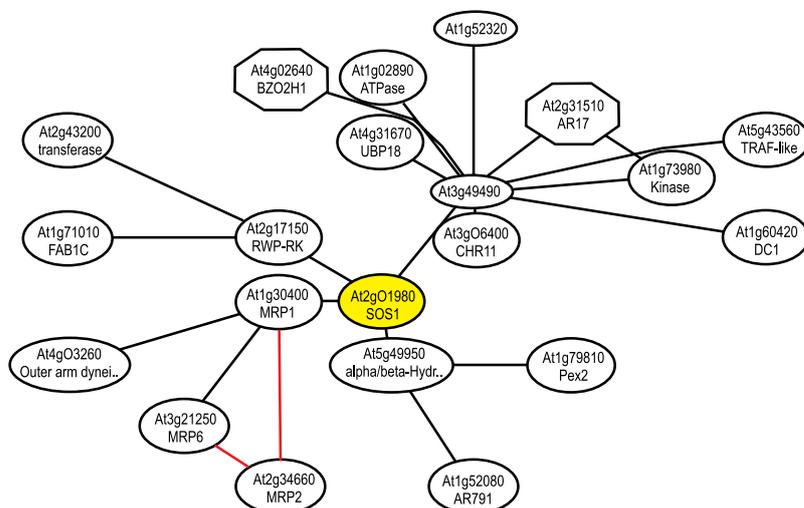
In silico identification of abiotic stress-tolerance candidate genes using co-expression network analysis and comparative genomics (AFRI)

High salinity, drought and extremes of temperature are a few of the most well-known abiotic stresses that result in loss of productivity and even mortality in plants. The efforts for Identification of genes (also known as, gene-mining / gene-fishing) that can impart abiotic stress tolerance has been slow paced. There is a big gap between the number of genes identified and sequenced to the number of genes with known functions. In tree species, this information is further highly deficient. Under the Plant Kingdom, trees are the most suitable candidates to explore for alternative gene variants (orthologs) of the known genes that may be responsible for higher capability for better adaptation and survival under environmental extremes. Trees grow and undergo climatic and seasonal cycles over and over again during their life cycle for many years. And thus have the best mechanisms for adaptability. Identifying such genes from trees can give impetus to the genetic improvement endeavors.

Bioinformatics (*in silico*) tools are being used under the current programme, to carry out new gene exploration and identification for abiotic-stress tolerance. High-quality gene

expression microarray data for model plant *Arabidopsis* is already available in public domain. This huge amount of experimentally validated data is being queried and processed through different bioinformatics and statistical tools and analyzed for identification of genes associated with abiotic stresses tolerance. The genes so identified are then being used to identify related genes in tree species like *Populus*. Though a herbaceous plant, *Arabidopsis* has been chosen as the primary species under this project because globally, maximum research has been done on it and thus maximum data is available in public domain. In trees, *Populus* is selected because its genome sequence data is available to enable orthologous-gene identification and new associated gene-mining.

So far under the project, a thorough and structured literature database scrutiny has been carried out using the 'PubMed' database of the National Center for Biotechnology Information (NCBI). Based on the search results, the genes implicated in plant's response to salt stress were selected. A list of 100 such genes of *Arabidopsis* has been finalized. Co-expression network analysis was conducted gene by gene using bioinformatics platform-ATTED-II. Based on this analysis, gene co-expression networks have been constructed. Figure



Gene co-expression network around *SOS1* gene: A sodium ion antiporter at plasma membrane is encoded by the *SOS1* gene which prevents sodium ion toxicity in plant under salt stress. The gene in the network is directly connected to 4 other genes. These thus have some pertinent role in abiotic stress tolerance, which will be further explored.



showcases one such gene co-expression network for a well-known gene *AtSOS1*, involved in plant's ability to manage salinity. Presently, a larger set of such associated genes is being prepared, for final identification of gene orthologs in *Populus*.

This effort will lead to the identification of matching gene orthologs in trees that should be functionally superior counterparts of the already known genes for abiotic stress tolerance (particularly salinity and drought tolerance). It will also enable identification of putative genes with unknown functions and assignment of probable functions to them, through bioinformatics analysis.

Clonal propagation, characterization and biochemical analysis of *Leptadenia reticulata* (Jivanti, Dodi, Dudi)– A threatened medicinal plant (AFRI)

Leptadenia reticulata is commonly known as Jivanti/Dodi/Dudi is a valuable threatened medicinal plant belonging to family Asclepiadaceae. This plant propagates naturally through seeds. However, very low seed setting and low germination rate of seeds has resulted in low natural regeneration potential. Hence, this plant has a threatened status. Development of technologies is being in progress in terms of selecting high yielding/superior genotypes, their mass multiplication and conservation. Plants of *Leptadenia reticulata* were selected from 3 sites at Manaii, Jodhpur & Barmer. Nodal segment were used as an explant and surface sterilized with 0.1% Mercuric chloride and inoculated on MS medium supplemented with different concentration of BAP. Bud break was achieved after one week of inoculation in the dark for initial 2-3 days followed by 16 h photoperiod. Best shoot proliferation was obtained on MS medium supplemented with 5.0 mg/l BAP. For *in vitro* shoot multiplication, cultures were transferred on Murashige and Skoog medium supplemented with Benzyleaminopurin and Kinetin. Experiments are ongoing for *in vitro* shoot multiplication. There is high scope of identifying superior genotypes having high contents of bioactive compounds which can be clonally multiplied and field tested.

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

Studies were conducted on development of macro-propagation and micro-propagation technologies for mass multiplication of selected superior trees of *Azadirachta indica* (Neem), *Dendrocalamus asper*, *Dendrocalamus hamiltonii* (Bamboo) and *Ailanthus excelsa* (Ardusa).

Macro-propagation of *Azadirachta indica* A. Juss

(Neem): Neem is an important multipurpose plant and is in demand for planting in every climatic condition. In the present case, vegetative propagation through hard wood, semi hard wood and mini-cuttings was found very promising method for multiplication of superior trees. Best rooting media and plant growth regulator in the process of vegetative propagation of hard wood, semi hard wood and mini-cuttings was developed. Among the different auxin used, IBA showed best results as compared to IAA & NAA. The formation of healthy plants after successful hardening showed that Neem could be successfully propagated by using hard wood, semi hard wood and mini cutting techniques in the nursery.

Micro-propagation of *Azadirachta indica* A. Juss

(Neem): Micro-propagation technique of *Azadirachta indica* through axillary bud was developed. Various physical and chemical conditions have been standardized for *in vitro* culture conditions using axillary buds (nodal segments) from mature (30 – 35 year) tree. Axillary bud break, *in vitro* shoot multiplication and *in vitro* rooting was developed. The protocol can be used for mass multiplication of superior trees of *Azadirachta indica* for quality plant propagation.

Micro-propagation of Bamboo and transfer of

technology: Over exploitation of resources due to population pressure and market demand has caused detrimental effects on Bamboo resources. To get a sustainable supply of such resources there is need to develop tissue culture methods for multiplication of bamboo species.

In vitro multiplication of three bamboo species has been taken up (*Dendrocalamus asper*, *D. hamiltonii* and *D. strictus*) through axillary bud proliferation. Nodal segments were pre-disinfected with a mixture of 0.2% bavistin and 0.1% streptomycin for 7-10 min, followed by surface sterilization with 0.1% HgCl₂ for 10-12 min. This gave maximum viable aseptic cultures. Amongst cytokinins tried, proliferated axillary shoots were obtained in liquid MS medium supplemented with BAP. MS medium supplemented with 10.0 μM BAP was proved to be optimum for *in vitro* shoot multiplication. *In vitro* raised shoots were cultured on auxin supplemented MS medium for *in vitro* rooting. This technology of bamboo multiplication was demonstrated and transferred to State forest Department laboratory at Gandhinagar successfully.

In ardusa attempts were made to develop tissue culture protocol through axillary bud induction and shoot proliferation but micropropagation technique could not be developed after so many experimentations.



2.4 Forest Management

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	1	2	-
Externally Aided	5	1	2
Total	6	3	2

2.4.1 Sustainable Forest Management (SFM)

Identification of the extent of forest lands in the forest fringe villages (Completed)-NRAA

National Rainfed Area Authority (NRAA) sponsored a study on "Identification of the extent of forest lands in the forest fringe villages" over 275 districts in 27 states and 1 Union Territory. The study focus ecological aspect as well as dependency of forest fringe villagers over forests located within 1 km distance from the fringe boundary.

North Zone: The total forest cover in North Zone States is 54,261 km², of which 44,603 km² happens to be the fringe forest. There are 40,040 villages in the North Zone, of which 25,462 were identified as forest fringe villages. The major crops are wheat, paddy, and maize. The average household size in the fringe village was from 5.50 to 6.26 persons, however the monthly income vary from Rs. 10,000 to 13,000. U.P. has lowest income (Rs. 3,253 per month). The annual fodder consumption is 48.659 Mt, of which 20.958 Mt is grazed and 27.701 Mt is stall-fed across the zone. The most utilized species for fodder are *Grewia optiva* (Bihul, Beul), *Quercus leucotrichophora* (Banjh), *Trifolium alexandrinum* (berseem clover), *Triticum aestivum* (residue) (Wheat), *Oryza sativa* (residue) (Asian rice) and *Cynodon dactylon* (Dhoob). Annual fuelwood consumption is highest in Uttarakhand fringe villages and lowest in U.P. The preferred species for fuelwood are *Pinus roxburghii* (Chir pine), *Grewia optiva* (Bihul, Beul), *Cedrus deodara* (Devdar), *Bauhinia variegata* (Kachnar), *Shorea robusta* (Sal), *Dalbergia sissoo* (Shisham), *Butea monosperma* (Palash), *Populus tremula* (Aspen), *Acacia nilotica* (Babul) and *Madhuca indica* (Mahua).

South Zone: The total forest cover in South Zone States is 1,32,451 km², of which 69,199 km² happens to be the fringe forest. There are 45,613 villages in South Zone, of which 15,581 were identified as forest fringe villages. Majority of

families are landless, except in A.P. and Telangana, where fringe families possess less than 1 ha land. Paddy, maize, sugarcane, millets, spices, cotton, tapioca, groundnut, coffee, rubber, and cashew are the major crops. The average fringe village household size and the monthly income vary from 3.99 to 4.69 persons and Rs. 5,000 to 21,000, respectively. The annual fodder consumption is 99.679 Mt, of which 85.671 Mt is grazed and 14.008 Mt is stall-fed across the Zone. Annual fuelwood consumption is highest in Karnataka fringe villages and lowest in A.&N.

East Zone: The total forest cover in the East Zone States is 91,720 km², of which 58,948 km² happens to be the fringe forest. There are 81,365 villages in the East Zone, of which 40,190 were identified as forest fringe villages. The average fringe village household size varies from 5.32 to 6.76 persons in fringe area. The monthly income was Rs. 6,000 to 8,000. Odisha has lowest income (Rs. 3,782 per month). The annual fodder consumption is 181.115 Mt, of which 154.216 Mt is grazed and 26.899 Mt is stall-fed across the Zone. Annual fuelwood consumption is highest in Odisha fringe villages and lowest in Bihar.

West Zone: The total forest cover in the West Zone States is 81,352 km², of which 52,932 km² happens to be the fringe forest. Highest plant diversity index of 3.35 was noticed in Rajasthan, followed by Gujarat (3.02). There are 55,419 villages in the West Zone, of which 22,199 were identified as forest fringe villages. The average fringe village household size and the monthly income vary from 5.06 to 5.47 persons and Rs. 4,000 to 5,000, respectively. The annual fodder consumption is 100.798 Mt, of which 78.865 Mt is grazed and 21.933 Mt is stall-fed across the Zone. Annual fuelwood consumption is highest in Maharashtra fringe villages and lowest in Gujarat.



Central Zone: The total forest cover in the Central Zone States is 1,33,374 km², of which 90,440 km² happens to be the fringe forest. There are 59,029 villages in the Central Zone, of which 25,460 were identified as forest fringe villages. Majority of families are landless in Chhattisgarh, while in M.P. fringe families possess less than 1 ha land. Paddy, wheat, and soybean are the major crops. The average fringe village household size and the monthly income vary from 5.53 to 5.56 persons and Rs. 3,000 to 6,000, respectively. The annual fodder consumption is 113.953 Mt, of which 94.028 Mt is grazed and 19.925 Mt is stall-fed across the Zone. Annual consumption of fuelwood is 64,24,842.33 and 44,99,161.04 t in the fringe villages of M.P. and Chhattisgarh, respectively.

North-East Zone: The total forest cover in North-East Zone States is 1,69,860 km², of which 69,957 km² happens to be the fringe forest. Highest plant diversity index of 4.50 was noticed in Manipur, followed by Meghalaya (4.04), Assam (3.98), and Tripura (3.65). There are 28,968 villages in the North-East Zone, of which 18,235 were identified as forest fringe villages. Paddy, maize, tea, oranges, banana, spices, and broom grass are the major crops. The average fringe village household size and the monthly income vary from 4.45 to 6.40 persons and 4,000 to 13,000, respectively. The annual fodder consumption is 4,50,73,488 t, of which 4,15,77,272 t is grazed and 34,96,216 t is stall-fed across the Zone. Annual fuelwood consumption is highest in Assam fringe villages and lowest in Mizoram.

In majority of the forest fringe villages, communities have high dependency on the forests for fodder, livestock grazing, fuelwood, and NWFPs. In spite of all tall claims by various agencies, the forests are still degrading (and also depleting) primarily due to over-exploitation, which needs to be reversed for sustainable forest management. Traditional agriculture including shifting cultivation, low crop productivity, monoculture, single cropping during kharif season, low percentage of skilled population, and high unemployment are the other characteristic features of the forest fringe villages in the study districts. Resorting to modern day diversified agriculture, horticulture, oliculture, floriculture, apiculture, organic farming, etc. are some of the viable options for raising the livelihood standards in the forest fringe villages. There is also need to impart training to local people on skill development for enhancing their employability, which would help them get better jobs as alternate livelihood options. Joint forest management through effective involvement of the forest fringe communities should be given top priority. These measures are also expected to reduce the pressure on the forests, and at the same time, restore forests and biodiversity significantly.

Monitoring and Evaluation of Greening Punjab Mission (GPM) and CAMPA plantations of Punjab Forest Deptt. for 2013-14 year (FRI)

The data indicates that both plantation schemes have significant importance for increasing green cover in the state.

The strategy and plantation techniques and sites selected for taking up plantation in majority of the cases were suitable for plantation. However, from the process efficiency perspective both the schemes had a major issue pertaining to inefficient funds flow during the implementation of activities with respect to plantations. The data reveals that about 64% of the plantation sites were classified as excellent to good in terms of survival. However there were about 10% sites which were classified as poor. Also there was no survival of plants in five sites.

Recommendations: The following recommendations were suggested to enhance the outcomes and outputs of the plantations.

1. *Adoption of silvicultural practices and genetically improved varieties:* Adoption of improvised silvicultural techniques and plantation of genetically improved tree may enhance crop productivity. Silvicultural practices and genetic selection are geared to increase the speed of tree growth and shortening rotation periods, which is imperative to achieve the goals and targets stated in the Punjab State Forest Policy.
2. *Research needs:* Research on plantation management, tree improvement, biodiversity, resource and related issues are most essential. Besides, considerable amount of research is available at regional and national level, which needs to be incorporated in the afforestation programmes.
3. *Biodiversity Assessment:* The plantations at this stage are too small for assessment of biodiversity, but as the plantations grow old, rapid assessment of biological richness in the plantation sites is required to understand the impact of plantation on biodiversity.
4. *Proper plantation inventory maintenance:* It has been observed that updated records in the plantation journals were not written. However, plantation maps were pasted in the journals. The current records in the journals will guide plantation managers in appropriate actions of protection, etc. Proper inventory of plantation activities is essential on all plantation sites to track issues, pitfalls and for course correction for enhancing outcomes.
5. *Capacity building and training of field staff:* The field staff needs to be trained with respect to the latest nursery and plantation techniques. Their capacity need to be enhanced on latest advancements in the field of plantation forestry. FRI, Dehradun can facilitate training to the frontline staff.
6. *Mapping of degraded forest:* The degraded lands affected by various land degradation drivers such as salinity, erosion, alkalinity, and water logging in the state should be mapped. Such degraded lands can be reclaimed and rehabilitated by taking up plantation activities.
7. *Location specific plantations:* There is a need to have stakeholders' consultation before selecting the plantation species so as to meet the local's desires and needs.



Assessment of livelihood support and NTFP dependence of rural women (FRI)

A study of socio-economy was carried out of 20 villages of Khirsu block, Pauri Garhwal. The villagers were highly dependent on agriculture, livestock and forest for their livelihood due to lack of employment opportunities. Occasionally, some earning comes from daily wages through MNREGA scheme and other such means. The annual average income was Rs.15.4 thousand. Few villages are able to grow various seasonal vegetables. Average livestock population was recorded to be 3.37 per family. Fodder for the livestock is extracted largely from adjoining forest that accounts 77.12% of

total fodder consumption per family. The average consumption of fodder was found to be 868.84 kg per household per month. Fuelwood occupies an important place in rural energy resource. The average fuelwood consumption was observed as 367.86 Kg per household per month and 2.83 kg per day per capita. Other alternate sources of energy used includes LPG (liquefied petroleum gas), kerosene and crop residues. These alternative sources are used occasionally like in rainy season when sufficient dried fuelwood is not available. Kerosene is mainly used for lighting lamps. Gradually kerosene lamps are being replaced by solar lamps in this region. Average amount of LPG and kerosene consumption was observed to be 6.71 Kg/HH/month and 2.96 L/HH/month respectively.

2.4.2 Forest Economics

Assessment of selected ecosystem services and their inter-linkage with human wellbeing in Dibru-Saikhowa Biosphere Reserve, Assam (RFRI)

Forest produces as provisioning services, carbon sequestration/storage as regulating service and recreation potential as cultural service was selected for the assessment. Survey was conducted in 12 villages selected around Dibru-Saikhowa National Park. Whole forest and non-forest area of biosphere reserve was surveyed to estimate the carbon

storage value. Tourists coming to visit the National Park were interviewed for the estimation of recreation value of the national park. It was observed that the forest villages are getting almost 80% part of their income from National Park by means of livestock grazing, fishing and forest products collection. Dependence of surrounding villages on the park is very low and only few families are dependent on national park for fishing and tourism occupation. National Park is having tremendous tourism potential and tourists coming to visit the park are increasing over the years.

2.4.3 Forest Biometrics

Development of Biomass Equations for important Tree Species of Meghalaya (RFRI)

Biomass equations for four species viz., *Michelia champaca* (Champa, Tita -sopa), *Duabanga grandiflora* (Ramdala, Dieng maloi), *Betula alnoides* (Silver birch) and *Toona ciliata* (Toon, Jati poma) were developed.

Presently more emphasis is being given to the non destructive methods of biomass and carbon stock estimation because they are less time consuming and cost effective than the harvest method. Therefore, species specific, regional and local volume equations give more accurate estimates of forest biomass and carbon as well as the merchantable timber wealth of a particular forest area. Forest and Environment Department, Govt. of Meghalaya felt the need of volume equations of some important tree species and suggested to develop equations for four ecologically as well as economically important tree

species of the state. Species and diameter class wise volume equations for each species are given.

Volume and biomass equations for *Betula alnoides* (Silver birch)

$V = 6.814 * d^2$ for Diameter class 10-30 cm
 $V = 6.272 * d^2$ for Diameter class 31-50 cm
 $V = 6.086 * d^2$ for Diameter class > 50 cm

Volume and biomass equations for *Duabanga grandiflora* (Ramdala, Dieng maloi)

$V = 4.926 * d^2$ for Diameter class 10-30 cm
 $V = 7.177 * d^2$ for Diameter class 31-50 cm
 $V = 7.889 * d^2$ for Diameter class > 50 cm

Volume and Biomass equations for *Magnolia champaca* (Champa)

$V = 6.120 * d^2$ for Diameter class 10-30 cm
 $V = 5.727 * d^2$ for Diameter class 31-50 cm
 $V = 6.535 * d^2$ for Diameter class > 50 cm



Volume and biomass equations for *Toona ciliata* (Toon, Jati poma)
 $V = 4.897 * d^2$ for Diameter class 10-30 cm

$V = 4.253 * d^2$ for Diameter class 31-50 cm
 $V = 6.591 * d^2$ for Diameter class > 50 cm

2.4.4 Policy and Legal Issues

Implication of legislation / deregulation policy (2001) on Sandalwood cultivation in Karnataka (IWST)

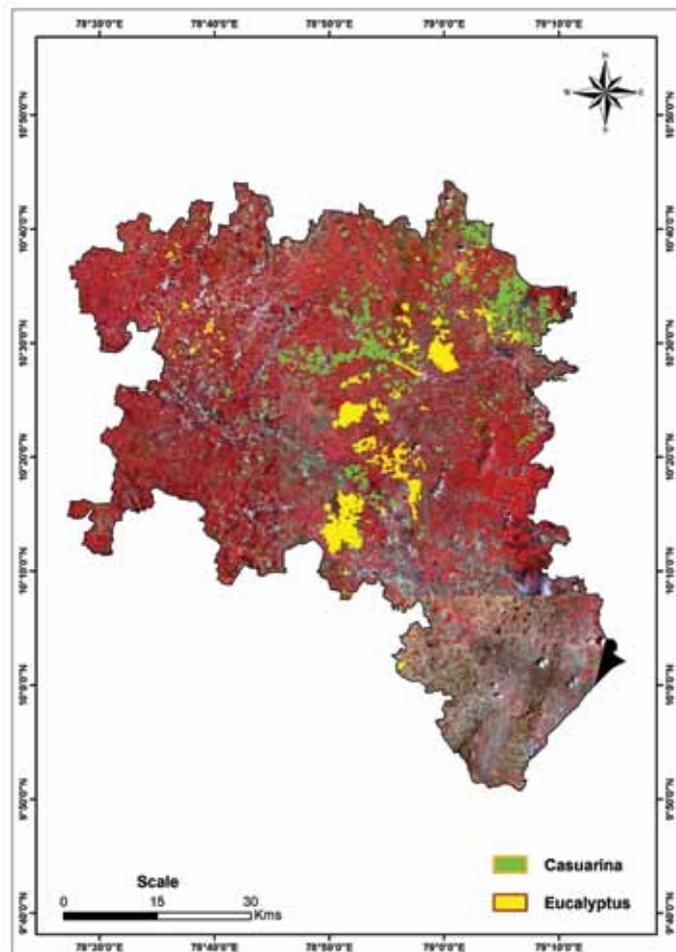
In order to understand the impact of Sandalwood deregulation policy, information from farmers of Kolar and Tumkur districts in Karnataka was collected through questionnaire. Preliminary

analysis of the data indicate that farmers are generally less aware about technical aspects of Sandalwood cultivation and harvesting procedures and there is no entry in the RTC (Rights, Tenancy and Crops grown) regarding the number of Sandalwood trees grown on the Farmer's Land. Further, Sandalwood related acts and rules are being analyzed.

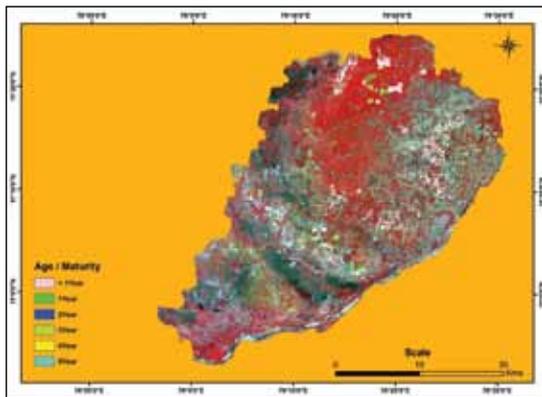
2.4.5 Information and Communication Technology (ICT)

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

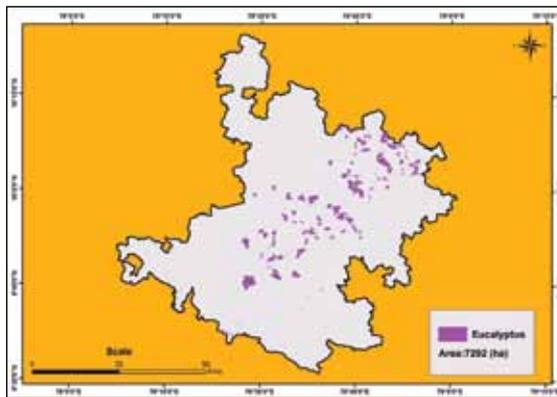
Spatial extent of Casuarina and Eucalyptus plantations in Ariyalur, Karur, Pudukkottai, Sivagangai, Cuddalore and Villupuram Districts of Tamilnadu was mapped using Remote sensing and GIS. The satellite images were pre-processed, geo-referenced and supervised classification was used to classify the satellite images into different landuse category. Plantation data collected during the field survey with the help of GPS was used for the creation of training pixels. Normalized Difference Vegetation Index (NDVI) was also computed for delineating the extent of plantation from other features. The accuracy of supervised classification was calculated and recode technique was used to reclassify the misclassified pixel with the help of Google Earth and field check. Further, an attempt was also made to delineate the extent of the plantations in Ariyalur District based on age/maturity of the plantations. The spatial extent of Eucalyptus plantations ranged from 103 to 28447 ha while Casuarina plantations extent ranged from 17 ha to 9921 ha. The study revealed that area under Eucalyptus plantations was highest (28447.98 ha) in Pudukkottai District followed by Ariyalur District with 12378.0 ha area. The area under Casuarina plantation was highest in Villupuram District (9921.20 ha) followed by Cuddalore District (3318.93 ha).



Extent of *Eucalyptus* and *Casuarina* plantations in Pudukkottai District, Tamil Nadu



Extent of *Eucalyptus* plantations based on age/maturity in Ariyalur District, Tamil Nadu



Extent of *Eucalyptus* plantations in Sivaganga District, Tamil Nadu

Database on Non-Timber Forest Produce (NTFP) in Karnataka (IWST)

Web database of Non Timber Forest Produce (NTFP) in Karnataka has been designed and developed and it has been hosted in a testing server for modifications. Further, NTFP data are being collected from different sources in Karnataka to update the database.

NTFP data are being collected from the Tribal Cooperative Marketing Development Federation of India Limited (TRIFED),

Agricultural Marketing Information Network (AGMARKNET), International Union for Conservation of Nature (IUCN), Convention on International Trade in Endangered Species (CITES), Directorate General of Foreign Trade (DGFT). NTFP market survey has been done at B.R. Hills, Hanur, Chammarajnar, Mysore, H. D. Kote, Hunsur, Bagalkot, Gokag, and Belgaum in Karnataka and information about NTFP collection details, market price and Large Scale Adivasi Multipurpose Society (LAMPS) related information has been collected. Residual data collection is under the progress from Internet, Library and local market survey.



2.5 Wood Products

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	3	6	13
Externally Aided	5	3	5
Total	8	9	18

2.5.1 Wood and other Lignocellulosic Composites

Natural fiber filled thermoplastic composites (WPC) (IWST)

Natural fiber reinforced polymer composites using variety of fibres (Lantana, wood, jute, and bamboo, coir, baggase etc) were prepared. The study established the suitability of these fibres for wood polymer composites. Specific formulations were developed to obtain injection moulded products and

profile extruded products with specific properties depending on the end applications.

To evaluate the durability weathering and biological resistance of wood polymer composites (WPC) is being evaluated at three different climatic regions of India (Jodhpur (Rajasthan), Palode (Kerala) and Nallal (Karnataka)).



Composite granules



Composite product (plate)

2.5.2 Wood Processing

Wood processing of *Melia dubia* (Malabar Neem) (FRI)

Untreated timber of *M. dubia* (Malabar Neem) is non-durable i.e. less than 5 years and on technical parameter is classified as class 'C' timber. The durability of the timber can be improved by treatment with preservatives. Field trials of *Melia dubia* (Malabar Neem) timber treated with chemical preservative formulations of CCA and Ziboc under

aboveground in open exterior conditions at three sites namely FRI, Dehradun, Chakrata and AFRI, Jodhpur showed that treated samples were normal while untreated control samples had moderate to bad effect.

Melia dubia (Malabar Neem) wood was found to have a composite rating factor (CRF) of 120.14 and ease factor (EF) of 93.1. The two indices when combined, yielded a working



quality index of the species as 102 which is very near to that of teak (100). It indicates that this species can be easily worked upon like teak suggesting its use where planning, sanding and shaping are of much importance.

Seasoning

- A latent heat based solar thermal storage system is being developed for a new design (double inclination) solar timber dryer. The solar thermal storage for the dryer will enable the kiln to dry timber in night also. A packed bed latent heat based solar thermal storage was designed and tested. The initial trials show that the thermal storage system has potential to enable solar kiln drying in night time also.

Studies on hard substratum fauna in five major ports on the East coast of India (IFB)

To study hard substratum fauna in five major ports, test panels collected at monthly intervals from five major ports, *i.e.*, Kolkata, Haldia, Paradeep, Chennai and Tuticorin. Observations were made on fouling aspects like percent cover of fowlers on the panel surface, species recruited during a particular month, intensity of fouling, biomass, etc. The test panels were preserved in neutral formalin for further observations. The panels were split open for observations on internal destruction by marine wood borers and the wood boring organisms collected and identified. The inventory of fouling forms at Tuticorin, Chennai, Paradeep, Kolkata and Haldia harbours revealed occurrence of 28, 13, 7, 3

and 5 species with fouling wet biomass of 5-370 g, 3-370 g, 3-42 g, 2-25 g and negligible weight and that of wood boring organisms 12, 11, 5, 7 and 5 taxa, respectively. Of the fouling characteristics, cumulative log number of species depicted slightly increasing trend while diversity and evenness exhibited inconsistency at Tuticorin; but these indices showed more of a consistency at Chennai; no discernable trend at Paradeep and stabilized trend at Kolkata and Haldia. Of the wood boring characteristics, cumulative log species richness, evenness and diversity profiles exhibited more or less smoothly transformed stable profiles at all the five ports.

Bioassay of plant extractives for antibacterial activity of marine biofilm isolates (IFB)

Efficacy of plant extractives for antibacterial activity against marine biofilm isolates was studied. Mother cultures from biofilms formed on marine wooden structures were harvested, subcultures developed and certain bacterial stains isolated. Extractives varying in quantity from 350 ml to 3500 ml from the herbaceous weeds *Ageratum conyzoides* (Goatweed), *Croton bonplandianum* (Kala Bhangra), *Lantana camara* (Lantana) and *Parthenium hysterophorus* (Gajar ghas) were prepared in acetone, benzene-alcohol and aqueous media. Bioassay of the acetone extractive of *A. conyzoides* (Goatweed) against antibacterial activity of *Streptococcus* spp., *Enterobacter* sp. and *Enterococcus* sp. revealed that the extractive was effective in inhibiting the growth of the candid isolates.

2.5.3 Value Addition and Utilization

Valorization of waste residues into antioxidants (FRI)

Chemo-enzymatic extraction of the bark and spent leaves of *Eucalyptus* hybrid and spent biomass of *Cymbopogon citratus* (Lemon grass), *C. nardus* (Citronella grass) and *C. martini* (Palmarosa grass) was carried out. Inclusion of ligno-cellulosic enzymes in extraction medium resulted in enhanced recovery of antioxidant phenolics from these biomass residues.

Liquefaction of Wood and value added products from the liquefied wood (IWST)

Optimization of liquefaction reaction on wood using three liquefying agents namely phenol, glycerol and polyethylene glycol was carried out. Liquefaction in phenol in the ratio 2:1 liquid ratio with 2 hours of reaction was found to be the most optimum condition to achieve satisfactory liquefaction. Liquefaction in cardanol resulted in about 78% liquefaction efficiency without the presence of phenol.

Microwave assisted liquefaction time could be reduced to 35 minutes from 120 minutes. Wood based adhesive was synthesized and the same was used as adhesive for preparation of plywood. The efficacy of the adhesive was evaluated in terms of water resistance, boiling water resistance, boiling water proof. The prepared adhesive was found to be effective in all three cases.

Natural durability of imported timbers (IWST)

Timbers are being imported in the country to meet domestic needs. Imported timbers were evaluated for natural durability in exterior condition which revealed that *Quercus robur* (English oak) was a durability class II (service between 5 to 10 yrs) timber and *Dryobalanops aromatica* (Camphor tree), *Tectona grandis* (Teak) (from five countries), *Shorea laevis* (Balau), *S. marcoptera*, *S. robusta* (Sal), *Pterocarpus soyauxii* (from two countries) and *Xylia dolabriformis* (Jambu) were performing as durability class I timbers.



Thermal modification of wood for value addition to plantation timbers (IWST)

To improve the utilization qualities of timbers heat treatment is given. Wooden planks of *Eucalypts* spp., *Melia dubia* (Malabar Neem), *Populus deltoides* (Poplar), *Leucena leucocephala* (Subabul) and *Casuarina eqisetifolia* (Casuarina) were heat treated at different temperatures and durations. Uniformity in colour was observed throughout the wood blocks. Modified

wood exhibited good dimensional stability and reduced equilibrium moisture content as compared to unmodified wood. Heat treated wooden panels as wall claddings were fixed at office of MOEF&CC, New Delhi and also at IWST, Bangalore for demonstration of modified wood. Heat treated wood may be used for different applications due to low EMC, higher dimensional stability and water resistance. A few furniture prototypes were developed for demonstration.



Subabul



Melia dubia



Eucalyptus

Products made from thermally modified wood

Microwave assisted chemical modification of wood (IWST)

A process of solvent free chemical modification of wood with acetic anhydride was developed. Modified wood showed good hydrophobicity, improved dimensional stability, and also reduced light induced colour changes at wood surfaces. Use of microwave heating reduced the reaction time significantly as compared to conventional heating. The results of this study will be helpful in upgrading the properties of low quality timbers for outdoor applications.

complex mixture of Copper sulphate, Potassium dichromate and *Prosopis juliflora* (Junglee kikar) bark extract which was prepared at the laboratory by using method prescribed by IWST Bangalore and was used at 2.5% dilution with water. After treatment, seasoning with standard method of wood was done at a wood based industry at Jodhpur and curved wood products were prepared. Coffee table (with chip carving) from *A. indica* (Neem) wood and photo frames with carving from *A. senegal* (Kumat) wood were prepared.

Once completed, the finding will be useful for wood and handicraft industry.

Studies on post harvest technologies of *Azadirachta indica* (Neem) and *Acacia senegal* (Kumat) as alternative timber species for handicraft industries (AFRI)

Sawn Wood of *Azadirachta indica* (Neem) and *A. senegal* (Kumat) was treated with Biflex Tc (industrial method) and a



Coffee table (with chip carving) from *A.indica* wood.



Photo frames with carving from *A. senegal* wood.

2.5.4 Pulp and paper

Chemo-enzymatic treatment of black liquor for bioethanol production (FRI)

Black liquor, from most of the agro waste paper mills, is rich in lignin and hemicelluloses. This hemicellulosic rich fraction is lost during the chemical recovery process. A detailed study has been carried out on hydrolytic behaviour of black liquor.

Conditions were optimized for acid hydrolysis and for lignin precipitation. Precipitated lignin and filtrate were analyzed for percent yield, total reducing sugar, dry matter content, and inorganic content. Based experimental results, protocol were developed to obtain maximum reducing sugar filtrate for alcohol production.



2.6 Non-wood and Forest Products (NWFPs)

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	9	8	10
Externally Aided	1	21	5
Total	10	29	15

2.6.1 Resource Development of NWFPs

Selection of superior quality germplasm of *Oroxylum indicum* (Shyonaka) an endangered species (FRI)

Oroxylum indicum commonly known as Shyonaka, is distributed throughout the country up to an altitude of 1200m. The roots of this plant are used in the manufacture of 'Dasmoolaristha' an Ayurvedic preparation used mainly as restorative tonic in women. The estimated demand of the roots of this species is above 100 MT annually.

Extensive field surveys were conducted in 18 Forest Divisions (both Garhwal & Kumaon region) of Uttarakhand between September, 2016 to February, 2017. A total of 74 locations were surveyed in whole Uttarakhand state and existing populations were observed/ documented at 50 sites/ locations. The maximum populations of the species were recorded between 250 to 750 masl elevations. Uttarkashi, Upper Yamuna, and Tons Forest division was recorded low density and scattered distribution found in others forest divisions.

Agar wood production in humid tropics of Karnataka (IWST)

Aquilaria malaccensis (Agar-wood) oil is an essential oil obtained by water and steam distillation of agar wood. It is used in luxury perfumery for application. The fragrance produced by the burning agar wood has been highly valued for thousands of years, and its use as incense for ceremonial purposes in Buddhism, Confucianism and Hinduism is widespread throughout eastern and southern Asia. The soil samples were collected from Karnataka and North-Eastern part of India and a total of 89 colonies of fungus were obtained. Fungal species which have been reported to induce agar wood in north-eastern part of India were selected and

40 pure cultures were isolated and grown and the colony characteristics similar to the earlier reported agarwood inducers were selected. Eleven cultures were inoculated in the field. Preliminary results suggest that trees inoculated with local strains of *Phaeocromonium* and *Fusarium* like pure cultures have resulted in initiating in agarwood induction.

Raising planting materials of selected Cane species and establishing plantations in fringe villages of Assam and Mizoram to sustain rural livelihood (RFRI)

Developed community nursery of rattan at Karbi-Anglong, RFRI, Jorhat and ARCBR, Aizawl and raised 10, 000 planting materials. Also carried out 10.0 ha enrichment plantation in fringe villages of Karbi-Anglong, Assam and Aizawl, Mizoram.

Productivity enhancement of *Capparis decidua* (Kair) to generate livelihood in rural area of 'Thar Desert (AFRI)

The field trials on yield of *Capparis decidua* (Kair) fruit were carried out in Gogelao Beed, Nagaur(site I) and Khari Khurd, Jodhpur(Site II). At Gogelao Beed, Nagaur the plants were divided into three block viz., Leaf compost (LCM), goat FYM (GM) and VAM with different combination of SSP, K, Zn and NPK fertilizers were applied during irrigation. Results indicated that maximum fruiting Percentage (80.2) were recorded in VAM block and followed by LCM block (75%) while the lowest Recorded in GM Block 62.5%.

In site II (Khari Khurd, Jodhpur) all plants were divided into two blocks viz., organic fertilizer and inorganic fertilizer were applied in different combination Result indicated that in LCM Block and GM block yielded 74.3 % and 60% fruiting percentage respectively.



Assessment of demand and supply of medicinal plants in India

'Study-cum-survey to assess the demand and supply of medicinal plants in India – in the national perspective, as well as in respect of the international market' was conducted under a project funded by National Medicinal Plants Board, Ministry of AYUSH, Government of India. The important findings of the study are summarised below:

- A comprehensive review and assessment of botanicals in foreign trade has resulted in drawing up of a consolidated inventory of 1622 botanicals correlated to 1178 plant species. This inventory includes the known plant species used as equivalents, substitutes, and adulterants of major botanical raw drugs whether or not specifically recorded in trade. The 1178 enlisted species belong to 781 genera spread over 177 families with Fabaceae, Asteraceae and Lamiaceae being the top three families in respect of medicinal herbs in commercial demand in the country. Nearly 53% of these species are subjected to destructive harvest to collect their underground parts, wood, bark or whole plants for use as herbal raw drugs.
- Total commercial demand of herbal raw drugs in the country for the year 2014-15 has been estimated at 5,12,000 MT.
- The trade value of 5,12,000 MT of botanical raw drugs, estimated to be consumed in the country during the year 2014-15, works out to around Rs. 7,000 crores.
- The species-wise annual consumption of herbal raw drugs obtained from the 1178 medicinal plant species enlisted under this study varies from less than 1 MT to more than 30,000 MT. Analysis of data gathered reveals that 242 species - wild gathered, cultivated or imported for main use as herbal raw drugs - are in high commercial demand.
- More than 85% of the medicinal plant species forming source of herbal raw drugs in active use in classical Ayurvedic, Sidha and Unani formulaons were still being sourced from the wild.
- There was an increasing trend towards use of 'extracts' as evidenced from the use of extracts of about 500 species, with major use of extracts in wellness formulaons.

Documentation of Neem products and their role in socio-economic upliftment of rural livelihood in Rajasthan and Gujarat (AFRI)

Detailed socio-economic survey of 103 villages in Pali district (Rajasthan) and 59 villages in Mahesana district (Gujarat) was carried out. Sojat city in Pali district, being only hub for collection and selling of neem leaves, there is a tradition of lopping 100 % trees in the farmers field in Sojat tehsil of Pali

district except trees 45 cm diameter at breast height. On an average, 150 tons dry green leaf powder is traded in India and abroad in the form of 80-100 kg packets @ Rs. 800/- kg. Baling of neem leaves is done at a rate of Rs.1/- kg. About 80 kg or 100 kg bales are prepared on job basis by M/s. Kamal Plastics, Sojat, Pali). Socio-economic survey reveals that 100-150 ton fruits are collected and traded in the market @ Rs. 10-12/- kg in Pali district.



Lopping of Neem trees in Pali



Purchase of fuelwood in Mahesana



Oil extraction unit in Sumerpur



Baling of neem leaves



Tree Borne Oil seeds (TBOs) in community lands for Improved Livelihoods of Vulnerable Groups of Jharkhand (IFP)

Clones were developed through grafting as well as stem cuttings. Variability in rooting success of CPTs was observed (3.5 – 57%).

A clonal trial of *Pongamia pinnata* (Karanj) comprising 24 plus trees each represented by two cleft grafts in three replicates

was evaluated at the age of ten years. The best height was recorded in the cleft graft of plus tree accession DIKDBD (3.82 m), basal diameter in DIKTIT (11.2 cm) and number of primary branches in DIGLBB (4.67).

Five year old plantation of karanj plots at Lalgutwa were converted into TBOs demonstration plots by removing of inferior trees.

2.6.2 Sustainable Harvesting and Management

Standardization of non-destructive harvesting practices of *Commiphora wightii* (Guggal) gum oleogum resin in Madhya Pradesh and Rajasthan (TFRI & AFRI)

Surveyed different regions of Madhya Pradesh for identification of potential areas to conduct experiments for sustainable harvesting of Guggul. Different girth size (10-20, 21-30, 31-40 cm) plants were selected at Piprai, Amba (Murena), Kankura, Barhi, Oosad (Bhind) in Madhya Pradesh. It was observed that the time of tapping, method and size of girth affect resin production. The quantum of gum yield showed an increasing trend with increase in girth size. The quantity of total Guggulsterone was found to decrease after storage. Maximum deterioration was observed in jute bags under both light and dark conditions. Maximum quantity of Guggulsterone Z and E were observed in samples stored in glass bottles under dark conditions. The non-destructive harvesting method developed under the project is of great value in the sustainable management of Guggul.

Twelve treatments (combination of 4 cut sizes x 3 cuts orientations) were applied on two sites viz. Kailana, Jodhpur

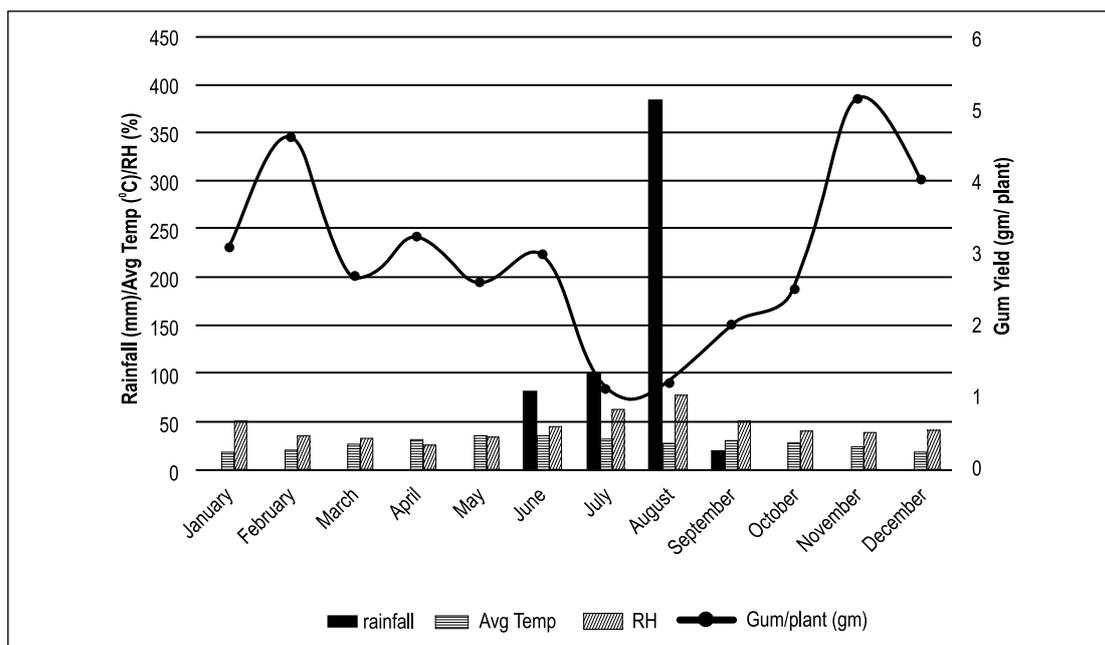
in Rajasthan and Ler, Bhuj in Gujarat. Horizontal cuts yielded higher gum, which increased with cut size. All cuts healed within three months of tapping. Gum yield production increased with girth size of the plants. Though this method yields lesser amount of gum but harvesting of guggul gum can be done every year or twice in a year without causing any damage to the plants.



Oozing of resin in multiple slants and V shape cuts in guggal



Oozing of resin in guggal



Changes in average gum yield in each month of a year under varying rainfall, average temperature and relative humidity

2.6.3 Chemistry of NWFPs, Value Addition and Utilization

Identification of superior germplasm of *Andrographis paniculata* (Kalmegh, Kirayat) and *Bacopa monnieri* (Brahmi) and its cultivation at farmers/tribals field for livelihood generation (FRI)

In *Andrographis paniculata* (Kalmegh, Kirayat), andrographolide content ranged from 0.76 to 2.56 % on dry weight basis. The highest andrographolide content was found in CIMAP, Lucknow accession (2.56%), followed by GAU 1 (2.32%) and Anand Gujarat 4 (2.23%). In *Bacopa monnieri* (Brahmi), Bacoside A content varied from 0.77 to 2.74 % on dry weight basis. Maximum bacoside content was found in samples collected from IIHR, Bangalore accession (2.74%), followed by Rishikesh (2.69%) and Kolkata (2.54%). A storage study is being carried out for the optimization of storage conditions and time for *A. paniculata* and *B. monnieri* with respect to quality of the produce. Air dried samples of Kalmegh and Brahmi were kept in different containers e.g. glass jars, plastic boxes, plastic bags, jute bags, jute bags with polythene lining and zip pouch bags. The active ingredients, andrographolide and bacoside present in the dried *A. paniculata* and *B. monnieri* at the beginning and at the end of each month during the storage period were determined by using the HPTLC. There was gradual decrease in andrographolide (Kalmegh) and bacoside (Brahmi) content during storage. With respect to containers Glass Jars and Plastic boxes were found better among all other containers.

Exploration of new sources of Luteolin (FRI)

Wild edible plants namely *Prunus armeniaca* (Chullu), *Pueraria tuberosa* (Sirola), *Myrica esculenta* (Kaphal), *Hippophae rhamnoides* (Amlich), *Callicarpa macrophylla* (Daiya) of Uttarakhand state were investigated for presence of an important bioactive chemical compound named luteolin, a phytochemical of flavonoid (polyphenol) group having diverse pharmacological properties viz., anti-inflammatory, anti-allergic, anti-tumor, anti-cancer, and antioxidant properties. In addition, luteolin reduces blood pressure, cholesterol and glucose levels, thus has immense role in prevention and treatment of heart problems, diabetes and degenerative diseases. Its recommended minimum dietary requirement is 50 mg/day. The content of luteolin in the edible parts of investigated species varied in the range of 662 – 209 mg/kg. Species-wise luteolin contents were recorded as: *M. esculenta* (Kaphal) (fruit) 662 mg/kg, *P. armeniaca* (Chullu) (fruits) 587 mg/kg, *H. rhamnoides* (Amlich) (fruit) 521 mg/kg, *C. macrophylla* (Daiya) (leaves) 364 mg/kg and *P. tuberosa* (Sirola) (rhizome) 209 mg/kg. Furthermore, antioxidant efficacy of all the 5 species was validated in terms of their total phenolic content (TPC) and total flavonoid content (TFC). Edible plants of all the 5 species found to contain considerable amounts of TPC & TFC and showed significant antioxidant activity.



Process refinement for extraction of fibre and bioactive constituents from *Agave sisalana* (Sisal) (FRI)

Procedural improvement was made for optimal extraction of good quality fiber and estimation of bioactive sapogenin compound from the leaves of *Agave sisalana* (Sisal). *A. sisalana* (Sisal) is one of the major fibre yielding plants apart from jute. Fibre from leaves is traditionally extracted through mechanical decortications or chemical treatment. Both the methods have the limitation of low yield, poor quality and eco-unfriendliness. Therefore, a process through biological pre-treatment of leaves has been developed for fibre extraction. The process resulted in increased yield of fibre of better quality as ascertained by morphological/anatomical (fibre length, diameter, wall thickness), compositional (chemical tests) and micro-structural (FTIR, SEM, XRD analyses) studies. Use of biological material and increased yield of good quality fibre make the entire process cost effective, efficient and eco-friendly. Furthermore, leaf juice of *A. sisalana* (Sisal) is an important source of steroidal sapogenins including hecogenin and tigogenin having commercial significance as sources of medically useful steroids. Separation of hecogenin-tigogenin mixtures remained a challenge due to exceedingly close relationship of the two compounds. Content of total as well as individual sapogenin reported to vary to a large extent in plants of different geographical origin. However, no work has been reported for the plants of Indian origin. The work carried out resulted in process development for isolation of bioactive steroidal constituents and a facile HPTLC method for quantitative estimation of hecogenin in *A. sisalana* (Sisal) leaf juice. The steroid mixture from sapogenin part and isolation of hecogenin was achieved with high purity. Quantitative estimation recorded Hecogenin content as 0.2%. The methods standardized and validated is specific and accurate and can be used for quantification of hecogenin in the plant and other *Agave* species as well.

Structural studies on *Acacia tortilis* (Vilayati Kikar) gum exudates (FRI)

Fine structural analysis of the polysaccharide was done using degradative and spectroscopic methods. The polysaccharide was found to be arabinogalactan with galactose backbone having 1,3 linkage and side chains of arabinose units linked to 6-position of galactose. This is the first structural analysis of gum exudate from *Acacia tortilis* (Vilayati Kikar) extensively planted in India. The studies offer a valuable utilization of Indian *Acacia tortilis* (Vilayati Kikar) gum exudates which is currently of minor economic importance.

Utilization of *Pinus roxburghii* (Chir pine) needles for value added products (FRI)

Pinus roxburghii Sarg. (Chir pine) is the most abundant species in Himalayan region. The needles of the species largely contribute to the forest biomass and the major cause

of forest fires leading to climate change, biodiversity loss, etc. The isolation of wax was standardized using different solvents and isolated in a quantitative yield of 1.64% using common organic solvent. Further, a distinctive approach towards complete structural analysis of the isolated wax in its native state has been achieved using NMR spectroscopy along with GC-MS. The analyses suggested that it is a polymer of linearly attached fatty acid esters which on hydrolysis yielded three types of α -hydroxy fatty acids viz. 12-hydroxydodecanoic acid, 14-hydroxytetradecanoic acid and 16-hydroxyhexadecanoic acid in a ratio of 1:1:2 respectively. Complete assignment of wax was achieved; corroborating the presence of polyester.

Further, facile methods have been standardized to prepare macrolides by intramolecular lactonisation of wax in common organic solvents. The lactones prepared have musk like odor and are important perfumery compounds. The study is significant to generate commercially important compounds derived from pine needles wax. This will offer an opportunity for utilisation of pine needle biomass; a root cause of Himalayan forest fires. The utilization aspect is also important for the viability, sustainability, livelihood support and hence wider acceptability of the *Pinus roxburghii* (Chir pine) plantations in Himalayan region.

Natural dye from fungal resources (FRI)

Natural dyes were developed from four fungus species namely *Xylaria polymorpha* (Dead man's fingers), *Pycnoporus sanguineus*, *Fusarium solani* and *Penicillium sublateritium* for textile applications. Protocols for their extraction and application on silk, wool and cotton fabrics were standardized. These dyes qualified for their application on these fabrics in terms of the shades and fastness towards light, washing, rubbing and perspiration. The outcome of the project work amply demonstrated the fungal resources as potential source of natural dyes. The fungi-derived dyestuffs qualify all standards of commercial natural dyes which can fulfil the expectations of consumers and industries.

Antioxidants from biomass residue (FRI)

In vitro antioxidant activity guided chemical analysis of different biomass residues (bark, saw dust and knots) generated from plantations of *Populus deltoides* (Poplar) and *Dalbergia sissoo* (Shisham) was carried out. All these biomass displayed antioxidant activity in three different antioxidant assays. Total phenolic content in these materials were also determined and found to be correlated with their antioxidant activity. These findings are useful for utilization of the above biomass residues into antioxidants.

Quality variation of Attars (FRI)

Chemical examination of the commercially traded attars of *Jasminum sambac* (Jasmine) and *Rosa damascene* (Rose) was undertaken. Gas Chromatography and Mass Spectrometry (GC-MS) analysis of these attars showed a complex mixture



of different chemical compounds representing the respective floral volatiles and the sandalwood oil. This knowledge is being used to identify the character compounds and establish relationship of these compounds to odour of these attars.

Gas Chromatography-Mass Spectrometry (GC-MS) based authentication of Sandalwood Oil (IWST)

This research is aimed at developing gas chromatography-mass spectrometry (GC-MS) based profiling protocol for pure and adulterated Sandalwood oil. More than forty essential oils and wood samples were collected from different locations (Uttarakhand, Delhi, UP, Haryana, Maharashtra, Telangana, Andhra Pradesh, Karnataka, Kerala and Tamil Nadu) and were subjected to distillation using Cleavenger's apparatus. Physicochemical analysis such as color, appearance, odour, relative density, refractive index and solubility etc. was carried out. Chemical profiling analysis was carried out and GC-MS profile protocol was developed for pure and adulterated oil samples.

Development of fast food products enriched with *Moringa oleifera* (Drumstick) leaves and skill upgradation training to rural women (TFRI)

Biochemical analysis of *M. oleifera* (Drumstick) leaves was conducted for proximate composition like moisture, ash, carbohydrates, fat, pH, macro-elements and ascorbic acid. Surveys were also conducted in Anganwadi at Poama, Chhindwara for collection of information on the menu provided during breakfast, mid day meal and third meal. Six food products enriched with *M. oleifera* (Drumstick) leaves powder were developed viz., noodles, nuggets, urad papad, biscuits, rice papad and aonla pickle. Developed food products were analyzed for their nutritional value from Standard Food Testing Laboratories (SFTL), Nagpur. Total 13 products were analyzed viz., crude leaves powder, developed food products and control food products for parameters viz., carbohydrates, proteins, fats, energy value, sodium, potassium, calcium and iron contents. Two training cum awareness programmes on "Nutritional benefits of *M. oleifera* (Drumstick) leaves

and prospects for its value addition" were conducted for Anganwadi women workers in Kundalikala and Parasia villages. Study will be useful as an income generation activity and help to overcome malnutrition.

Quantification, value addition of NTFP and improved agricultural productivity to enhance livelihood opportunities in Tribal belt of Sirohi district of Rajasthan (AFRI)

The data analysis on market price in Abu road areas of Sirohi district in Rajasthan at collectors level revealed that average family members involved in collection of identified key NTFPs was 3.65 and normal employment generated per family per year was 13.37 days. In respect of employment generated by an individual NTFP, maximum employment generated per family per year was by *Tamarindus indica* (5.28) followed by *Annona squamosa* (Sitaphal - 4.57), *Momordica dioica* (Kankeda - 4.42), *Pithecolobium dulce* (Jungle Jalebi - 4.25), *Madhuca indica* (Mahua seeds (3.95), *Pongamia pinnata* seeds (Karanj-3.86), *Diospyros melanoxylon* fruits (Tendu - 2.98), *Syzygium cumini* (Jamun - 2.88), *Phoenix* fruits (Khajoor - 2.82), *Jatropha curcas* (Ratanjot) and *Manilkara hexandra* (Rayan) 2.58 each. In studied villages, NTFP provided 20.21 mandays/annum employments to the tribals.

Programme support on elucidation of biosynthetic pathways and development of gene markers of high valued endangered medicinal herbs of NW Himalayas (Phase II)"- Collaborative project with JUIT, Wagnaghat (HFRI)

In this collaborative project with JP University of Information Technology (JUIT), Wagnaghat, Solan, areas were identified to establish field gene bank of *Picrorhiza kurroa* (Karoo). The field gene bank of the species with 52 provenances was maintained. The germplasm was multiplied and raised 5200 plants for JUIT for biosynthetic study.



Germplasm maintenance at Field Research Station, Bruhandhar



2.6.4 Biofuels and Bioenergy

Conservation and improvement of *Calophyllum inophyllum* (Nag champa)-A potential TBO of Karnataka (IFGTB)

CPTs of *C. inophyllum* (Nag champa) (66 Nos.) were selected from the districts of Dakshina Kannada, Udipi and Uttara Kannada in Karnataka. Fruits and stem cuttings from the high fruit yielding CPTs were selected for propagation and raised nursery. CPT-wise oil content was estimated and ranking of 55% and above in oil content was shortlisted as superior trees. Established 2 clonal trials of *C. inophyllum* (Nag champa) at Narebail in Sirsi (1 ha) and Thanneerbhavi (1 ha) near Mangalore. Completed field maintenance activities at germplasm/trial of *C. inophyllum* (Nag champa) clones in Kasargod near Honnavar (1 ha), Narebail and Thanneerbhavi.

Assessment of *Calophyllum inophyllum* (Nag champa) clones for oil yield and site specificity (IFGTB)

Completed trial maintenance work including weeding, soil working, manure application etc. for various *Calophyllum* trials at four research stations, Panampally, Gudalur, Salem and Neyveli. Recorded growth data of the clones at regular intervals. Raised clonal nursery for popularization of the TBO.

Briquettes from invasive forest weeds (IWST)

Fuel properties and combustion characteristic of *Lantana camara* (Lantana) and *Prosopis juliflora* (Jungle kikar) biomass has been studied. Both the species were found to have high calorific value ((18-21 MJ/kg), high elemental carbon (46-50%), and less ash content (1-2%). *L. camara* (Lantana) and *P. juliflora* (Jungle kikar) biomass produces very good briquettes (high density, high calorific value and high carbon content) due to high lignin present in the biomass.



2.7 Forest Protection

Projects under the theme.

Projects	Completed Projects	Ongoing Projects	New Projects initiated during the Year
Plan	5	12	19
Externally Aided	5	13	4
Total	10	25	23

2.7.1 Insects pests, diseases and control

Plant based bio-pesticide for management of poplar defoliator (FRI)

Biopesticide based on methanol and aqueous extract of *Calotropis procera* (Sodom apple) leaves was developed and tested at 1% concentration against the third instar larvae of poplar defoliator. After 24, 48 and 72 hrs of exposure the average mortality of insect was 57.50, 61.25 and 62.50%, respectively.

Diversity of egg parasitoid wasps *Trichogramma* spp. (FRI)

Ten species of *Trichogramma* - *T. achaeae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilostraeae*, *T. flandersi*, *T. japonicum*, *T. plasseyensis*, *T. poliae* and *T. raoi* have been recorded for the first time from Punjab and Haryana from the later state *T. semblidis* has also been recorded for the first time. Detailed diagnostic characters and genitalia components of all these species have also been studied.

Laboratory efficacy of *T. chilonis* and *T. japonicum* were carried out against key insect pests of Poplar and Shisham. Both



Trichogramma chilonis parasitizing eggs of poplar defoliator, *Clostera fulgurita*

species showed good parasitisation by *T. chilonis* (18.80% by one pair and 58.90% by five pairs in the eggs of *Clostera fulgurita*; while parasitisation was recorded 22.00% by one pair and 59.70% by five pairs in the eggs of *Plecoptera reflexa*). *T. japonicum* does not accept the eggs of *Clostera fulgurita*, but it showed good parasitisation in Shisham defoliator (19.20% by one pair and 44.90% by five pairs in the eggs of *Plecoptera reflexa*).

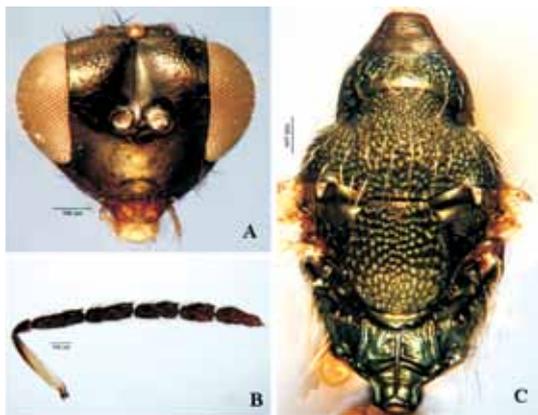
Biology and management of hispine bamboo borer-*Estigmene chinensis* (FRI)

E. chinensis (Coleoptera: Chrysomelidae) was found damaging thirteen green standing bamboo species in natural stand viz. *Bambusa bambos*, *B. burmanica*, *B. multiplex*, *B. nutans*, *B. striata*, *B. tulda*, *B. wamin* *Dendrocalamus asper*, *D. calostachyus*, *D. giganteus*, *D. longispathus* and *Schizostachyum pergracile*. Out of these thirteen bamboos eight species - *Bambusa tulda*, *B. multiplex*, *B. striata*, *B. wamin*, *D. asper*, *D. calostachyus*, *D. giganteus* and *D. longispathus* - were observed attacking for the first time. *P. crassicornis* completes one generation in a year For insecticidal control three systemic insecticides - dimethoate, monocrotophos and imidacloprid at 0.04% provided 65.28% 63.57% 51.12% control, respectively.

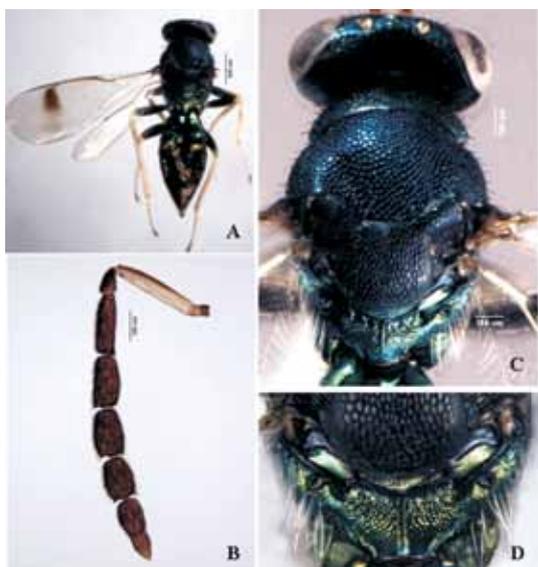
Studies on Taxonomy of the Family Eulophidae (Hymenoptera: Chalcidoidea) (FRI)

Unidentified collection of Eulophidae in National Forest Insect Collection (NFIC) was identified, earlier there were only 10 identified eulophid species in NFIC, and now 89 more species have been added.

Present study resulted in discovery of following 13 species new to the science: three each under the genera *Aprostocetus* and *Pleurotropopsis*, two under *Prigalio* and one each from



Pnigalio sp. nov., female: A, head in frontal view; **B**, antenna; **C**, mesosoma in dorsal view showing setal and sculptural pattern.



Sympiesis sp. nov., female: A, body dorsal view; **B**, antenna; **C**, mesosoma in dorsal view and **D**, propodeum showing setal and sculptural pattern.

Baryscapus, *Hemiptarsenus*, *Neotrichoporoides*, *Platyplectrus* and *Sympiesis*. Eighty nine species of eulophids belonging to four sub-families (31 species of Tetrastichinae, 39 species of Eulophinae, 2 species of Euderinae and 17 species of Entedoninae) have been identified and added in NFIC.

Studies on the economically important diseases of medicinal and aromatic plants of Assam to develop management practices through organic approach (RFRI)

Economically important diseases of some medicinal and aromatic plants (MAPs) of Assam were studied. Plant pathogens, viz., *Curvularia andropogonis*, *Alternaria alternata*, *Curvularia maculans*, *Pestalotiopsis theae*, *Colletotrichum gloeosporioides*, *Fusarium solani*, *Septoria* sp., *Phytophthora* sp., *Rhizoctonia solani* were found to be associated with diseases of MAPs. *Trichoderma* isolates were found effective against the target pathogens.

Population genetic structure of *Calamus* species and influence of infectious diseases in Mizoram and Tripura, North East India (RFRI)

Fourteen populations of four *Calamus* species viz., *Calamus guruba*, *C. nambariensis*, *C. flagellum* and *C. tenuis* were screened to find out diseases of rattan in nurseries, plantations and natural stands in Mizoram and Tripura. Study revealed that the leaf spot and blight caused by *Pestalotiopsis calami*; *Colletotrichum gloeosporioides* and *Fusarium* species were the most predominant diseases in these four species of rattans. Mortality of the newly emerged cane seedlings due to collar rot caused by *Fusarium oxysporum* has been reported. Conservation of germplasm of *Calamus* species has been done.

Field evaluation of biopesticides, ivermectin and spinosad against major insect larval defoliators (TFRI)

Toxicity of 0.03% Ivermectin (IVECOP-12), a biopesticide, gave cent per cent larval mortality of teak defoliator (*Hyblaea puera*) larvae in nursery. Similarly Ivermectin and Spinosad 45% Soluble Chemical (SC) (CONSERVE) at 0.03% and 0.003%, respectively, resulted in cent per cent mortality of teak leaf skeletonizer (*Eutectona machaeralais*), Khamer defoliator (*Hapalia aureolalis*) and *Ailanthus* web worm (*Atteva fabriciella*) larvae in plantations.

Mortality of *Parkia roxburghii* (sapota) a popular tree legume of North East India (RFRI)

Coptops aedificator (Long horn beetle) as major cause of the mortality. The fungus *Fusarium* sp. was also found to be associated with the disease. Painting of mixture of malathion 50% EC : lime powder (1:10) followed by spraying of carbendazim was found to check the further spread of the mortality.



Drying (Decline) of *Parkia roxburghii* trees: Photo on left side shows a dead tree and on right side shows long horn beetle, *Coptops aedificator* (Col.: Cerambycidae) which attacks and kill this tree.



Development of package for integrated management of insect pests and diseases (IPDM) and improvement of planting stock material of *Azadirachta indica* (Neem) through biofertilizers (AFRI)

For management of diseases bioagents, botanicals and chemical fungicides were tried. Out of three bio-agents viz. *Trichoderma harzianum*, *T. viride* and *T. pseudokoningii* were tested for their antagonistic effect against the isolated pathogens of neem. *T. viride* showed maximum inhibition (70%). Various botanical extract (*Azadirachta indica*, *Calotropis procera* and *Balanites aegyptiaca*) and entomopathogenic fungi (*Metarrhizium anisoplaea* and *Beauveria bassiana*) were found effective for management of insect pests of the neem seedlings. Dhatura and Hingota extracts were effective against snail.

About 32 combinations of 5 growth promoting rhizobacteria as well as fungi were tested to study their efficacy in promoting growth and vigour of Neem seedlings in greenhouse condition. Data collected on shoot length, root length, collar diameter, fresh weight and dry weight after 90 days of treatment with these biofertilizers showed that the consortia of biofertilizers were more effective as compared to application of individual microorganisms. Overall, maximum growth in Neem seedlings was observed with *Azotobacter*+*Azospirillum*+*Trichoderma* followed by *PSB*+*Azotobacter*, *Azospirillum*+*AMF* and *PSB*+*Azotobacter*+*Azospirillum* combinations.

Integrated management of Khejri mortality for socio-economic upliftment in North-East Rajasthan (AFRI)

Prosopis cineraria (L) Druce, (Khejri), the state tree of Rajasthan, provides economic and social security to desert dwellers. Besides providing food (fresh and dried pods - *Sangri*), fodder (fresh and dry leaves - *Loong*), fuel (wood) and fencing material (lopped branches), it enriches the soil and serves as a shelter for the animals during hot summers.

Over last 15 years Khejri mortality problem has been a cause of concern in western Rajasthan. Four groups of scientists worked on the project which was completed in 2017 with the following major highlights:

(1) Plant Protection Group (Pathology, Entomology and Nematology):

Ganoderma lucidum, a root rot pathogen and *Acanthophorus serraticornis* a root borer, were identified as major biotic factors for Khejri mortality. Mortality rate varied from 18.08- 22.67%. Root treatment with aqueous suspension containing a mixture of fungicide- Bavistine (0.1%), insecticide - Chloropyriphos (0.1%) (20 ml) and growth enhancer - Agromin (0.2%) @ 20 liters per tree at three months interval, encouraged loong (leaves) production. There was also an increase in loong production in infected trees after treatment.

(2) Management Group (Silviculture and Ecology):

Mechanical ploughing with tractors did not play direct role in mortality of Khejri but reduced the population of Khejri by damaging the new sprouts and lateral roots of the tree resulting in attack of pathogen affecting natural regeneration. Analysis of various abiotic factors like rainfall, ground water level, temperature, evaporation etc., did not reveal correlation with *Khejri* mortality.

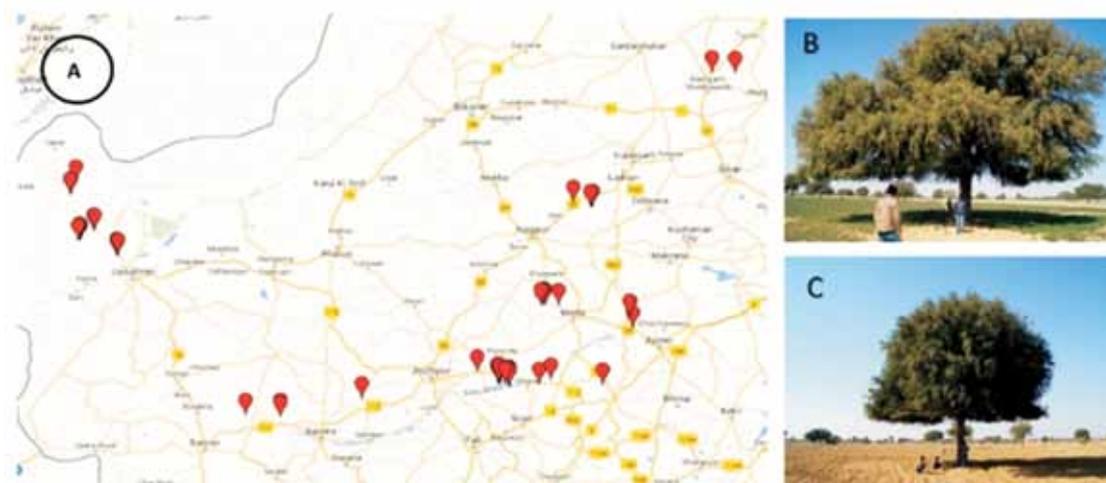
(3) Genetic improvement and biotechnology Group

(Germplasm collection, characterization, mass propagation): Ninety two Candidate Plus Trees (CPTs) were selected from Nagaur, Churu, Jhunjhunu, Sikar and Jaisalmer districts and progeny trial established at Jodhpur (with 30 families) and at Samaspur, Jhunjhunu (with 52 families, 6 individuals, 4 replication). The selected trees exhibited wide variation which was significant seed germination parameters including seed germination percent and germination velocity index. Results revealed moderate heritability and exhibited high genetic gain estimates.

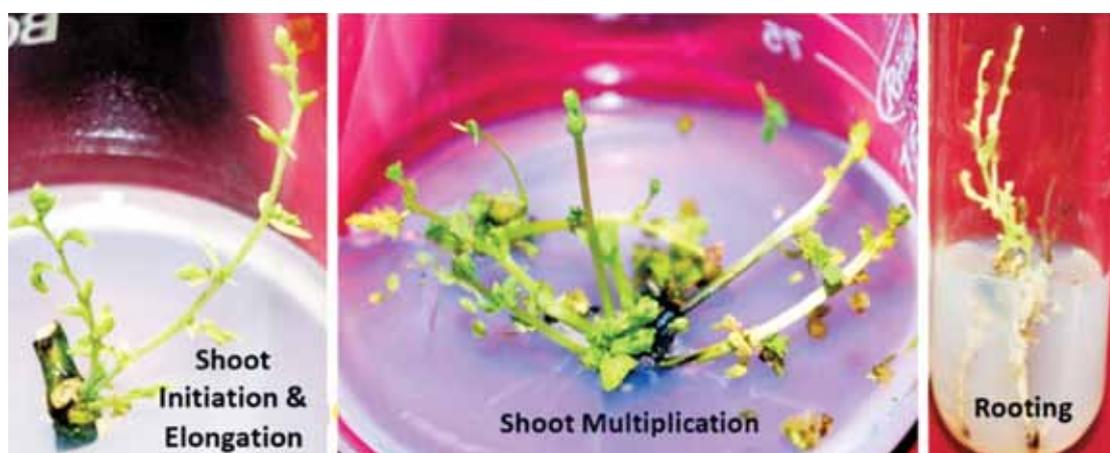
The species was found to be highly recalcitrant and difficult to micropropagate under *in vitro* conditions. The bud-break from nodal segments was initially difficult from mature trees. However, fresh coppice shoots obtained from partially pollarded trees gave rise to good shoot multiplication under culture conditions. Rooting was found to be very erratic and low in frequency. Best rooting was after pulse treatment but the associated callus production proved to be a major issue throughout that did



Left: Fruiting body of *Ganoderma lucidum* on Khejri; **Middle:** Larvae of root borer insect *Acanthophorus serraticornis*; **Right:** Mature *A. serraticornis* insect



(A) *Prosopis cineraria* (Khejri) selected CPT Locations in Rajasthan; (B) CPT at Merta; (C) CPT at Lanela



Stages of micropropagation of Khejri from shoot initiation, elongation, multiplication to rooting

not allow the rooted plants to survive for long. Maximum rooting percentage achieved was 30%. Plantlets transferred to potting mixture survived only up to 2 weeks.

Random Amplified Polymorphic DNA (RAPD) markers and Inter Simple Sequence Repeat (ISSR) markers were used to study the extent of genetic diversity between and within Khejri populations, primarily from the areas of high mortality. A total of 75 markers (25 RAPD and 50 ISSR) were initially screened. The top 6 highly polymorphic markers from each system were used for carrying out the analysis of genetic diversity amongst the individuals of the populations as well as between the populations. Amongst the 5 populations, the variation amongst the individuals of the population was around 89% while between populations it was 11% indicating a good amount of variability within a population cluster. The variability difference from population to population was not very high. This analysis shows that the populations with highest mortality rate have low heterozygosity.

Among the biochemical parameters (sugar, protein, phenols, ash, proline contents) studied in leaves, bark, roots and pods of Khejri, proline and phenol content were

higher in infected trees as compared to healthy trees.

They may be used as biochemical markers for identifying infection in Khejri trees.

(4) Socio-economic Group (Economics & Sociology):

Socio-economic surveys of 382 villages indicated income from lopped fuel wood in the affected mortality area of trees ranged from Rs. 132/tree in Nagaur to Rs. 151/tree in Churu and Sikar at a prevailing rate of Rs. 5/Kg. Income from fodder ranged from Rs. 111/tree in Jhunjhunu to Rs. 178/- per tree in Jodhpur at a prevailing rate of Rs. 7/Kg. A marginal reduction in fuel wood and fodder production was observed in the affected districts.

As an extension strategy, emphasis was given on educating the masses about the problem of Khejri mortality. For this pamphlets in both Hindi and English on 'Problem of Khejri mortality in North-western Rajasthan' were distributed among farmers and other stakeholders and recommendations for control of various factor affecting Khejri tree were explained. AFRI has also taken the initiative of raising Khejri seedlings which are being made available to the villagers. AFRI is also trying to convince the villagers to adapt the practice of Khejri plantation.



Studies on changing forest insect pest status of high Altitudinal Transitional Zone & their management in Himachal Pradesh.

Studies on the status of forest insect pests was initiated and three sites in high altitudinal transitional zones viz. Rohtang Pass (Distt. Kullu), Chanshal Pass (Distt. Shimla), Sach Pass, (Distt. Chamba) with control site at Indrahar Pass (Distt. Kangra) were selected. Insect fauna at these selected

sites were surveyed and the specimens of the insect orders Coleoptera, Hymenoptera, Diptera, Hemiptera, Odonata and Lepidoptera collected and processed. Moderate incidence of leaf defoliator in *Betula utilis* (Bhojpatra) was recorded in Raksham beat in Kilba Range in district Kinnaur. A Lepidoptera leaf defoliator was found in epidemic form affecting *Quercus dilatata* (Mohru oak) as on an average 2000 larvae/ tree were recorded in 10-15 km² forest in Demarcated Protected Forest (DPF) Guwari, Tissa range in Chamba district.



Defoliated Moru Oak tree by lepidopteran larvae in Churah Forest Division, Himachal Pradesh

2.7.2 Mycorrhizae, rhizobia and other useful microbes

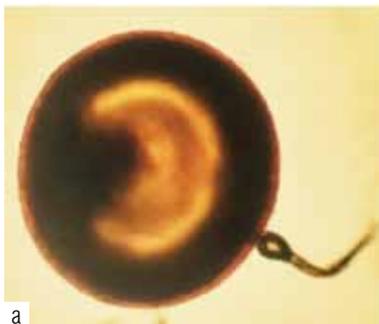
Health and age assessment of the trees of Rastrapati Bhawan, New Delhi.

Assessed the situation and condition followed by sample collection and laboratory examination for the health and growth of the trees in the President House Estate. The trees were examined along the main Veethis, different gardens, forecourt and adjoining areas. The age of only 5 tree species viz. *Dalbergia sissoo* (Shisham), *Tectona grandis* (Teak), *Pinus roxburghii* (Chir pine), *Prosopis juliflora* (Junglee kikar) and *Azadirachta indica* (Neem) were estimated because growth rings were distinct. In other selected older tree species growth rings were not distinct so age could not be estimated

Exploration of potential beneficial microbes in different forest and agriculture ecosystems in Kolli Hills, Tamil Nadu (IFGTB)

Diversity of Plant Growth Promoting Rhizobacteria (PGPR) and Arbuscular Mycorrhizal (AM) fungi in roots and rhizosphere

soil samples of economically and medicinally important plant species was explored in forest and agriculture ecosystems in Kolli Hills, Namakkal District, Tamil Nadu. AM fungi belonging to 4 genera viz., *Acaulospora*, *Gigaspora*, *Glomus* and *Scutellospora* and some of them were reported as new host records.



Arbuscular Mycorrhizal (AM) A. *Scutellospora calospora*, B. *Glomus clarum* and C. *Glomus* sp. identified from important tree species



Pure culture of Actinomycetes and Plant Growth Promoting Rhizobacteria (PGPR)

Isolation and study of the efficiency of Arbuscular mycorrhizal fungi, phosphate and potash solubilizing bacteria in enhancing productivity and nutrient status of degraded soil under shifting cultivation of Karbi Anglong, Assam (RFRI)

Seven isolates of Phosphorus Solubilizing Bacteria (PSB) and 4 strains of Potassium Solubilizing Bacteria (KSB), were found efficient under laboratory condition. As per the promising efficacy of PSB and KSB, 4 strains were inoculated in Maize crops in pot experiment, which would be later transferred to jhum fields.

Formulation of biofertilizers consortium and their distribution to forest department (TFRI)

Strains of bacterial biofertilizers and Arbuscular mycorrhiza (AM) fungi were isolated for selected tree species of Madhya Pradesh. Inoculants of bacterial biofertilizers and consortium of AM fungi were prepared for selected species. Carrier material being used for making packets of bacterial biofertilizers were: activated charcoal powder, saw dust, grinded and filtered soil (clay loam), vermicompost and calcium carbonate. Carrier based packets of selected bacterial biofertilizers were prepared for distribution to Forest Department. Inoculants of AM fungi were also prepared in bulk (25 bags of 40kg each). Soil, sand and farmyard manure (FYM) in 2:1:0.5 ratio were used as carrier for production of AM inocula for Beejasal, Sissoo and Teak. Biofertilizers were supplied for application in nurseries of 11 research and extension circles include 661 packets of *Rhizobium*, 668 of *Azotobacter*, 308 of *Azospirillum*, 544 of Phosphate Solubilizing Bacteria (PSB) and 24 bags of Vesicular Arbuscular Mycorrhizae (VAM) fungi. The application of these biofertilizers will enhance the growth of tree species.

Value addition to economically important plants by application of consortium of root fungal endophyte and nitrogen fixing prokaryote – *Azotobacter* spp.

Seeds of *Azadirachta indica* (neem), *Prosopis cineraria* (Khejri), *Cassia angustifolia* (Senna) and *Plantago ovata* (Isabgol) were treated with formulation of the AM fungi *Piriformospora indica*, *Azotobacter* spp. and consortia of both these microbes to study their individual as well as combined effect on the growth and development of these plant species. Growth parameters like collar diameter, shoot length, root length, biomass, sturdiness quotient, quality index and vigour index were calculated for the neem and Khejri, while yield was calculated for Isabgol and Senna. In case of Khejri, the consortia showed better results in case of shoot length (28.7 cm), root length (48.2 cm), number of leaves (18.4), sturdiness quotient (9.4) and vigour (28.7) followed by *P. indica* (shoot length (20.6 cm), root length (34.7 cm) number of leaves (18) sturdiness quotient (10.4) and vigour (15.6) as compared to control (shoot length, 17.8 cm; root length 29.8 cm; number of leaves 15.2; sturdiness quotient 14.7 and vigour, 13.5). In neem seedlings, *P. indica* showed better results (shoot length 13.12 cm; root length, 27.1 cm, number of leaves- 7.8 sturdiness quotient - 3.2 and vigour - 12.5 as compared to control (shoot length - 11.54 cm; root length-19.92 cm, number of leaves -4.6, sturdiness quotient -11.376, and vigour - 10.41). In annual plants senna and isabgol, *P. indica* has performed better than all other treatments. Mean yield in Isabgol seed and husk, respectively, increased to 57% and 33% in *P. indica* treated seeds followed by 36% and 14% in consortia of the fungus and bacterium, and 23% and 4% in *Azotobacter* treated seeds as compared to control. Similarly, mean yield of senna seeds was maximum in *P. indica* treated seeds (39.7 g), followed by consortia (20.0 g) and *Azotobacter* (19.2 g) than in control (16.3 g).



2.7.3 Weeds and Invasive species

Impact of *Mikania micrantha* (bitter vine) on microenvironment of native species in Bherjan-Borjan-Padumoni WLS, Dilli and Abhayapur RReserve Forests of Upper Assam (RFRI)

Mikania micrantha (bitter vine) vegetation was quantify

and its dominance spectrum on existing species growing at different strata in various seasons was analysed. Reduction in regeneration of and structural changes in the trees like *Dipterocarpus retusus* (Rusty Leaf Garjan) etc. were observed. Soil nutrient characteristics were also observed.



Mikania micrantha infestation in the forest (left) and regeneration of *Dipterocarpus retusus* (right) in the Bherjan-Borjan- Padumoni (Wild Life Sanctuary), Dilli and Abhayapur (Reserve Forests) of Upper Assam

