

Managing Forests and Forest Products for Livelihood Support and Economic Growth



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Sustainable management of the forest and natural resources aims to protect and conserve the natural resources on one hand and to provide opportunity for economic well-being of the people and the country on the other. It requires integration of environmental issues with the suitable developmental strategies; that will pave the way for sustainability of the resources for providing livelihood support to the people merging with the ecology of the area. This may benefit the millions of people living in poverty especially in the rural and forest fringe areas. The tree resources in the forest also act as the safety net for millions of such people using diversity of the resources with the aim to enhance food security. It is beyond any doubt that the diversity of products, goods and services that are available from the forest is tremendous. In view of this, the Council had undertaken/is implementing the following research projects:



2.1 Silviculture and Forest Management

Biomass, net primary productivity and shoot productivity of seven industrially important bamboo species in semi-arid and humid tropics of Peninsular India (IWST)

Assessment of biomass, net primary productivity (NPP) and water use efficiency (WUE), assessment of shoot production, nutrient analysis and standardizing management schedule for sustainable production of edible bamboo shoots of seven important bamboo species in humid tropics and semi-arid zones of peninsular India has been carried out. Based on the growth performance *Dendrocalamus brandisii* (Burma bamboo) exhibited best growth, followed by *D. asper* (Sweet Bamboo) in Chikmagalur, whereas *D. stocksii* (Marihal Bamboo) and *D. strictus* exhibited best growth in Hoskote. Biomass productivity in both the locations also followed the same pattern. Significant difference in physiological parameters amongst the 7 species was noticed. Water Use Efficiency (WUE) was maximum in *D. strictus* in Hoskote and in *Bambusa balcooa* in Chikmagalur. Initial assessment has shown that the 6 treatments (different combinations of Biochar, NPK, and compost) has given enhanced shoot emergence and size of shoots in six bamboo spp. Amongst these, Biochar + compost appear to be promising.

Benefits of the research: The outcome of research suggested that pressure cooking of processed bamboo shoots for 15 minutes and discarding the supernatant water has been found to remove bitterness in shoots due to HCN and represents a quicker and more efficient way of removing bitterness compare to the traditional methods which are very time consuming. This method results in minimal nutrient loss as compared to other known methods of processing. The financial gains accrued through commercial cultivation of *D. asper* plantations in humid tropics has been worked out and documented in IWST Technical Bulletin.

Expanding carbon sinks through sustainable tree biomass energy production in semi-arid areas of Tamil Nadu (IFGTB)

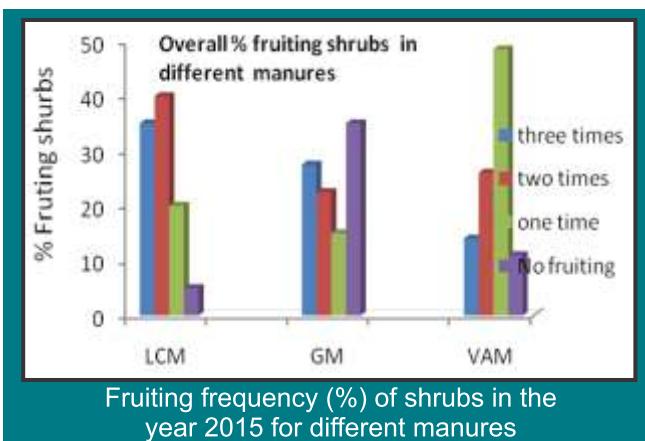
Under this collaborative project involving IFGTB, Tamil Nadu Forest Department and CSIRO, Australia 28 species of Eucalyptus 'mallees' have been introduced in the target areas to select the best accessions for biomass

production in dry areas. 'Mallee' Eucalyptus are highly adapted to grow in areas receiving low rainfall (>400 mm) and in nutrient-poor sites. They also produce multiple stems from the ground level and amenable for multiple harvests for biomass production. Two replicated species-provenance trials have been established in IFGTB's field stations at Neyveli and Thuvankurichi in Tamil Nadu.

Benefits of research: Development of nursery and plantation techniques for "Mallee" Eucalyptus, a new group of species, suitable for cultivation in water and soil nutrient deficient areas in Tamil Nadu. 'Mallee' Eucalyptus are highly adapted to grow in areas receiving low rainfall. Hence, helpful in greening of low rainfall and low productive lands, wood biomass energy plantations in wasteland along semi-arid areas of Tamil Nadu. The results a published in "A Field Guide on tree crops for semi-arid areas".

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

Field experiments were established at Gogelao Beed, Nagaur and Khari Khurd, Jodhpur for enhancement of Kair (*Capparis decidua*) productivity. Fertilizer treatments with leaf compost manure (LCM), goat FYM (GM) and VAM in combination with different fertilizers viz., SSP, SSP+K, K, Zn and SSP, K+Zn and NPK etc were applied with irrigation. Three times flowering and fruiting were observed in the experimental shrubs. Out of three organic manures, application of LCM in combination with various inorganic fertilizers has enhanced the number of fruiting plants and fruit yield



significantly, followed by VAM application. Two types of fruit shapes were also noticed i.e. round and elongated. In few trees, fruits with

penta lobular shape were also noticed.

Benefits of the research: Enhancement of Kair fruit yield.



LCM treated plant Oct-15



GM treated plant Oct-15



VAM treated plant Oct-15



Control plant Oct-15

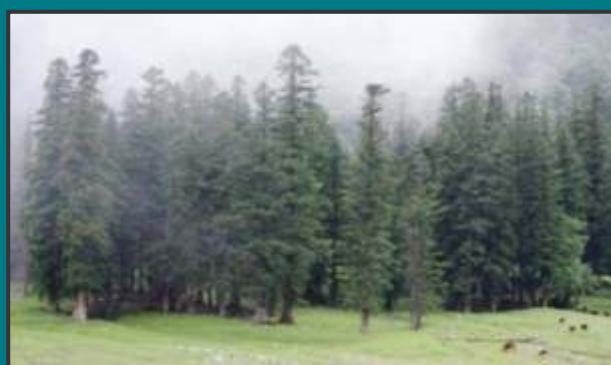
Performance of Kair plants under different treatments

Studies on Seed Germination and Longevity of *Abies spectabilis* (HFRI)

Nine more natural populations of *Abies spectabilis* (Talishpatra) were identified, thus raising the total number of population to 39 in various forest divisions of Himachal Pradesh. The effect of time of collection on germination of seeds revealed that optimum time of collection

is 2nd fortnight of October as seed collected during this period recorded maximum germination (42%) compared to seeds collected during other collection dates.

The effect of seed size on germination of *A. spectabilis* revealed that large sized seed recorded maximum 40% germination whereas, in small seeds germination per cent was as low



Natural Populations of *Abies spectabilis* in Himachal





Seeds of *Abies spectabilis*

as 12% only. The seeds collected from trees having 40-50cm dbh recorded maximum 46.40% germination. The effect of depth of seed sowing on germination of seeds revealed that seeds sown at a depth of 1.50 cm recorded maximum 44.50 % germination. The seed storage trials revealed that the viability of seeds stored in air tight Polysac container in deep freezer (<-50°C) retained 21% viability even after 18 month of storage.

Benefits of the research: Seed size, seed collection time, Seed container / temperature requirement were optimised and standardized for maximizing seed germination and enhancing seed viability. A booklet titled "*Distribution and Seed Studies in Abies spectabilis* (D.Don) Spach" has been published which is an excellent data base for users. The outcomes of the study will be useful to Himachal Pradesh State Forest Department while preparing the conservation strategies for the species and also for successful Afforestation programmes in high temperate regions.

Develop tools, techniques, and methods for enhancing REDD+ forest management in India (FRI)

The study area includes states of MP, HP and Sikkim. Field data was collected on forest vegetation, growing stock, regeneration etc. from various landscapes of study area and analysed using appropriate statistical tools. Draft report on various deliverables such as NTFPs, biophysical conditions, detailed description of preservation plots, drivers of forest degradation, silviculture techniques, forest management techniques and socio-economic aspects have been submitted to

funding agency for their approval.

Benefits of the research: Enhancing REDD+ in forest management of the country.

Monitoring and Evaluation of PUNCAMPA/ FDA and GPM plantations of Punjab (FRI)

Under this project, monitoring and evaluation of PUNCAMPA plantations and GPM plantations of the year 2013-14 was carried out in all the Forest Divisions of Punjab. The report has been compiled for submission.

Benefits of the research: Developed recommendations for planting technique, protection and management of plantations and enhancement of biodiversity. Revenue to FRI/ICFRE was generated.

Feasibility study on Facilitation of Tree Nursery for Enhancing the Livelihood of Tribal Community in Tamil Nadu (IFGTB)

The seeds of various commercially important tree species including some ornamental tree species are sown in the mother beds in farmers' nurseries for seedling production for livelihood support to the local tribal community. With the involvement of the tribal community, 24,000 seedlings of various tree species have been produced. This involved germination of seeds in mother beds, maintenance and transplanting into polybags. Various commercially important tree seedlings viz. *Tectona grandis* (Teak), *Swietenia macrophylla* (Mahogany), *Dalbergia sissoo* (Sissoo), *Dalbergia latifolia* (Rose wood), *Gmelina arborea* (Kumil), *Terminalia bellerica* (Thandri), *Thespesia populnea* (Poovarasu), *Terminalia arjuna* (Neer Kadambu), *Pterocarpus santalinus* (Red sanders), *Albizia saman* (Rain tree), *Delonix regia* (May flower), *Peltophorum*

pterocarpum (copper pod tree), *Pongamia pinnata* (Pungam) and *Azadirachta indica* (Neem) has been produced, transplanted into the poly bags and maintained in the nursery for commercial supply.

Benefits of research: A model tree nursery which is self sustaining has been demonstrated in tribal hamlets. The livelihood issues of the tribal community were addressed. The community was trained in areas of nursery management and maintenance of seedlings. Sale of seedlings has brought in revenue of Rs. 1.30 lakh. The sale amount acts as 'corpus fund' or 'seed money' for future nursery activities.

Standardization of plantation techniques for major forest plant species in Madhya Pradesh (TFRI)

Growth data recorded under irrigated condition on eight species revealed that the maximum average height was attained by *Dendrocalamus strictus* (Bans) (294.25 cm) at spacing 3x3m, pit size 60x60x60 cm followed by *Dalbergia sissoo* (Sissoo) (242.13 cm) at spacing 2x2m, 45x45x45 cm and minimum in case of *Terminalia bellerica* (Behera) (77.50 cm) at spacing 5x5 m, 60x60x60 cm.

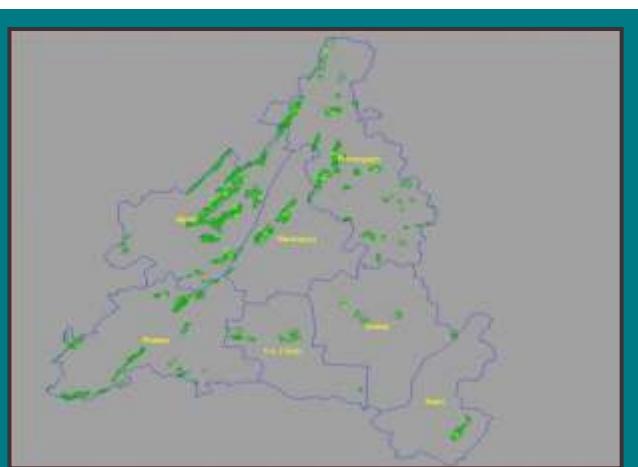
Benefits of the research: Standardization of plantation techniques with reference to pit size spacing under irrigated and non-irrigated conditions for species *Dendrocalamus strictus* (Bans), *Dalbergia sissoo* (Sissoo) and *Terminalia bellerica* (Behera) were done to select the best techniques for planting forestry tree species. It will result in increase in quality and productivity of plantations.

Carbon stock and soil classification mapping for Rajasthan forests (AFRI)

The process of linking the database with the geo-referenced data points for all 33 districts has been completed. The district maps have been prepared and displayed by two different methods: One with the use of Forest Type Map of FSI using the TNT mips software and the other using Google earth through TNT mips software. User can view the details of site characteristics, vegetation composition, carbon stock, soil nutrient status etc. by clicking the geo-referenced data points on the map.

Benefits of the research: Information on carbon stock and soil characteristics of different

forest blocks of Rajasthan will help in sustainable forest management.



Map of Ajmer district showing carbon stock generated over Forest Type Map using TNT mips software



Map of Ajmer district showing carbon stock generated over Google earth using TNT mips software

Refinement of modern nursery practices for raising quality seedlings of selected important forest tree species for arid and semi-arid areas (AFRI)

Nursery practices for raising quality seedlings of three important forest tree species *Prosopis cineraria* (Khejri) *Tecomella undulata* (Rohida) and *Azadirachta indica* (Neem) for arid and semi-arid areas were refined. On the basis of initial data and subsequent observation taken at the end of 9th month for all 3 species, following changes have been observed:



Seedlings	Control	Compost	Vermi-compost	Leaf manure
<i>Azadirachta indica</i>				
(av. height in cm)	74-140	115-246	130-270	112-192
(av. girth in mm)	8.74-18.14	11.66-33.71	14.78-36.31	12.35-29.66
<i>Tecomella undulata</i>				
(av. height in cm)	14-19	25-35	20-31	-
(av. girth in mm)	1.93-2.33	2.14-4.21	2.98-4.71	-
<i>Prosopis cineraria</i>				
(av. height in cm)	38-49	56-68	-	-
(av. girth in mm)	3.41-5.8	4.42-7.4	-	-

It was observed that the *Azadirachta indica* seedlings grown with compost and vermi-compost performed better in comparison to other treatments. Similarly, *Tecomella undulata* seedling grown in compost performed better in terms of height.

Benefits of the research: Refined modern nursery practices for production of quality planting stock of *Azadirachta indica* and *Tecomella undulata* were developed that improved survival and better productivity. Stakeholders will get better financial returns by adoption of modern nursery practises.

Standardization of nursery techniques of selected fruit-plants of North East India for their effective conservation and development of value added products for inclusive growth (RFRI)

Fruits, stem cuttings, root cuttings etc. of *Rhus semialata* (Nogatenga), *Flacourtie jangomas* Syn: *Flacourtie cataphracta* (Ponial), *Dimocarpus longan* (Asphol, Nagalichi) and *Garcinia lancifolia* (Rupahi-thekera) were collected from forest areas and homestead gardens of Jorhat, Golaghat, and Sibsagar Districts of Assam and Garo Hills Districts of Meghalaya. The collected material was treated with various chemicals and growth regulators to ensure uniform germination. Seed propagation techniques were standardized for *Flacourtie jangomas* (Ponial).

Benefits of the research: Nursery technique developed will be useful in artificial regeneration of these species which are becoming scarce. The forest departments will be able to use these techniques in propagation of the species. The value added products developed will add to the income of the forest

dependent people, who collect and process these forest fruits.

Commercial production of quality planting material of bamboo species (RFRI)

The tissue culture lab was renovated and upgraded to "10 lakh Sterility Standard", with financial support from National Bamboo Mission. Cultures of *Bambusa tulda* (Jati Bah) and *B. balcooa* (Bhaluka Bah) have been established by using selected mother clumps. Shoot proliferation and root induction have been achieved in both the species.

Benefits of the research: *In vitro* propagation protocols for *Bambusa tulda* and *B. balcooa* have been developed using ammonium nitrate free medium. Development of ammonium nitrate free medium is a modification rendered necessary due to ban on the sale of ammonium nitrate, which is also used in explosives. This is an improvement over the existing protocol. Selected high-yielding clumps of the said bamboos are being multiplied for improving the productivity of the said species in the region, which will add economic benefit to the bamboo farmers in future.

Production of Quality Planting Material of *Aconitum heterophyllum* Wall. ex Royle, *Podophyllum hexendrum* Royle and *Angelica glauca* Edgew and Extension of their Cultivation Technology to Local Communities (HFRI)

Quality planting material (1.9 lakhs nursery stock) of *Aconitum heterophyllum* (Atish), *Podophyllum hexendrum* (Ban Kakari) and *Angelica glauca* (Chora) was raised and maintained in the nurseries. In total, around 1.8 Lakhs medicinal plants were distributed to

various stakeholders in the state of H.P. and J&K to initiate cultivation of these species in their farmlands. Under the extension activities, three training programmes at Udaipur (Lahul & Spiti, H.P.), at Bhadarwah, Doda (J&K) and at Bhutti (Shimla, H.P.) were successfully organized for local communities. Two meetings, one each in HP & J&K, and two camp workshops at Nichar, Kinnaur (H.P.) were organized to sensitize local communities towards medicinal plants cultivation. Work towards preparation of database of herb collectors and traders of Kullu and Rampur regions have been initiated for the benefit of cultivators.

Benefits of the research: About one million quality planting stock of these medicinal plants have been distributed during last three years to the farmers for large scale commercial cultivation. Growing the quality planting material of these medicinal plants has helped in augmenting the income of the rural farmers.



Training programme at Bhaderwah (J&K)



Camp Workshop at Nichar, Kinnaur (H.P.)

Determination of Nursery Requirements and Initial Planting Performance of *Diploknema butyracea* (Roxb.) H. J. Lam (Chura) and *Myrica esculenta* Buch. Ham.

(Kafal) under Mid-hill Conditions of Himachal Himalayas (HFRI)

A small plantation of *Myrica esculenta* (Kaphal) was established at Model nursery Baragaon during August 2015 and observations were recorded periodically. The seeds of Cheura collected from Champawat District of Uttarakhand during 2015 were subsequently sown in two nurseries located in mid and lower



Established Cheura plant in the field



Protection of Cheura plants during winter months

Himalayas, respectively. In *Diploknema butyracea* (Cheura) plantations, the initial survival was found to be encouraging. However, during last two winters, it was observed that Cheura plants are frost sensitive and around 44% survival in Cheura plantation was recorded after two winters in the field with special plant protection care during winter months in lower Himalayan region of Himachal Pradesh.

Benefits of the research: Standardization of nursery techniques for Cheura and subsequent establishment of the plantation in the field conditions have been achieved. Kaphal will provide additional income to the local farmers and nutritional security on account of being rich in nutrients.

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

Tendu growing areas (pruned and unpruned sites) in Gondia and Gadchiroli Forest Divisions of Maharashtra were selected to evaluate harvest practices for sustainable collection of tendu leaves with reference to enhance natural regeneration of the tree species and also to improve quality of leaves. Experiments were



laid out in selected areas. Baseline information on 'tendu' leaves and shoots before pruning of bushes was collected.

Benefits of the research: Maximisation of productivity and quality of Tendu bushes vis-a-vis natural regeneration of trees through choosing appropriate management/harvesting practices having achieved. It will result in increase in quality and quantity of Tendu leaves and conservation of species.

Preparation of Management Plan for Asola Bhatti Wildlife Sanctuary (FRI)

The management plan of Asola Bhatti Wildlife Sanctuary was prepared on the basis of extensive field surveys and data analysis, and has been submitted to the funding agency.

Benefits of the research: Management plan will be useful in management of wild life sanctuary.

Impact of Sal ANR in Shiwalik forests of Dehradun and Kalsi forests (FRI)

A regeneration survey was carried out in 10 forest ranges of Dehradun and Shiwalik Forest Divisions in which Uttarakhand Forest Department has been involved in *Shorea robusta* (Sal) ANR activities since 2004-05. The study observed that out of 10 ranges, the

best regeneration of Sal was found in Thano Forest Range, followed by Lachhiwala, Timli, Langa, Asarori and Choharpur Forest Ranges. However, other forest ranges showed poor regeneration. The probable reasons of poor regeneration in these areas were thick layer of leaf litter, variable moisture contents in the soil, impact of shades of weeds and trees etc.

Benefits of the research: Recommendations for improvement in sal natural regeneration through application of silvicultural operations were developed. The outcome will be helpful in solving problem of poor natural regeneration of in Siwalik belt.

Preparation of Working Plan of Karanpur, Bindraban & Nandbir Ranges of Dasuya Forest Division (FRI)

Working plan for bamboo forests of Karanpur, Bindraban and Nandbir Ranges of Dasuya Forest Division of Punjab has been prepared as per the guidelines of New Working Plan Code -2014, and same has been submitted to the Department of Forests and Wildlife Preservation, Punjab.

Benefits of the research: Outcome will assist in improvement in forest health and productivity.

2.2 Agro-forestry and People Forestry Interface

Enhancing fodder productivity through silvi-pastoral system on degraded land of India (AFRI)

Colophospermum mopane (mopane) *Cenchrus ciliaris* (Dhaman) trial : Under this silvipastoral system, *Cenchrus ciliaris* (CAZRI 75) was successfully introduced in the inter-spaces of *Colophospermum mopane*. It recorded 30-107 cm height with biomass yield of 130 – 208 gm². But, *C. ciliaris* (CC 358) could not be established in saline area. Other grasses that occurred in the experimental area were dominated by *Sporobolus diander* with biomass yield of 572-720 gm², which is three times higher than the yield of *C. ciliaris* (CAZRI 75). Other grasses are *Chloris virgata*, *Cyperus*, *Dactyloctenium scindicum*, *Dactyloctenium aegypticum*. As compared to growth in control plot (7.3% in height, 8.64% in crown diameter and 8.56% in collar diameter) performance of

Colophospermum mopane trees with grass were found to be better.

Soil analysis of 0-20 and 20-40 cm layers showed higher pH values on soil slope (8.23 & 8.44) as compared to plant pit (7.97 & 8.31). Soil EC values were higher in the 0-20 cm layer (0.625 & 0.915 dSm⁻¹) as compared to 20-40 cm layer (0.377 & 0.43 dSm⁻¹).

Suaeda nudiflora (Unt morad) : *Cyamopsis tetragonoloba* (Guar) trial : *S. nudiflora* was maintained with mean percent survival of 70.5% and no significant change from the survival status was recorded in previous year (71.3%). Height increment was 21.5 % over mean height (128 to 146.5 cm), 57.4% in crown diameter (81.3 to 128.0cm) and 137% in mean collar diameter (20.3 to 48.12 mm) registering 34.4% increase over October values. BS RGC 1003 & TFL RGC 1017 varieties of *C. tetragonoloba* from Agriculture Univ, Mandore were sown in



C. mopane with *C. ciliaris* (CAZRI 75) and other grasses after monsoon



Crop germination in the 3rd week of August 2015



S. nudiflora on DRM after rain

the inter row spaces of *S. nudiflora* plantation in the first week of August 2015. 11 cm height was attained by C 1017 and 10 cm for 1003, and survived up to 6-8 leaf stage but due to lack of rain it withered. 17 plant species were recorded as compared to 22 in the previous year (a better distributed rainfall year). Out of 17 species, 8 were grasses as compared to 9 grasses in 2014 (*Aristida* did not appear). The biomass yield was 269.5 to 387.1 gm⁻² dominated by *Dactyloctenium aegypticum* and *Chloris* spp. grasses.

Soil moisture was higher with 0.86 to 0.70% for 0-20 cm depth and 1.58 to 1.50 % for 20-40 cm depth. Higher results were obtained for soil EC also. Plant growth of a succulent halophyte is responsible for higher EC as leaf fall recycled the salt back to soil. However, no difference was observed in soil pH values.

Benefits of the research: Productivity enhancement from degraded salt land will lead to better and enhanced production of fodder.

Development of Silvi-agri-medicinal and agri-medicinal system in Vidharbh region of Maharashtra (TFRI)

Silvi-agri-medicinal and agri-medicinal systems in both the sites i.e. On Station Research(OSR) Plots, TFRI, Jabalpur (M.P.) and On Farm Research(OFR) Plots, Chandrapur (M.S.) were standardized. The rapid appraisal revealed that communities are in need of market to sell their medicinal plant products. Farmers are keen to grow fast growing and short rotation timber yielding species like *Gmelina arborea* (Khamer/Gamhar) in their farms.

Benefits of the research: Silvi-agri-medicinal model suitable for agro-forestry in Vidarbh region has been developed. Evaluation of combinations of tree, agricultural and medicinal plant species suitable for short rotational multi-tier agroforestry in Vidarbh region were done.

Empowering Tribal Community through Lac Cultivation in Madhya Pradesh (TFRI)

A programme on "Livelihood Generation through Lac" was organised for the rural youth and women groups of selected villages in the presence of Gram Vikas Co-ordinator and Gram Vikas Secretary. Issues were identified related to maintaining quality of broodlac and its marketing at village level. The participants were informed about the market linkages and potential buyers in Jabalpur region.

The farmers were motivated to cultivate lac on the non-conventional lac hosts in their courtyard to get income during the lean period. Experiments were conducted to cultivate 'baisakhi' crop of 'rangini' strain of Lac after the pruning of lac host trees i.e. *Butea monosperma* (Palash) and *Zizyphus mauritiana* (Ber) existing in the fields. From the yield of lac, it was observed that the crop gave maximum yield from the trees existing nearby the water stream.



Collection of seedlings by the community people

Benefits of the research: Development of brood-lac farm and market linkages in the area in which lac was discontinued over the period of time. Promotion of lac culture and increase in livelihoods.

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

The survey conducted in Karbi-Anglong District of Assam; Aizawl and Kolasib Districts in Mizoram shows that only six cane species i.e. *Calamus nambareensis* (Teng-yer, Hnah-bawr), *C. latifolius* (Teng-yer, Hnah-bawr), *C. khasianus* (Raidang, Mawt), *C. flagellum* (Tor, Hrui-pui), *C. gracilis* (Pre-lude, Kawr-tai) and *C. tenuis* (Pre-shek, Chang-dam) are useful. A model plantation of 3 ha area was raised in Karbi-Anglong involving the local communities.

Benefits of the research: Ten thousand planting materials of the selected Cane species were raised to establish plantation of 10 hectares in fringe villages to support their livelihood. These canes are in demand and

highly exploited. These plantations have contributed to the conservation of the species. Their exploitation on maturity would be a source of income and livelihood to the villagers living in forest-fringes.

Extension of mushroom cultivation technology for livelihood support (FRI)

An awareness about nutritional as well as monetary value of mushrooms was generated among rural people especially women. As mushroom cultivation is a potential venture, women are willing to adopt mushroom cultivation as an additional source of income. The local graduate youth were trained in cultivation technology so that they provide technical support to these women self-help groups. Some of them are also interested to become entrepreneur to supply raw material, spawn and other services.

Benefits of the research: Development of low cost cultivation techniques of *Ganoderma lucidum* and Oyster mushrooms (*Pleurotus* spp.). Dissemination of this technology can help in self employment/ income generation of 'self help groups', women and marginalized farmers.



Cane plantation and canopy management

Managing Resources to enhance productivity of agro-forestry system in Dry Areas of Rajasthan (AFRI)

Hardwickia binata (Anjan) and *Colophospermum mopane* (mopane) trees based agro-forestry experiment were established in 2012-13 at AFRI, Jodhpur to study the effect of tree pruning and root barriers on crop/grass production and resource utilization. Four treatments were: intact tree (T_1), tree branch removal only - 70% of tree height (T_2), root barrier (T_3), and both tree branch removal and root barrier (T_4). *C. tetragonoloba* crop was grown with *H. binata* and *C. Ciliaris* (Dhaman) grass with *C. mopane* trees. Crop failed after poor rainfall in 2015 but grain production of *C. tetragonoloba* over three years was high. Photosynthetic Active Radiation PAR was high in sole crop and grass plots as compared to different treatments. PAR was highest in T_2 and T_4 treatment and low in T_1 treatment. PAR increased with the distance from tree trunk. Soil water content (SWC) was same among the treatments in *C. Tetragonoloba* (Guar) grown with *H. binata* but it was higher with increasing soil depth and distances.

Benefits of the research: Enhanced agricultural production under agro-forestry system will lead to better livelihood option.

Development of agro-forestry models with RET species for Telangana and Andhra Pradesh (IFB)

Species layouts were raised in 2.25 ha, with rose wood + red sanders; teak + sandal and eucalyptus + sandal were ploughed and sown during rainy season with *Ocimum* species (Tulsi), sorghum and pigeon pea species. 2.25 ha land where *Eucalyptus*, *Annona*, *Emblica officinalis* (Amla, Usiri), Bamboo, *Azadirachta* (Neem, Vepa), etc. raised has been cleaned and sown with agri-crops and medicinal plants like cotton and *Withania somnifera* (Ashwagandha). An agroforestry system based on red sanders + *Flemingia semialata* has been established in one hectare area. A total of 1200 farmers were trained on medicinal plants based agroforestry techniques during the year.

Benefits of the research: Agroforestry systems with RET species for Telangana and Andhra Pradesh have been developed and maintained for demonstration. 1200 farmers and foresters have been trained and nearly 5000 farmers are in touch with the Institute for

establishing these models on their farms.

Study on status of Agro-forestry Systems existing in Punjab, Haryana, Uttarakhand and North-West region of Uttar Pradesh (FRI)

Data on existing agro-forestry and socio-economic status of total 107 villages from districts Yamunanagar, Ambala and Kurukshetra (Haryana), Haridwar, Dehradun, Pauri and U.S. Nagar, Nainital (Uttarakhand) and Bareilly District of Uttar Pradesh have been compiled and analyzed.

Benefits of the research: Information on prevailing agroforestry practices in the region will lead to development of suitable agroforestry model for the region. The study will be beneficial in assessing the adoption of agroforestry on farmland.

Development of model of some important medicinal plants with *Melia dubia* (Burma Drake) and *Embllica officinalis* (Aonla) in degraded land of Punjab and Uttarakhand (FRI)

On Farm Research (OFR) plots of agri-silvimedical agroforestry system were established in degraded lands at Naukragrant in district Haridwar (Uttarakhand) and Handesra in district Mohali (Punjab). Saplings of *Melia dubia* (Burma Drak) and *Embllica officinalis* (Aonla) were planted at 6m x 4m spacing and medicinal plants namely *Rauvolfia serpentina* (Sarpagandha) and *Withania somnifera* (Aswagandha) at 60cm x 60 cm spacing as an intercrop along with seasonal agriculture crops. *Melia dubia* and *E. officinalis* plantation performed well in both the experimental sites. *R. serpentina* also performed well under Aonla and *Melia* in



Field demonstration during awareness programme



Survey on socio-economic status of farmers and their Agroforestry Systems in Sitarganj (U.S. Nagar)

experimental sites under rainfed condition. A farmers' visit to the trial was organized for awareness generation.

Benefits of the research: New Agroforestry model having medicinal plants as intercrop with *Melia dubia* and *Emblica officinalis* were

developed for degraded land of Punjab and Uttarakhand. Developed models will be useful for farmers, forest department and industries dependent on medicinal plant.

2.3 Wood Science and Technology

Utilization potential of timber from *Melia dubia* syn *Melia dubia* (Burma Drak) (FRI)

Lops and tops of *Melia dubia* (Malabar neem) were utilized to prepare Particle Board and Medium Density Fiber Board. The suitability of combi-ply from *M. dubia* and poplar combination plywood of 3-ply, 5-ply, 7-ply, and 9-ply have been developed and tested. Poplar and *Melia* were found compatible for combination plywood.

The study illustrates that lacquer gives very high gloss on *M. dubia* wood substrate compared to even polyurethane. Melamine, on the other hand gives only half the gloss that is provided by Lacquer. However, on exposure to high humidity for 25 days, Lacquer, NC lacquer and PU coated samples lose their initial glosses heavily by around 38% to 40 %. On the other hand, melamine coated samples retain almost 83 % of their initial gloss. Besides finishing studies, the systematic evaluation of working quality index of *M. dubia* under six machining parameters viz. Planning, Sanding, Shaping, Boring, Mortising and Turning indicates that the working quality of *M. dubia* wood is comparable to teak.

Benefits of the research: Developed process for preparation of ply board from *M. dubia* and

also assessed utilization potential of the species in various uses.

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

Various properties of treated wood samples were tested for comparing them with untreated wood and between different treatments. Testing of hardness, compression, nail and screw holding powers of the heat treated and untreated wood samples of these species were carried out. Darker brown colour of wood was increased due to increasing treatment temperature. Heat treated wood from fast grown plantations may be used for different value-added applications due to low EMC, higher dimensional stability and water resistance. Heat treated wood panels were fixed as wall cladding at office of MOEF&CC, New Delhi and also at IWST, Bengaluru for demonstration of thermally modified wood. Two fast growing wood species raised in Punjab, namely Subabul and *Casuarina* are included for evaluating their behaviour against thermal treatment, optimizing the processing parameters and value addition by making prototypes.

Benefits of the research: The modified wood exhibits certain improved properties such as



Chair from heat treated Melia wood



Table made from heat treated Poplar wood



File Tray made from Melia wood

higher dimensional stability, darker brownish colour, improved durability etc. which provides value addition to the fast grown plantation timbers.

Microwave assisted chemical modification of wood (IWST)

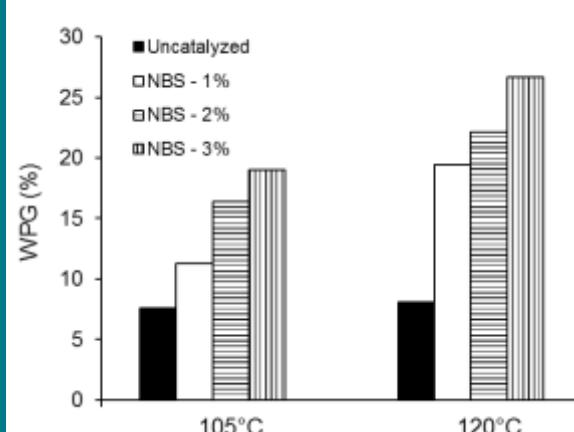
Solvent free acetylation of *Hevea brasiliensis* (rubberwood) with acetic anhydride and by means of N-Bromosuccinimide (NBS) as catalyst was carried out in an oil bath at 105°C and 120°C. The hydrophobic properties and dimensional stability of the acetylated wood were elevated. NBS was found to be an effective catalyst for wood acetylation. ASE increased with increase in degree of modification and microwave heating has no adverse influence on anti-swelling efficiency as compared to conventional heating. TGA analysis showed that modified wood is more thermally stable as compared to unmodified wood. Microwave-assisted solvent free modification of rubberwood was carried out using iodine as a catalyst. Degree of

modification in all cases increased with iodine concentration. The modified wood exhibited good ASE. The use of microwave irradiation minimizes use of excess reagent and avoids use of solvent. The significant reduction in reaction time means less energy consumption. Thus problems associated with generation of by-products can also be minimized.

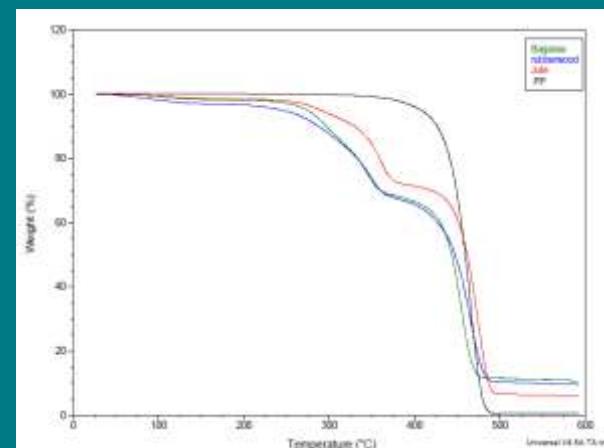
Benefits of the research: Development of new method of acetylation of wood using a new catalyst (NBS). It imparts dimensional stability and weathering resistance in wood for outdoor applications.

Bio-thermoplastic composites: Evaluation of physical, mechanical, morphological and thermal properties (IWST)

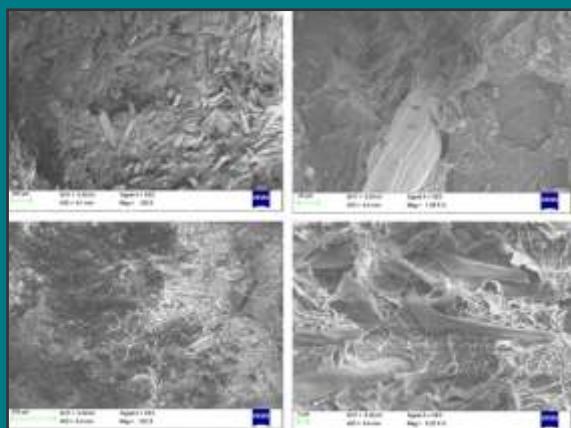
Bio fibre -Thermoplastic composites have been prepared in twin screw extruder. Composites of Rubberwood, coir and jute (20, 40 and 50% respectively) with 85 mesh and 150 mesh size particles were prepared with polypropylene and high density polypropylene (PP) as matrix material. Bagasse (20, 40, 50%) with 85 mesh



Comparison of WPG at different NBS concentrations after 60 min reaction at 105°C and 120°C.



Thermogravimetric analysis of various bio-fibres with reference to PP composites



SEM Micrograph (A), (B) are Jute-PP MAPP, (C) and (D) are Jute-HDPE g-MAPE

was prepared using PP. All the composites were characterised by FTIR to confirm the reaction between the coupling agents and fibre. SEM micrograph was recorded to evaluate the morphology and the compatibility between the thermoplastics and bio fibres. Flexural and Tensile strength of bio fibre-PP composites was significantly higher when coupling agent was added (5 wt % based on fibre content) compared to control composites (without any coupling agents) at all the filler loadings.

In case of coir-PP and coir-HDPE composites, properties of composites with coupling agents were more than that of uncoupled composites as observed in rubberwood based composites. However coir based composites exhibited inferior properties than rubberwood based composites. Coir also exhibited thermal degradation on compounding and injection moulding.

Benefit of research: Development of bio-fiber-thermoplastic composites (This is part of the technology developed earlier on Wood Plastic). It has potential of reducing the use of plastic, which pollute the environment. These can be used mainly in automobile, building and construction field (wall cladding, decking, railing etc.). These composites are cost effective and environmental friendly. Based on the research, industrial collaboration has been taken up, which is generating revenue on monthly basis.

Wood Science and Technology for Livelihood and Economic Growth (FRI)

Five fire retardant-cum-preserved compositions were developed and three

bamboo species viz. *Bambusa nutans* (Burmese timber bamboo), *Dendrocalamus strictus* (Calcutta bamboo) and *Bambusa polymorpha* (Betwa) were treated. Samples treated with all compositions performed better than the control samples and samples treated with two compositions that passed all the three tests in all bamboo species. Durability of bamboo species when exposed to above ground under shade was studied by double layered test results. After 12 months of exposure, they did not show any attack on all the treated samples, but the control samples of *B. polymorpha* and *B. nutans* showed slight attack whereas the control samples of *D. strictus* showed no attack.

Benefits of the research: Developed fire retardant-cum-preserved compositions for bamboo for improving durability of bamboo products.

Nano-cellulose filled starch based composites (IWST)

Thermo-plasticization of starch with different plasticizers like glycol, glycerol, urea, formamide, poly-vinyl alcohol (PVA), poly ethylene glycol (PEG), water and their combination was carried out to achieve optimum thermo-plasticization. The microscopic characterization indicates the disruption of granulated structure of starch after thermo-plasticization.

Completely bio-degradable composites were developed by blending TPS with PLA along with the fillers (Nanocellulose, MCC, wood, nanoclay) in different proportions and tested for mechanical properties. Injection moulding parameters were also standardized for the developed composites. Increasing TPS



Thermoplasticized Starch



TPS50/PLA50



TPS70/PLA30

proportion in the composite resulted in reduction in strength properties. The results indicate the potential of tailoring properties of



Nanocellulose reinforced biodegradable composites for specific applications

the composites depending on the end-applications. Injection moulded and die-casted products were prepared from the developed biodegradable composite materials for demonstration purpose.

Benefit of research: This research has contributed in the development of technology on wood plastic composite that has potential of developing completely bio-degradable composites. New application of nano-cellulose for developing products for specific applications like packaging, insulating materials, etc. These composites are environmental friendly. Based on the research, trials are being carried out with industry for taking up biodegradable composites at commercial scale.

Evaluation and comparison of wood quality of teakwood produced from tissue culture and seed sources (IWST)

Certain wood quality parameters of two categories of plantation teak trees of 12-14 years old grown from the tissue culture (TC) and seed-based (non-TC) sources raised in Nalgonda district of Telangana state were evaluated. TC grown teak exhibited slightly higher growth rate, wood basic density, bark thickness, while moisture content (air-dry) and shrinkage properties were found to be comparatively higher in non-TC grown teak. However, no statistically significant difference was observed in terms of heartwood percentage, and most of the anatomical properties between TC teak and NTC grown teak.

Benefits of the research: The work involved testing and comparison of certain anatomical and physical properties of two categories of teakwood using increment core samples. The results will suggest the proper source (TC/Non-TC) for growing teak as per the requirement.

New methods of chemical modification of wood for improving dimensional stability and durability (IWST)

A process of solvent free chemical modification for *Hevea brasiliensis* (rubberwood) with isopropenyl acetate (IPA) in presence of anhydrous aluminium chloride and iodine as catalyst has been developed. Modified wood exhibited good dimensional stability and hydrophobicity. Unmodified wood showed rapid colour changes and degradation of lignin upon



exposure to UV light. Chemical modification of wood polymers with IPA was effective in reducing light induced colour changes at wood surfaces. Thermo-gravimetric analysis showed that modification with IPA improved thermal stability of wood. Decay resistance of IPA modified wood was evaluated by exposing unmodified and modified wood to a brown rot (*P. meliae*) and white rot (*T. hirsuta*) fungi for a period of 16 weeks. Modified wood inhibited decay due to brown rot and white rot fungi.

Benefits of the research: Development of new method of chemical modification of wood using iso-propenyl acetate that imparts dimensional stability and weathering resistance in wood for outdoor application.

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

Optimization of liquefaction reaction using three liquefying agents namely phenol, glycerol and polyethylene glycol was carried out at different reaction temperatures and at different wood to liquid ratio. Liquefaction efficiency of different wood fibres like *Melia*, *Eucalyptus*, rubberwood, silver oak, bamboo, *Lantana* and coir was also evaluated. Among the liquefying agents, phenol was found to be the most effective and liquefaction efficiency of up to 90% and 3:1 liquid ratio was achieved at 140°C. Among different species, lantana stem meal was found to exhibit the highest liquefaction efficiency in phenol.

Benefits of the research: Development of new way of utilizing woody waste that is potential substitute of petroleum based phenol in adhesives for wood based composites. Liquefied wood can be raw material for developing new products like polyesters and foams.

Wood modification of *Melia dubia* for improving its dimensional stability and durability (IWST)

M. dubia (Melia/Hebbevu/ Malabar neem) wood were thermally modified in the temperature range of 180°C–235°C in a vacuum oven. Mass loss due to heat treatment and colour changes were evaluated. Heat treated wood was characterized using FTIR spectroscopy. Thermal modification of *M. dubia* using hot Pongamia oil was carried out in the temperature range of 170°C -220°C. Modified

wood showed good dimensional stability.

Benefits of the research: Development of Thermal Modification Technology that improves dimensional stability, decay resistance and aesthetic value of secondary timbers.

Determination of the treatability and durability of imported timbers as per Bureau of Indian Standards (IWST)

Observation at 96 months after implantation has been taken in all the testing sites, viz., Hyderabad, Jabalpur, Nallal, Palode and Visakhapatnam except Jodhpur, on the durability of moderately resistant timber *Quercus robur*, and highly resistant timbers viz., *Dryobalanops aromatica*, *Tectona grandis* (from five countries), *Shorea laevis*, *S. macroptera*, *S. robusta*, *Pterocarpus soyauxii* (from two countries) and *Xylia dolabiformis*. Data on the bio-efficacy of CCB and Timber Protect on highly susceptible timbers viz., *Fagus sylvatica*, *Fagus grandifolia*, *Fraxinus angustifolia*, *F. excelsior*, *Acer pseudoplatanus* were collected upto three years after treatment. Natural durability observation of two additional imported timbers viz., *Instia palembanica* (Merbau) from Malaysia and *Dipterocarpus grandiflorus* (Gurjan) from Myanmar at 36 months after implantation has also been taken.

Benefits of the research: The research findings provide way for the right choice of timber species to various uses as per the requirement.

Assessment of wood quality variability in tree species prevalently grown in Punjab (IWST)

For evaluation of plantations of Poplar, *Melia dubia* (Melia/Hebbevu/ Malabar neem), *Salix* and *Eucalyptus*, growth data along with Pilodyn measurements and transit time were collected. The trees were evaluated for wood quality and few trees of *M. dubia* and *Eucalyptus* species were identified for seed collection. In addition, plantations of Sandalwood at Bir Sanour Patiala and *Ailanthus excelsa* (Mahaneem) were also evaluated for wood quality.

Benefits of the research: Identification of superior genotypes of *Melia* and *Eucalyptus* based on wood quality parameters. Protocols for selection of superior genotypes was developed and demonstrated to the field staffs of Punjab Forest Department.

Assessment of natural variability in selected wood traits using non-destructive tools and identification of superior genotypes of *Melia dubia* (IWST)

Wood quality assessment was carried out in 9-year-old plantation of *Melia dubia* located at Yeshwanpura Range, Kolar District. Pilodyn penetration with and without bark, acoustic velocity, bark thickness, tree height and girth at breast height were recorded in nearly 600 trees. Increment cores were extracted from few selected trees for determination of sapwood/heartwood content and wood density. The average wood density was found to range between 330 kg/m³ to 520 kg/m³ with an average density of 400 kg/m³ (CV- 11%). Based on pilodyn penetration and acoustic velocity, few trees were identified as the potential superior genotypes in the plantation.

Benefits of the research: Identification of superior genotypes of *Melia* based on wood quality parameters for further propagation.

Development of natural fibre filled thermoplastic composites from natural resources available in the state of Punjab (IWST)

The process of compounding *Lantana* stem flour with polypropylene to get composite material that can either be injection moulded or profile extruded has been completed. The proportion of various additives required to be added during the compounding has been worked out. The injection moulding parameters have been studied for composites with varying polymer-fibre ratio. At low fibre content i.e. 30% or less, injection moulding is generally defect free. However, at higher filler loading (>30%) streak is a major issue. Effective drying of WPC granules before moulding, increasing the screw

filling and injection pressure were found to be remedial measures. WPC spoons were moulded with 40% lantana fibre filled composites.

Benefits of the research: Development of *Lantana* fiber filled thermoplastic composites (Part of Development on Wood Polymer Composite Technology). Utilization of Lantana for value added Products. Expanding the choice of natural fibers for Wood Polymer composites.

Study on constraints in the export of carved out wood products and its economical and social impact on the livelihood of dependent people in North India (FRI)

The study area includes Uttar Pradesh, Uttarakhand, Punjab, Rajasthan and Jammu & Kashmir. Preliminary reports based on reconnaissance survey of ten wood carving centres indicate that in Nagina, Uttar Pradesh approximately Rs. 30 crore worth wooden products are exported to various countries and about 1400 manufacturing units are there, employing about 10,000 people in carving industry. In Nagina and Saharanpur, 20 trucks/day (1truck = 200 quintals) raw material was used. From Jodhpur and Saharanpur, approximately Rs. 1,500 crores and Rs. 400 crores worth of wooden items have been exported in a year, respectively. About 90% of the products are exported and only 10% are sold within the country. USA, Canada, Spain, Japan Taiwan, Philippines and Gulf countries are the main export destination countries.

Benefits of the research: Development of qualitative data bank on constraints in export of furnished timber that would help exporters in planning and execution of export of finished wood products.

2.4 NWFP and Medicinal Plants

Phyto-chemical screening of selected wild edible plants for exploration of new sources of Luteolin (FRI)

Callicarpa macrophylla (Dahiya, Priyangu, Beauty berry) leaves, *Prunus armeniaca* (Chulu, Khubani, Urumana, Armenian plum

or Tibetan apricot) fruits and *Myrica esculenta* (Kaphal, Katphala, Mahavalkala, Box myrtle, Bayberry) fruits were collected, processed and prepared for further analysis to carry out replicated analysis of some physio-chemical and phyto-chemical traits.

Presence of luteolin in the extracts of edible parts of the target species were detected through co-TLC with standard sample. Total phenolic content and total flavonoid content in extracts were estimated and free radical scavenging (FRS) activity of extracts was assessed following DPPH protocol.

Benefits of the research: Bioactive profiling and investigation of functional properties of wild edible plants are significant addition to the scientific knowledge on nutraceutical and pharmacological value of Wild edibles plants. New sources of bioactive phytochemical, Luteolin have been identified from these wild edibles which would help in economic gain through value addition.

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

Biomass residues of three *Cymbopogon* spp. namely *C. citratus* (Lemongrass); *C. nardus* (Citronella grass); *C. martinii* (Palmarosa or Rosha grass) (spent leaves), *Eucalyptus* hybrid (Mysore gum) (bark and spent leaves); *Populus deltoides* (Poplar) (bark and saw dust); *Shorea robusta* (Sal) (bark and saw dust), *Ocimum sanctum* (Holy basil or Tulsi) and *Mentha arvensis* (Mint or Pudina) were collected from wood based industries and essential oil distilleries located at Haryana, Uttar Pradesh and Uttarakhand, shade dried and milled. TPCs and DPPH free radical scavenging capacity (DFRSC) of these extracts were determined. The amount of TPCs (mg GAE/g extract) varied widely. All the extracts exhibited concentration dependent varied scavenging capacity. A significant correlation between TPCs and DFRSC was observed indicating that extracts with the highest phenol contents showed the lowest EC₅₀ values. Thus, phenolics in these biomass residues were attributed to be the good contributors of their DFRSC.

Benefits of the research: The extracts from poorly valorized biomass residues showing previously unknown free radical scavenging capacity could be utilized to develop antioxidants.

Process refinement for extraction of quality fibre and optimal isolation of bio-active constituents from *Agave sisalana* (Sisal) (FRI)

Altogether five different analytical approaches were worked out and tried for sapogenin separation from leaf extract. The steroid mixture, Hecogenin-Tigogenin was recovered from sapogenin part and isolation of hecogenin was attempted with 95% purity. *A. sisalana* (Rambas, Sisal, Sisal hemp) leaves were subjected to disintegration with bio-degradable materials for extraction of full length fibre. Fibre extracted from differently pre-treated sisal leaves were evaluated for yield, physico-chemical (solubility, response towards different tests/reagents) and anatomical (fibre length, diameter, wall thickness) characteristics.

Benefits of the research: The study will be helpful in identification of plant or population having high content of its major bioactive compound. Process for fibre extraction through biological pre-treatment will be beneficial for all engaged in extraction and marketing of natural fibre.

Evaluation of antifungal properties and chemical characterization of active principle(s) of *Berberis aristata* D.C. collected from different provenances of Himachal Pradesh (FRI)

Berberis aristata roots (from 13 locations) were collected from Himachal Pradesh and screened for their antifungal properties. Out of thirteen samples, six samples were extracted with different solvents and it was observed that maximum yield was obtained in methanol extract of sample collected from Khadrala, Sungri at an altitude of 2864m. During screening of antifungal activity, chloroform extract seemed most effective as it showed inhibitory activity

against all the fungi barring source Narkanda in case of *Fusarium solani* and source Chirgaon in case of *Sclerotium rolfsii*.

Benefits of the research: The research findings have the potential of developing eco-friendly bio-pesticides.

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

Germplasm of *Andrographis paniculata* (Kalmegh) and *Bacopa monnieri* (Brahmi) was collected from Ranchi, Jharkhand; Jabalpur and Bhopal; Madhya Pradesh; Lucknow, Uttar Pradesh; Bengaluru, Karnataka; Anand, Gujarat; Sonipat, Haryana and Haridwar and Rishikesh; Uttarakhand. Germplasm was also collected from research institutions like Central Institute of Medicinal and Aromatic Plants, Lucknow; National Botanical Research Institute, Lucknow; State Forest Research Institute, Jabalpur; Directorate of Medicinal and Aromatic Plants Research, Anand; Anand Agricultural University, Anand; Indian Institute of Horticultural Research, Bengaluru; FRLHT, Bengaluru; Natural Remedies, Bengaluru; Dabur, India Ltd and Patanjali Ayurved, Haridwar. These are being maintained in the nursery as mother plants. Observations on their growth attributes were recorded for all the accessions. Methods for estimation of andrographolide and bacoside from *A. paniculata* and *B. monnieri* respectively were standardized. Andrographolide content in *A. paniculata* accessions ranged from 2.15 to 2.65 percent whereas bacoside content in *B. monnieri* ranged from 1.85 to 2.35 percent.

Benefits of the research: Standardisation of methods for extraction of active ingredients from medicinal plants from different sources. Identification of superior germplasm will benefit forest department and farmers.

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

Wax (1.64%) was isolated from *Pinus roxburghii* needles. It was saponified to prepare acids. Quantification of saponified and non-saponifiable products was done. The saponified wax was converted to its methyl esters.

Benefits of the research: A process was developed to isolate pure wax in 1.64% yield. Pine needles may be utilised for isolation of wax and its derivatives thereof.

Studies on harvesting time of some medicinal plants for their natural antioxidants constituents (TFRI)

The samples of *Asparagus racemosus* (Satawar), *Argeria speciosa* (Elephant creeper) and *Curculigo orchoides* (Kali Musli/black gold) collected from Maharashtra were estimated for antioxidant activity and phytochemicals - phenol, flavonoids, phenolic acids, quercetin, β -sitosterol and lupeol for the standardization of suitable harvesting time with respect to antioxidant constituents. The total antioxidant activity of *A. speciosa* was observed to be maximum in samples collected in the month of October (0.031 mg/ml, low IC⁵⁰ value) followed by January. The IC⁵⁰ value in the leaves varied between 0.031-0.804mg/ml. The IC⁵⁰ value of *C.orchoides* varied from 0.0151 to 0.939 mg/ml in different months. The lowest total antioxidant activity (equivalent to highest IC⁵⁰ value) was estimated in samples collected in the month of July. It was determined that antioxidant activity was highest (low IC⁵⁰) in the month of January followed by April.

Benefits of the research : Standardization of harvesting and collection time of medicinal plants to optimize antioxidant potential and other bio-chemicals. The present study has focused on seasonal variation in natural antioxidants and other useful biochemicals, for optimal harvesting of these species.



Standardization of processing and storage techniques of Malkangni (*Celastrus paniculatus*), Baheda (*Terminalia bellerica*) & Baividang (*Embelia tsjeriam-cottam*) fruits/seeds (TFRI)

The fruits/ seeds of Malkangni, Baividang and Baheda were collected from the forest areas of Chhindwara, Madhya Pradesh. Dried seeds of Malkangni, Baividang and Baheda were stored in different containers (jute, polythene, markin cloth, tin, glass and plastic) and control was kept in open environment. The study showed that the polythene containers at room temperature were found suitable for storing the said seeds.

Benefits of the research : Processing and storage techniques of seeds of Malkangni (*Celastrus paniculatus*), seeds of Baividang (*Embelia tsjeriam-cottam*) and rind of Baheda (*Terminalia bellerica*) fruits were standardized. Improper storage of medicinal plants or their plant parts lead to rapid deterioration.

Development of database on Non-Timber Forest Produce (NTFP) in Karnataka (IWST)

Under the web based database project, data were collected on various aspects from different National and International leading networks, agencies and organization in consultation with NTFP experts. Market survey was done in B.R. Hills, Hanur, Chammarajnagar, Mysore, H. D. Kote, Hunsur, Bagalkot, Gokag and Belgaum in Karnataka. The information about NTFP collection details, market price and LAMPS society related information was collected. Residual data collection is under progress through Internet, Library and local market survey.

Benefits of the research: The database development will be helpful to stakeholders such as Forest Department, NGOs, general public etc.

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

Studies on market price in tribal dominated area of Abu Road in Sirohi District of Rajasthan reveals that NTFP collection at village level is not organized. Barter system still exists in the village. NTFP collected by tribals are sold at minimum/very low rates to the local agents i.e. mostly owner of grocery shop, from where tribals barter the items of daily needs with their NTFPs. Family labour is the key input in collection and processing of NTFPs. *Butea monosperma* (Palash) plays an important role in tribal livelihood. Fresh flowers are collected and sold by children @Rs.20/- per kg in local market. Leaves are plucked and used for making Dona-pattal (substitute of bowl and plate) during societal functions of tribals. In March-April, *Diospyros melanoxylon* (Tendu) fruits are collected and sold in nearby Market @ Rs.15-Rs.20/- per kg. In May-June, 'khajoor' and 'rayan' fruits are collected and in June-July, *Anona squamosa*(Sitaphal) and *Syzygium cumini* (Jamun) fruits are collected and sold. On the onset of monsoon collectors earn good money by collection of *Momordica dioica* (Kankeda) fruits in the market which are sold @Rs.80/- per kg in the beginning of the season (July) and @ Rs.30/- per kg in the end of the season (Sept.). In Nov.-Dec. the tribals get involved in *Cassia tora* seed collection, cleaning and selling @ Rs. 10/-kg.

Benefits of the research: Value addition of *Momordica dioica* (Kankeda) will diversify its utility amongst tribal population.

Development of sustainable model for enrichment of selected Medicinal Plant Conservation Areas (MPCAs) of Uttarakhand Himalayas (FRI)

Total 3796 propagules of three target species were planted under enrichment field trials in Khuliya and Kandara MPCA area

which includes *Aconitum heterophyllum* (Atis), *Nardostachys grandiflora* D. C (Jatamansi) and *Picrorhiza kurrooa* Royle ex Benth (Kutki). Survival percentage of Kutki propagated by rhizomes, seedlings and seeds has been recorded as 41%, 57% and 33%, respectively at Kandara. In Atis, 30% and 45% survival percentage was recorded when propagated by seeds and seedlings, respectively. At Khuliya MPCA, the survival percentage of Kutki was better as compared to Kandara MPCA. Jatamansi seedlings did not perform well in Khuliya MPCA.

Benefits of the research: Resource Enrichment techniques have been developed. The research shall help the stakeholders in enriching the MPCAs.

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

Experiments were laid out using different types of incisions in different months and quantity and quality of Oleogum resin was evaluated to standardize harvesting technique. Samples were stored in different containers i.e. Polythene Black & White, Jute Bags, Plastics Bags, Plastics Bottles and Glass Bottle in light and dark. Guggulsterone Z &E was estimated in stored samples monthly. The quantity of Guggulsterone Z&E varied 0.249-1.02% and 0.47-1.96%, respectively. Maximum quantity of Guggulsterone Z &E was observed in samples stored in glass bottles in dark conditions.

Benefits of the research: Non destructive harvesting and storage techniques of oleogum resin from *Commiphora wightii* (Guggul) were standardized, which will be useful for sustainable harvesting. This will result in increase in productivity of Guggul and conservation of species.

Standardization of non-destructive harvesting practices of *Commiphora wightii* gum Oleogum resin in Rajasthan (AFRI)

The experiments with treatments of four different cut sizes and three cut patterns were executed at both sides of selected *Commiphora wightii* (Guggal) plants. A total of 234 treatments at Kailana hills, Jodhpur (Rajasthan) and 180 treatments at Ler, Bhuj, Gujarat were applied on the selected plants. The extracted gum from each treatment was collected in zip lock bags and recorded for statistical analysis. Initial results of gum collected from treatments at Kailana hills revealed that there is significant difference in the average gum production by different sizes of cuts (1 cm- 0.45 gm, 2 cm- 0.69 gm, 3 cm- 0.76 gm, 4 cm- 0.88 gm; F- 7.436; p- 0.000) and also in different pattern of cuts (Horizontal- 0.81 gm, Oblique- 0.73 gm, Vertical- 0.53 gm; F- 6.338; p- 0.002). The gum production was also found to be proportional to the girth size. The tapped plants were monitored and all were healthy and there were no casualties even after one year.

Benefits of the research: Standardised non-destructive method of guggal gum harvesting will keep the tree healthy and productive.



Guggul gum tapping at 'Ler' site of Bhuj forest division in Gujarat

Optimization of processing methods for *Prosopis cineraria* and *Capparis decidua* fruits for their improved utilization in Western Rajasthan (AFRI)

Kair fruits were graded using custom-fabricated sieves of different sizes viz. <4mm, <6mm, <8mm, <10mm, <12mm, >12mm. Khejri pods were categorised on the basis of their thickness. Moisture content of kair fruits was 65-78% (April-May), 63-78% (June-July) & 67-73% (Oct-Dec). Moisture content of Khejri pods was 66-74%. Sugar content in kair fruits was 10-11% in marked trees from Jodhpur. After 3 months, fruits preserved at -22 oC showed slight decrease in sugar content (9-10%). Sugar evaluation in traditionally processed fruits showed that there was slight change in sugar content after 10 days of soaking in buttermilk (9-11%). Hence, this appears to be the best treatment as far as processing in different solutions viz. salt solution, lime and buttermilk is concerned. With storage, both ash and protein content was found to decrease with time. On soaking the kair fruits in different solutions, both ash &



Graded kair fruits as per size

protein was found to remain almost constant upto 8 days of treatment and after that their value decreased. Pre-heated solar drying was found to be best among all the other methods for ash content. Kair fruits and sangri pods preserved in refrigerator, deep freezer (-22°C), brine and vinegar, remained in good condition upto 10 months of storage.

Benefits of the research: Preservation & packaging of Kair & Sangri for longer use and longer shelf life.

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

28 industries dealing with neem (*Azadirachta indica*) products were visited in Sojat city of Pali. It was observed that there is no organized market for selling of neem leaves. Farmers bring neem leaves to Krishi Upaj Mandi along with other agriculture products. There is a large variation in the sale price of neem products viz. neem leaves and neem powder, as only the neem leaves are tax free whereas 5 % tax is applicable in case of neem powder. Knowledge regarding marketing channels of neem products is very limited right from farmers to the industries at Village/District level. Further, facilities like collection, drying and trading/exporting etc. are also not available.

Benefits of the research: The study will



Preservation of Kair



Preservation of Khejri Sangri

Different processing methods for *Prosopis cineraria* (Khejri) and *Capparis decidua* (Kair) fruits

help in better planning for socio-economic upliftment of people involved in trade of neem products.

Tapping the potential of some selected indigenous lesser known wild edible plants for food and nutrition in arid and semi-arid region (AFRI)

High ash content was observed in *Haloxylon salicornicum* (Sajji) (14.09-53.65%) after analysis of samples, which was followed by *Calligonum polygonoides* (Phog) (8.84-9.68%), *Cassia tora* (Puad) (7.33-14.7%), *Ceropegia bulbosa* (Khedula) (5.9-10.9%), *Cordia gharaf* (Goondi) (5.9-9.33%), *Leptadenia reticulata* (Jivanti) (5.39-7.40%) and *Grewia tenax* (Gangeti) (3.7-4.2%). Sugar content in the samples was highest in *Cordia gharaf* (39.1-47.7%) followed by *Grewia tenax* (24.7-34.1%), *Ceropegia bulbosa* (15.1-22.7%), *L. reticulata* (6.7-12.2%), *Calligonum polygonoides* (6.3-7.3%), *Cassia tora* 3.3- 5.3% (Bali) and *H. salicornicum* (2.8-7.8%). Maximum phosphorus content was found in *Cassia tora* (Bali) - 42.73 mg/100 gm, followed by

L. reticulata (Nagaur), 24.85 mg/100 gm, *Cordia gharaf* (Jodhpur) - 24.65 mg/100 gm, *Grewia tenax* (Jodhpur) (21.62 mg/100 gm), *Leptadenia reticulata* (Bali) - 21.13 mg/100 gm, *Haloxylon salicornicum* (lathi, Jaisalmer) - 20.79 mg/100 gm, *Calligonum polygonoides* (Bikaner) - 9.36 mg/100 gm and *Ceropegia bulbosa* (Bali) - 4.46 mg/100 gm. Gamma irradiation (5 Gky) was given to *Grewia tenax* and *Cordia gharaf* fruits in DRDO, Jodhpur and delay in fungal infestation was observed in irradiated samples. *Cordia gharaf* fruits stored in freezer of refrigerator were preserved for more than a year. Cut and dried pieces of *L. reticulata* pods were preserved for 3 months.

Benefits of the research: Development of value added products from indigenous lesser known wild edible plants will act as nutritional food supplements for rural population.

Studies on the traditional knowledge of the medicinal plants used by Nepali community in Assam and identification of important species for chemical analysis (RFRI)

A total of 123 plant species representing 51 families were recorded from 29 Nepali villages, in Kamrup, Morigaon, Jorhat, Golaghat, Sibsagar, Dibrugarh, Tinsukia, Sonitpur, Darrang and Dhemaji Districts of Assam. Among 123 recorded species, 29 plants are being used as medicine by the Nepali community. The most common species used by them are *Aloe vera* (Salkuvari), *Cuscuta reflexa* (Akasilata), *Ocimum sanctum* (Tulsi), *Centella asiatica* (Manimuni), *Leucas aspera* (Durun), *Tagetes erecta* (Narji), *Alternanthera brasiliensis* (Bishoilyakarani), *Psidium guajava* (Guava, Madhuri), *Drymeria cordata* (Laijabari) and *Ananas comosus* (Mati Kothal). The medicinal plants are used for fever, cough, blood pressure, jaundice, diabetes, worms in children, injury or cut and piles. Most of the plants are used to cure stomach problems. People consume



Cut & dried
L. reticulata pods



Cordia gharaf fruits
under refrigeration



Haloxylon salicornicum fruiting branches
Indigenous lesser known wild edible plants
and products of Rajasthan

medicinal plant parts in the form of powder, decoction, paste, and juice. It was observed that women and school teachers have fair knowledge on the use of traditional medicine. However, people below the age of 25 years did not show any interest in the traditional medicine.

Benefits of the research: The study has helped to document the indigenous knowledge of Nepali community, which can be useful later in bio-prospecting and drug formulation. It also recorded the change in attitude towards traditional medicine among the younger generation.

Exploration of adhesive materials for incense sticks from the plant species (RFRI)

A total of 77 plant samples were collected from different parts of Assam, Meghalaya, Manipur and Arunachal Pradesh, and evaluated for their binding efficacy. Leaves, flowers, seeds and bark of 10 plant species, viz., *Actinodaphne obovata* (Pati-chanda) *A. angustifolia* (Petarichawa), *Litsea sebifera*



Seeds of *Litsea sebifera*



Actinodaphne angustifolia

(Neluka), *Hibiscus rosa-sinensis* (Jobaful, Gurhal), etc., were found suitable for use as adhesive material for agarbatti. The agarbattis so prepared were tested for their adhesive quality, durability, burning ability/efficiency, length of burning time and odour. Standardization of application of adhesive material was worked out for making hand rolled agarbattis.

Benefits of the research: These alternatives to the commonly used jigat, will help in conservation of *Litsea glutinosa*, which is becoming scarce due to debarking and over-exploitation for making jigat. It will also help in saving of foreign exchange, which is being spent on import of jigat. The raw materials identified in the project are all locally available in the villages, and would reduce the drudgery involved in collection of jigat from forests, and help in increasing the productivity of hand-rolled incense sticks. This will be of great benefit to the local communities involved in making hand-rolled agarbatties at Dhupdhara in Assam.

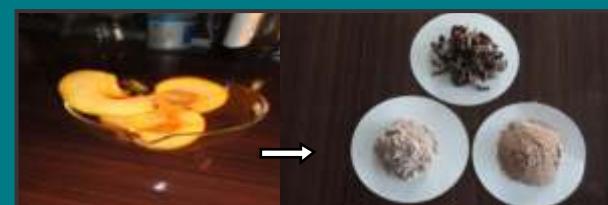
Evaluation of forest fruits for the nutritional value and development of value added products for economic enhancement of the local people (RFRI)

Sixteen value added products were prepared using *Carallia brachiata* (Kuji thekera), *Crataeva magna* (Borun), *Spondias axillaries* (Mitha Amora), *Dillenia indica* (Ou tenga), *Garcinia pedunculata*



Dillenia indica

Developed product



Garcinia pedunculata

Developed product

(Borthekera) and *Flacourtia jangomas* (Panial). In the process of value addition, the visual appearance and shelf life of the products have improved, compared to the traditional products.

Benefits of the research: New products developed will be of economic benefit to the villagers living in the vicinity of forests, engaged in collection, processing and sale of wild fruits.

National Medicinal Plants Board (NMPB) - Medicinal Plants Conservation Project (HFRI)

Three days training programme on, "Capacity Building Programme for the Frontline Field Staff of HP Forest Department" was organized under the project in collaboration with HP Forest Department Research Wing in which about 35 frontline field functionaries posted at various Forest Divisions actively participated. A field visit was also organized to give practical exposure about plant identification in general and medicinal and aromatic plants in particular.

Benefits of the research: The institute has helped the forest department in achieving its target towards *in-situ* conservation of the threatened and endangered species.

Ethno-botanical study on indigenous medicinal and aromatic plants used by local people of Chopal Forest Division, Shimla Forest Circle, Himachal Pradesh (HFRI)

Reconnaissance surveys in five ranges viz. Chopal, Deiya, Nerwa, Tharoach and Sarain of Chopal Forest Division were conducted. The ethno-botanical information on medicinal and aromatic plants from total twenty-seven villages falling in twenty two Beats of five Ranges after conducting semi-structured interviews was also collected and is being compiled. Geo-referencing of important medicinal plants such as *Berberis aristata* (Kashmal), *Polygonatum multiflorum* (Salam misri), *Angelica glauca* (Nihani), *Malaxis*

muscifera, *Podophyllum hexandrum* (Ban kakari) etc. were carried out.

Benefits of the research: The outcome of the research will be inventorisation and enumeration of medicinal and aromatic plants and status of ethno-botanical knowledge of indigenous people of Chopal Forest Division of Shimla forest circle. Geo-referencing of critically important medicinal and aromatic plant will help in identifying the habitat of these plants. This will also help in planning of conservation of traditional knowledge and devising management strategies for conservation of medicinal plants of the area.

Establishment of demonstration plots of Nisoth (*Operculia turpethum*) and Sheonak (*Oroxylum indicum*) (IFP)

The spacing at which plants need to be planted of both the species were standardized i.e. 60 x 30 cm in case of *Operculina turpethum* and 1m x 0.75 m in case of *Oroxylum indicum*. Kalmegh as an intercrop with *O. indicum* was successful. Vegetative propagation technique of Nisoth has been standardized for commercial seedling production. Preliminary chemical analysis of roots of both species was also carried out, depicting the presence of flavonoides, terpenoides and sugars.

Benefits of the research: Spacing for both Nisoth and Sheonak species has been standardized along with cultivation techniques for the targeted agro-climatic zone. The findings may be utilized for commercial cultivation of the species.

Raising of model nursery: Sponsored by the Telangana State Medicinal and Aromatic Plants Board (IFB)

A total of 50000 seedlings of *Santalam album* were raised in the nursery apart from trees like *Terminalia chebula* (Karakkai, Harra), *Pterocarpus santalinus*, *Gloriosa superba* (Glory lily, adavinabi, bachnag, kadyanag, kari hari, languli), *Terminalia bellerica* (Tani, Bahera) (10000) *Terminalia arjuna* (12000) *Emblica officinalis* (10000)



Aloe vera (Kalamanda, Kumari Ghritakumari, Indian Aloe) (26000) *Aspragus racemosus* (Pilliteegalua, Pillipesara, wild asparagus, Shatavri) (4000) *Ocimum sanctum* (Basil, Tulsi) (12000).

Benefits of the research: The nursery techniques for above species were developed. Farmers were encouraged and guided to raise these tree and medicinal crop plants in different Agro-forestry systems.

Establishment of Herbal Garden (IFB)

Seedlings of *Santalum album*, *Terminalia chebula*, *T. bellerica*, *T. arjuna*, *T. catappa* and *Gloriosa superba*, *Aloe vera*, *Aloe barbadensis*, *Pterocarpus santalinus*, *Emblica officinalis*, *Andrographis paniculata*, *Asperagus racemosus* and *Ocimum sanctum* plants were collected and maintained in the nursery for the purpose of herbal garden. The area of 2.0 ha has been fenced with chain link fencing to exclude wild boar and rabbits. The drip irrigation system for the entire area has been procured and an overhead tank installed in the garden.

Benefits of the research: Nursery technique has been perfected using seed for species, *Gloriosa superba* (Glory lily, adavinabi, bachnag, kadyanag, kari hari, languli). The garden serves the purpose of germplasm conservation and is also being used to demonstrate the medicinal plants.

***Morinda citrifolia* L. (Noni) - livelihood option for the people of North East India (RFRI)**

Elite clones of *Morinda citrifolia* (Noni) were procured from Central Agricultural Research Institute, Port Blair, and introduced in Assam, Mizoram and Tripura. Growth parameters, phenology and insect-pest incidences were studied. Methods of increasing the shelf-life of fruits were tried. Antioxidant properties of leaves and fruits were determined.

Benefits of the research: Plantations of noni have been raised on private lands, and

efforts have been made to link the cultivators to a food-processing industry at Jorhat, for supply of fruits at assured price, through the North East Centre for Technology Application and Reach (NECTAR), Department of Science and Technology.

AICRP on Networking of NTFPs in collaboration with HNB Garhwal University, Srinagar (FRI)

Survey on *Rhododendron arboreum* (Burans) was carried out in two districts viz., Pauri Garhwal and Rudraprayag District in Garhwal region. Field survey to explore information on occurrence of *Morchella esculenta* (Guchhi) in six villages of Uttarakashi District is under progress.

Benefits of the research: The findings will help in supporting livelihood of rural people.

Study on production of briquettes from invasive forest weeds and its utilization by JFM village (IWST)

Biomass samples of *L. camara* (Lantana) and *P. juliflora* (Vilayati babul/Bellary Jall) (2-3 tons each) has been procured. The fuel properties analysis (moisture, density, calorific value etc.) of *L. camara* and *P. juliflora* has been carried out. Both the biomass were found to have higher calorific value (19 to 20 MJ/kg), low ash content (< 1.5%), high volatile matter content and high fixed carbon content. Combustion characteristics of biomass sample has been done under oxidizing atmosphere. Biomass briquettes from the biomass sample have been prepared. Both the species are found to have excellent briquetting properties, mainly due to presence of high lignin content.

Benefits of the research: Development of good quality briquettes with high density, high calorific value, less ash content, high fixed carbon content.

Standardization of protocol for extraction of high Camptothecin from *Nothapodytes nimmoniana* (Ghanera/ Peenari) using cell culture technique (IWST)

Phyto-chemicals from the vegetative parts



(leaf and twigs) were extracted and camptothecin content were compared using standard camptothecin by TLC. Seed material was used for *in-vitro* culture initiation. Standardization of *in-vitro* germination was optimised by using different combinations of hormones (Auxins and Cytokinins). Callus culture initiated from young leaf and suitable precursors for suspension cultures for mass multiplication is in progress.

Benefits of the research: New method for extraction of resin -Herring bone method was standardized. The method is more efficient and also allows for the regeneration of the tapped area. Whereas, in the traditional tapping method, the cambial layer is totally destroyed which harms the growth of the tree.

Value addition of *Acacia* resources of the Nilgiris for employment generation and livelihood support (IFGTB)

Extracts of the seeds / pods of *Acacia mearnsii* (wattle), an invasive weed, could be used as sprays to control pests in agricultural fields. A commercially viable extraction protocol for the aromatic oil of the flowers has been developed. The forest dependent communities of the Nilgiris would be able to adopt the same to support their livelihood just as eucalypts oil is being produced and marketed by SHGs. The nutritive value assessment of the pods revealed that the species lacks anti-nutritional factor. With appropriate fortification, the species has high potential use in development of food / feed products

which can be marketed by the SHGs of the Nilgiri region.

Benefits of research: The study revealed that extracts of the seeds / pods of *Acacia mearnsii* could be used as sprays to control pests in agricultural fields. A commercially viable extraction protocol for the aromatic oil of the flowers has been developed. The technologies developed under the project could enable the self help groups of the Nilgiris to develop bio-pesticides, food / feed products and briquettes which would enable revenue generation.

Standardization of extraction methods, evaluation and quantification of Halmaddi from *Ailanthus malabarica* DC (IWST)

Halmaddi is a transparent resin and the major adulterants were identified to be maida and melamin powder. New method reduces cambial damage and hastens the healing process and no secondary infection by fungus and bacteria extraction was observed. The tapping can be continued after an interval of two years. The resin purification method is efficient, but prevention from moisture and soil particles is must. The resin should be kept in air tight bottles to prevent oxidation. It retains resin's fragrance. The yield per tree is observed maximum in the winter season. During summer, maximum resin accumulation takes place due to stress and yield is more when tapped during winter. With proper care and judicial way of extraction, Halmaddi can be a potential enterprising product.

Benefits of the research: The outcome of the research would reduce the pressure on natural forests for the need of raw material to extract the drug-Camptothecin.

2.5 Forest Diseases and useful Microbes

Studies on ecological and ethno-mycological aspects of wild mushrooms of Meghalaya (RFRI)

A total of 97 species of mushroom were collected from forest areas of Meghalaya. These mushrooms were identified on the basis of their macroscopic features and through microscopic studies. The traditional knowledge

on wild mushrooms was gathered from group interactions with local communities. Four important wild edible mushrooms have been selected for cultivation trials based on their potential market demand.

Benefits of the research: The study has documented the mushroom diversity in Meghalaya for the first time. As poisoning due



to contamination while collecting wild mushrooms is common in the region, cultivation of wild mushrooms would be of great benefit to the local tribal people, who regularly consume wild mushrooms.

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

Herbage belonging to *Ageratum conyzoides*, *Croton bonplandianum*, *Lantana camara* and *Parthenium hysterophorus* was collected and leaves separated, washed with distilled water, cured thoroughly in shade and pulverized to suitable size. Crude extract derived was stored for use in further experiments. Bacterial constituents from the biofilms formed on wooden structures in Visakhapatnam harbour waters were harvested. Mother cultures raised in the laboratory were sub-harvested and individual isolates of two genera were separated for further experimentation.

Benefits of the research: Outcome of the research will help in developing plant based anti-bacterial preparations.

Prospecting fungal resources for development of natural dye (FRI)

Protocols for producing various shades on silk, wool and cotton fabrics were standardized using *Xylaria polymorpha* (Dead man's fingers) dye. The dyed and mordant samples of different fabrics were tested for washing and light fastness as per Indian Standards so as to determine their quality and suitability for dyeing of textile fabrics.

Benefits of the research: Process for extraction of natural dye from *Xylaria polymorpha* and process for dyeing of various fabrics using *X. polymorpha* extracted dye have been developed. The natural dye from *X. polymorpha* offers an eco-friendly alternative to the harmful synthetic dyes.

Evaluation of antifungal properties and chemical characterization of active principle (s) of *Berberis aristata* D.C.. (English name – Indian beriberi, Hindi name – Daru Haldi) collected from different provenances of Himachal Pradesh (FRI)

Berberis aristata roots were collected from different zones of Himachal Pradesh and screened for their antifungal properties. Out of thirteen samples collected from various

altitudes, six samples were extracted with different solvents and it was observed that maximum yield was obtained in methanol extract of sample collected at an altitude of 2,864 m. During screening of antifungal activity, chloroform extract seemed most effective as it showed inhibitory activity against all the fungi barring source Narkanda in case of *Fusarium solani* and source Chirgaon in case of *Sclerotium rolfsii*. Sample from Sungri had maximum activity against all the three fungi in all the three extracts.

Benefits of the research: Bio-fungicide may be developed from Daru haldi for use as alternative method of disease management.

Effect of altitude and season on soil respiration, bacterial communities and enzyme activities in Uttarakhand (FRI)

With an aim to study soil respiration (refers to the production of carbon dioxide), sites were selected at different altitudes viz. < 500 m, 1000 m and > 1500 m in different locations in Tehri Garhwal, Dehradun and Pauri Garhwal Districts of Uttrakhand. Soil samples were collected from Pine, Deodar, Sal, Oak and miscellaneous forests during winter season. The samples have been processed for physico-chemical and microbiological analysis. Lab work is in progress for analysis of microbial population, enzyme activities and bacterial community.

Benefits of the research: Soil biological parameters are main indicators of soil health; therefore studies on effect of altitude and season on these parameters will provide very useful information about forest ecosystem of the area which could be utilised in better and informed forest management.

Exploration of Potential Beneficial Microbes in different Forest and Agriculture Ecosystems in Kolli Hills, Tamil Nadu and Imparting Training cum Demonstration on Bio-fertilizer Production and Application in Nursery and Field (IFGTB)

Analysis of physico-chemical parameters of the soil samples exhibited that all the soil samples were slightly acidic (pH 4.8 to 6.1). The EC ranged from 0.07 to 0.48. The available nitrogen was observed high in the soil samples collected from root zones of *Elettaria cardamomum* (Cardamom). The available phosphorus content was found more in the soil



samples collected from root zones of *Adhatoda vasica* (Adathoda). The amount of calcium and magnesium was found low. Population density of Plant Growth Promoting Rhizobium (PPGPR) and Actinomycetes was quantified using colony forming units. The population density of PGPR isolates was observed high as compared to Actinomycetes. It was also observed that all the rhizosphere soil and root samples had AM fungal spores colonization particularly in three different species viz., *Acaulospora*, *Gigaspora* and *Glomus*. Among them, the genus *Glomus* was found dominant with three species of medicinal plants.

Benefits of research: Potential beneficial microbes will be identified and their strain cultures bank will be developed and maintained. VAM bio-fertilizers will be mass multiplied and supplied to the user groups. Bio-fertilizer production units will be established for livelihood of Women Self help Groups in Kolli hills. Production and use of biofertilizers will help the end-users to reduce the money spending on purchase of chemical fertilizers.

Occurrence and diversity of the entomopathogenic fungus, *Metarhizium* in the soils of varied eco-climatic forest habitats of South India (IWST)

The fungus was identified from 1500 soil samples on the basis of morphological characteristics. Colonies once obtained were maintained in the form of pure culture for further identification. DNA extraction for genetic level identification was done by amplifying ITS sequence, EF1alpha gene and RPB1 alpha gene. Physical, chemical and organic characteristic of soil were studied. The results tend to indicate that the site-specific climatic conditions and soil characteristics play important role in occurrence and diversity of *Metarhizium*.

Benefits of the research: Information generated on the diversity of different strains of *Metarhizium*.

Formulation of bio-fertilizers consortium and their distribution to Forest Department (TFRI)

Strains of bacterial biofertilizers and AM fungi were isolated for selected tree species of Madhya Pradesh. Inoculants of bacterial bio-fertilizers and consortium of AM fungi were

prepared for selected species. Carrier based (activated charcoal powder, saw dust, grinded and filtered soil, vermi-compost, calcium carbonate) packets of different selected bacterial bio-fertilizers were prepared for distribution to forest department. Inoculants of AM fungi were also prepared in bulk in cemented beds (1 x 1 x 0.75m). Soil, sand and FYM in 2:1:0.5 ratios were used as carrier for production of AM inocula for beeja-sal, sissoo and teak.

Benefits of the research : Development of biofertilizers and consortia of AM fungi for use in nurseries of Beeja sal, Sissoo and Teak.

Studies on the causes of *Gmelina arborea* (Khamer/Gamhar) mortality in plantation of Madhya Pradesh (MP), Chhattisgarh (CG) and its integrated management (TFRI)

Disease and insect survey in *Gmelina arborea* plantation was conducted to record mortality status in MP and CG. On an average, only 16.5% trees were found healthy with no infection while rest 83.5% trees showed low to heavy infestation at different sites. Eight insects viz. *Eocanthecona furcellata*, *Eupterote geminata*, *Hapalia aureolalis*, *Indarabella quadrinotata*, *Tingis beesonii*, a leaf binder, a bark eating cutter pillar and a grasshopper and 8 fungi viz. *Ganoderma lucidum*, *Grifospaeria gmelinae*, *Epicoccum nigrum*, *Flavodon flavus*, *Hendersonula toruloidea*, *Hexagonia tenuis*, *Hypoxyton rubigenosum* and *Torula herbarum* were identified as associated with mortality of khamer. Field experiments at four sites, three in, Madhya Pradesh (Betul, Chhindawada and Jabalpur) and one in Chhattishgarh (Bilaspur) were conducted for management of *Gmelina* mortality. Treatments applied in these experiments include fungicide, (ridomil 0.2%) and insecticide (monocrotophos 0.05%) along with organic matter and vermi-compost in RBD. Average % increase in girth over control was obtained in mulch + vermi-compost treatment followed by Ridomil + Monocrotophos application after one year. In standing trees branches showing die back due to disease insect attack or damage were cut and the cut ends were painted with modified Chaubattia paste. The recovery of cut ends was found to be 28.6% more in so treated as compared to control after nine months of application.



Benefits of the research : Pest, disease complex infesting plantations of Khamer and its management have been identified.

Studies on the diversity of soil-borne entomo-pathogenic fungi in different land use system of North East India and their utility for the management of major defoliators of *Gmelina arborea* Roxb. and *Aquilaaria malaccensis* Lamk (RFRI)

Soil samples were collected from different land use systems in Assam, Meghalaya and Nagaland. *Fusarium oxysporum*, *Fusarium* sp., *Mucor* sp., *Aspergillus ochraceus*, *A. flavus*, *Trichoderma hamatum*, *Trichophyton* sp., *Beauveria bassiana*, *Rhizopus* sp., *Verticillium lecanii*, *Paecilomyces* sp. and *Metarhizium anisopliae* were isolated from the cadavers of *Galleria mellonella*. Molecular level identification was done for an isolate of *Beauveria bassiana* and the culture was deposited in National Fungal Culture Collection of India (NFCCI), Pune. Under both lab and field conditions, *B. bassiana*, *M. anisopliae*, *V. lecanii* and *Paecilomyces* sp. were found very effective against *H. vitessoides* and *C. leayana*. The concentration of 2.4×10^{10} spores/ml was found promising in achieving high levels of larval mortality. The potential isolates were also tested and found safe for the beneficial insects like egg parasitoids *Trichogramma chilonis* and *Samia ricini* (Eri silkworm).

Benefits of the research: By using these entomo-pathogens, the major defoliators of *Gmelina arborea* (Gamari) and *Aquilaaria malaccensis* (Agar or Sasi), the two economically important species, can be controlled successfully which will in turn increase productivity of these tree species.

Studies on nursery diseases of economically important tree species of Mizoram and their management (RFRI)

Disease surveys were conducted in Aizawl, Kolasib and Mamit forest divisions of Mizoram. Leaf spot and blight were observed as the two major foliar diseases of *Michelia champaca* (Tita sopa). The pathogen was identified as *Colletotrichum gloeosporioides*.

Benefits of the research: Indigenous *Trichoderma* strains were recovered from soil samples and tested against the pathogens,

along with *in-vitro* evaluation of fungicides. The study will help in controlling the two major diseases of an economically important timber species of the region.

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

Leaf samples of *C. guruba* (Phil-te in Mizo) (3 populations), *C. nambariensis* (Hnah-bawr in Mizo), (4 populations), *C. flagellum* (Hrui-pui in Mizo), (4 populations) and *C. tenuis* (Chang-dam in Mizo) (3 populations) were collected from Mizoram and Tripura. DNA was extracted from 80 samples and ISSR genotyping was initiated. In natural stand, plantation and nursery, *Pestalotiopsis calami*, *Colletotrichum gloeosporioides* and *Fusarium* sp. were observed to cause severe spotting and blight of leaves. Morphological characterization of the dominant pathogens was carried out and pathogenicity has been proved.

Benefits of the research: The project will be helpful in assessing the genetic diversity of canes in the region, and also documenting the important diseases. This will prove useful to the forest department and farmers planting canes.

Studies on *Trichoderma* isolates inhabiting different forest ecosystem of North East India (RFRI)

Trichoderma isolates were characterized on the basis of colony morphology, colour, conidial arrangements and growth pattern. *Fusarium* sp. was isolated from infected Agar trees showing symptoms of branch drying and rotting of root system. *Trichoderma harzianum* was found effective against the pathogen. Three *Trichoderma* isolates were deposited in National Fungal Culture Collection of India (NFCCI), Pune and identified as *T. asperellum* and *T. virens* using DNA sequence data analysis of ITS rDNA. The isolates were found promising against some economically important diseases of medicinal and aromatic plants.

Benefits of the research: The study will provide bio-control agents against important plant diseases in the region, both for forestry and agriculture and reduce the use of synthetic fungicides, which are harmful to ecology.

Investigations on the mortality of *Parkia roxburghii* in North East India (RFRI)

Large scale mortality of *Parkia roxburghii* (Yongchak in Manipur and Zyongtho in Mizoram) is a serious problem, affecting this species whose pods are eaten. Isolation from infected wood samples yielded *Fusarium*, but it did not produce any disease symptom under control conditions. Physico-chemical analysis of rhizospheric soil samples showed high organic carbon and nitrogen and pH of soils was found to be acidic. Further investigations are on to determine the cause of mortality.

Benefits of the research: Control of this disease would be of great benefit to the local population of Manipur and Mizoram who are dependent on this plant for food.

Interaction between *Pseudomonas fluorescens* and AM Fungi on *Dendrocalamus strictus* (Bans) (FRI)

Plants raised in co-inoculation of *Pseudomonas fluorescens* and *Glomus etunicatum* performed better in terms of growth and macro-proliferation of bamboo seedlings in unsterilized soil. The treatment having combination of *G. etunicatum* and *P. fluorescens* with half dose of NPK was most effective in enhancing growth (collar diameter, height, shoot weight, P content etc).

Benefits of the research: By using the consortium, the performance of bamboo seedlings can be improved in phosphorus deficient tropical soils especially waste lands besides cost cutting on phosphatic fertilizers.

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

Twenty forest nurseries of Jodhpur, Barmer, Jaisalmer and Jalore district of Rajasthan were visited to study different diseases and insect pest infestations on neem seedlings. Pathogens like *Fusarium*, *Colletotrichum*, *Phytophthora* and *Macrophomina* were identified, and the loss caused by them was approximately 3-5%. Among insect pests, scale insects, termites and *Myllocerus* were

observed but the major loss was caused by two mollusk species which was approximately 10-40%. It was observed that extract of *Dhatura* reduces the population of the mollusk by 20%.

Benefits of the research: Outcome of the project will lead to production of quality planting material and insect pest management in neem. Adoption of technology to be developed will help in increase in productivity.

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)

Soil samples were collected from different areas of Silonijan, Nilalong and Bagori in Karbi-Anglong district. *Glomus* sp., *Gigaspora* sp. and *Acaulaspis* sp. were identified. Strains of phosphate and potash solubilizing bacteria (PSB and KSB) were isolated and pure cultures were maintained. Four strains of PSB have been found as efficient solubilizers under laboratory conditions.

Benefits of the research: The use of these rhizosphere microbes will improve the productivity of the crop in the agricultural lands, which are degraded by burning during shifting cultivation, resulting in loss of microbial population. The study can lead to mass culture of these beneficial organisms and their introduction in degraded areas to restore the soil fertility.

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

Fifty *Bambusicolous* macro-fungi were collected from 23 sites in Jorhat, Golaghat and Sibsagar districts of Assam, identified on the basis of macroscopic and microscopic characteristics, and host-fungus relationship was also worked out. Two new macrofungal species (*Lysurus habungianus* and *Gelatinomyces conus*) were collected and described.

Benefits of the research: The species are new to science discovered from this region.



2.6 Insect Pests and their Control

Studies on diversity of egg parasitoid wasps *Trichogramma* spp. (*Trichogramma*) from Punjab and Haryana and their application in biological control of important forest insect pests (FRI)

Collection of *Trichogramma* spp. (*Trichogramma*) was done in all agro-climatic zones of Haryana and 240 samples of insect fauna were collected from various localities in the districts of Bhiwani, Fatehabad, Hisar, Jhajjar, Jind, Karnal, Kurukshetra, Panipat, Rewari, Rohtak, Sonipat and Yamuna Nagar. 168 specimens of *Trichogramma* were sorted out from the samples. Studies have been carried out on morpho-metrics of nine *Trichogramma* viz. *T. achaearae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilotraeae*, *T. flandersi*, *T. japonicum*, *T. plasseyensis*, and *T. poliae*. *Corcyra cephalonica* culture was maintained for rearing *Trichogramma chilonis* and *Trichogramma japonicum* in the laboratory. Culture of Poplar and Shisham defoliator were maintained in laboratory for testing the efficacy of *Trichogramma chilonis* on their eggs.

Benefits of the research: Exploration of the *Trichogramma* spp. and their utilization in biological control of defoliators in Punjab and Haryana States.

Biology of hispine bamboo borer *Estigmena chinensis* Hope damaging green standing bamboo and its management (FRI)

Biology of the Hispine Green Bamboo Borer, *Estigmena chinensis* (Hispine green bamboo borer), was studied in the field and laboratory conditions. Observations on the incidence and

intensity of attack on eight bamboo species viz. *Bambusa nutans*, *Dendrocalamus giganteus*, *Dendrocalamus longispathus*, *Bambusa multiplex*, *Bambusa tulda*, *Dendrocalamus calostachyus*, *Dendrocalamus asper*, *Bambusa striata* was recorded for the year 2015-16 and the percentage of attack was found to be 40.35, 3.20, 4.36, 4.76, 22.29, 18.53, 30.00 and 5.38%, respectively. Chemical experiment using three contact (Deltamethrin, Cypermethrin and Chloropyriphos) and three systemic (Dimethoate, Monocrotophos and Imidacloprid) insecticides and a control were laid out at selected sites for the control of borer. The average percentage control by systemic insecticide was approximately 60-70% whereas the contact insecticides showed average control of approximately 30-35% only.

Benefits of the research: Standardized chemical control protocol for the hispine green bamboo borer has been developed. Application of the protocol developed will reduce the borer damage thereby increasing the bamboo production in the country.

Contributory factor in the establishment of *Leptocybe invasa* (Fisher and aLaSalle) on *Eucalyptus* plantations in Tamil Nadu (IFGTB)

Study on establishment of gall wasp *Leptocybe invasa* was conducted in different *Eucalyptus* growing areas of Tamil Nadu particularly in the TAFCORN and TNPL *Eucalyptus* growing areas in six agro-climatic zones viz. Cauvery Delta, North Eastern, Western, North Western, high altitude and Southern zones respectively.



Estigmena chinensis Hope (Coleoptera: Chrysomelidae): Egg masses, damaged bamboo and adults feeding on leaves of the host plant



Infestation of Gall insect
Leptocybe invasa

Clones viz., C10, C3, C7, C274, C226, C413, C2045, C285, T61, T81, T113, T93, T97, KK5, C271, C283 were raised in aforementioned areas. Clones C10, C283, C7, T61, KK5, C3 and C271 were severely infested with gall insect (80-100%). The most preferred clones such as C10, C3 and C7 were infested with gall insect. Clone C283, C271 and C3 were found to be most susceptible clones in southern zone, north-eastern and north-western zones respectively. Clones such as C274, C413, C226 and IFGTB-4 clones were free from gall insect. Species in high altitude zone were free from gall insect. GIS based mapping was also done on gall infestation on *Eucalyptus* in Tamil Nadu. The most preferred clone was C10 followed by C3, C7, and C283 in terms of host preferences. Phyto-chemical screening was also carried out such as tannin, phenol, alkaloids, steroids, terpenoids etc. Phenolic compounds in leaves were evaluated and it was found that the variation in chemical composition among clones were the influencing factors.

Benefits of research: Identified the contributory factors for the establishment of eucalyptus gall insect in eucalyptus plantations in Tamilnadu. Monitoring of the influencing factors such as biotic and abiotic factors would help to manage the insect under control. There will be 25-30% increment in biomass production due to management of eucalyptus gall insect which leads to considerable financial gain.

Biological control of *Eucalyptus* gall wasp, *Leptocybe invasa* (FRI)

Diagnostic survey of gall wasp *Leptocybe invasa* (*Eucalyptus* gall wasp) on *Eucalyptus* was carried out at different nurseries, VMG's, plantations in different districts of Punjab and about 20,000 parasitoids, *Megastigmus* sp.



were released at different localities. Data on gall intensity of experimental release site (Bhunga) revealed that the gall infestation reduced from 26% to 2.5% from April, 2013 to December 2015, while at non-release control site (Kailon) gall infestation was 25% in April, 2013 and decreased up to 15.05% in December 2015. In VMG at Satyal, nursery infestation of gall reduced from 61.5% to 6 % in clone 2070 while in clone 316 F gall intensity reduced from 58% to 9%. Similarly, in clone 2045 gall intensity reduced from 22% to 11.5% from 2012 to 2015. In Bassi Jana nursery, Hoshiarpur; gall intensity also reduced with the release of parasitoids. In clone 2045 and clone 2070, gall intensity was reduced respectively from 10.79% and 7.91% to zero% between 2012 and 2015. Release of parasitoids *Megastigmus* spp. reduced the intensity of infestation at released site and at other sites.

Benefits of the research: Parasitoid, *Megastigmus* sp. can be utilised as bio-control agent of *Eucalyptus* gall wasp thereby reducing the damage caused due to gall wasp in *Eucalyptus* plantation.

New Bio-control Opportunities for prickly Acacia: Exploration in India (IFGTB)

Prioritized insects were collected from the fields to continue the ongoing host specificity studies in lab and field. Sixteen species of Australian acacias were raised and maintained in nursery along with two species of Asian acacias namely *A. tortilis* (Umbrella thorn acacia) and *A. farnesianai* (Sweet smelling acacia / Kasturivel). Field confirmative host specificity trials for the targeted prioritized agent, *Anomalococcus indicus* were organized during different period of time at three different locations in and around Coimbatore using 17 species of Acacias using *Acacia nilotica* ssp. *indica* (babul / karuvelam) as control. The first trial through multiple choice method was

established at Thevarayapuram under a naturally scale insect infested tree. The other two trials were established in Latin Square Design within the Forest Campus, Coimbatore. Data from the Trial I exhibited 40% of the control plants, *A. nilotica* ssp. *indica* and 20 % of one of the test plant species, *N. major* infestation by the scale insect. Data from the Trial II revealed no incidence of the scale insect on test plant species. Whereas the data from Trial III showed 26% of control plants, *A. nilotica* ssp. *indica* and 2% of the test plants, *N. major* and *A. southerlandii* infestation by scale insect. Further trials are under progress.

Benefits of research: The study helped to document the insects associated with *Acacia nilotica* ssp. in Tamil Nadu and Karnataka and identify the major pest problems. The information generated would facilitate the acacia growers to be aware of the major pest problems so as to take appropriate management practices and avert the expected loss through reduction of growth biomass and mortality of seedlings and grown up trees.

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

Studies on marine fouling and wood boring organisms in five major ports on the east coast of India, viz., Tuticorin, Chennai, Paradeep, Haldia and Kolkata was completed. Aluminium and wooden test panels were deployed and retrieved in the harbours on monthly basis to monitor fouling organisms and wood boring organisms. At Tuticorin port; sponges, sea anemones, ectoprocts, sabellids, serpulids, balanids, bivalves and ascidians were present in fouling complexes. Biofoulers encountered at Chennai port were also same except ascidians. Only ectoprot foul groups together with green algae were observed at Kolkata. The fouling groups, ectoprocts, sabellids, serpulids and balanids were identified at Haldia. Two fouling groups, viz., ectoprocts and spirorbids along with green algae were noticed at Paradeep. Fouling was found to be heavy at Tuticorin port followed by Paradeep, Haldia and Kolkata ports. Marine wood borers infesting the test panels belonged to only a single group falling under Teredinidae of the phylum Mollusca at the all ports investigated. The causative species were identified as *Lyrodus saffinis*, *L. takanoshimensis*, *L. pedicellatus*, *L. bipartitus*, *T. eredoparksi*, *T. furcifera*, *T. bartschi*, *T. navalis*, *T. clappi*, *Bankia carinata*, *B. brevis* and *B. campanellata*.

Benefits of the research: Documentation of fouling and wood boring organisms will help in developing suitable management practices.

Status of sal heartwood borer, *Hoplocerambyx spinicornis* Newman and its management (TFRI)

Survey conducted for monitoring of sal borer and investigation of borer incidence and related abiotic and biotic factors in various forest areas nearby Balaghat, Mandla and Dindori Forest Divisions including Satpura Tiger Reserves and Kanha Tiger Reserve in Hoshangabad and Mandla Divisions. Survey of timber depots of MP were also conducted for collection of natural enemies of sal borer. Location specific meteorological data were collected for Kanha Tiger Reserve to correlate with sal borer incidence. Trap tree operation and pesticidal experiments were carried out by using bio-pesticide (Spinosad) and chemical pesticides (Monocrotophos and Cartap hydrochloride) against borer beetles in captivity, sal forests and timber depots for its management.

Two trainings on sal heartwood borer and its management were imparted to the frontline staffs of State Forest Departments. Leaflet on sal heartwood borer, categorization of borer affected trees and trap tree operation were distributed during the training programme.

Benefits of the research: Status of sal borer infestation assessed. Natural enemies identified. Treatment of affected logs in depot standardized. The study helps understand the sal borer infestation and its management. That in turn provides better management of sal borer and improved health of forests.

Studies on effect of introduction of Honey Bee on seed production of teak seed orchards (TSO) (TFRI)

At TSO, Ghissi, 800 trees were marked in 5 ha area, whereas in Nanditola, 500 trees were marked and numbered and initial data on flowering status, fruit/seed production at both the sites were recorded. Flowering status was recorded in both the sites during the flowering season. The colonies of *Apis mellifera* (Honey bee) were released at TSO, Behrai @ 1 colony per ha, during the flowering season. Simultaneously, colony of local honey bee species, *Apis indica* was also initiated, maintained and multiplied. Field observations are in progress.

Benefits of the research: The findings will promote maintenance of honey bee

populations, which will have positive ecological impact on vegetation in the surrounding area by acting as natural pollinating agents and improvement in production of quality teak seed.

Development of plant based bio-pesticide for management of poplar defoliator, its field trial in northern region and conduction of awareness programme for farmers (FRI)

Poplar defoliators were collected from Poplar plantations in Chhichrauli (Haryana), Bhadrabad (Uttarakhand) and Saharanpur (Uttar Pradesh) and reared in the laboratory to lay down a series of experiments. The plant material was collected from different sites in and around Dehradun and was extracted sequentially with different selected solvents viz. petroleum ether, acetone, methanol and water. The different concentrations of each extractive were prepared and tested against the third instar larval stages of the defoliator to determine effectiveness of different concentrations of bio-pesticide.

Benefits of the research: Successful field trials of bio-pesticide against poplar defoliator will help in successful management of insect pests in poplar nurseries/ plantations in non-hazardous and environment friendly manner. Thus, it will help in enhancing productivity of poplar uplifting socio-economic status of poplar growers.

Genetic improvement for productivity and insecticidal properties of *Polygonatum verticillatum* Linn (Meda) (FRI)

Rhizomes of *Polygonatum verticillatum* (Meda) were collected from Chakrata during the month of January; no insect infestation was seen on the rhizomes. For testing the insecticidal property of *Polygonatum verticillatum*, four test insects of store grains (Borers) –*Rhizopertha dominica* (lesser grain borer, stored grain borer) and *Tribolium castaneum* (red flour beetle) on wheat, *Sitophilus oryzae* (rice weevil) on rice, and *Callosobruchus chinensis* (pulse beetle) on cow pea were reared.

Benefits of the research: Development of pest resistant *P. versitellum*. This will improve the productivity of medicinal plant.

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

The cultivation and natural growth of MAPs were found to be drastically affected by several

diseases, i.e., leaf spot, quick wilt, fruit rot, leaf blight, target leaf spot, root rot, wilt, anthracnose, mosaic, etc. The pathogens were isolated, morphology was studied and conidial structures were examined.

Benefits of the research: The results will be useful for management of some economically important pathogens of medicinal and aromatic plants.

Insecticidal potential and biological activity of *Semecarpus anacardium* against defoliators (IFGTB)

Quality seeds of *Semecarpus anacardium* (marking nut tree / taatamkottai) were collected from Southern Western Ghats viz. Burliyar, Mettupalayam, Anaikatti, Thengumarahada, Chavadi, Mukkali, Sholiyur, Mannarkaad, and Palghat. Crude oil was extracted with different organic solvents and studied physico-chemical properties (optimum level) to determine the stability and shelf-life of the oil fraction. Insect culture of *Eligma narcissus* and *Atteva fabriciella* was established to study the efficacy of oil extracts at different doses. Bioassays are in progress to evaluate the minimum inhibitory dose of the fraction.

Benefits of research: Development of Biopesticide from potential TBO, *S. anacardium* for use in forestry is an eco-friendly approach to the management of insect pests. This will lead to enhanced productivity. There is a scope for patent after completion of all the activities of the project.

Development of coccinellids based bio-control programme for the management of sandal scales and mealy bugs (IWST)

Monthly surveys were conducted in Bengaluru and Jarakbande Sandalwood Reserve. Other survey areas include Mysore, Shimoga, Sagar, Bevanahalli and Mudinahalli. Thirty species of scales and mealy bugs infesting sandalwood have been identified. Out of which, seven species of scales and mealybugs were found breeding on sandalwood for the first time. Population studies completed for three species of coccids. A total of 25 species of coccinellids were found very active in the sandalwood growing areas. Mixed cropping with diversified flora is found to support more diversity of Coccinellids. Out of the 25 species of coccinellids identified, by assessing the predatory potential in laboratory *Cryptolaemus montrouzieri* and *Chilocorus nigrita* have been identified as potential predatory coccinellids on

sandalwood scales and mealy bugs. Mass multiplication of *Cryptolaemus montrouzieri* was done and evaluated in field condition against *Nipaecoccus viridis* and *Ferrisia virgata* infesting sandalwood. Its potential in controlling the scales and mealy bugs has been demonstrated in field condition.

Benefits of the research: Eco-friendly way of managing scales and mealybugs infesting sandalwood in the present scenario of cultivation of sandalwood.

Studies on insect bio-control agent, *Chrysoperla carnea* (Common green lacewing) and its potentiality as insect predator (TFRI)

Native populations were collected from natural forests and nursery of teak and bamboo selected in Madhya Pradesh, Chhattisgarh and Maharashtra. Observations from rearing of *C. carnea* were recorded for predatory potential. Most promising populations were reared in laboratory and mass-multiplied. After developing mass-multiplication protocol through experiments, the populations were evaluated for their potentiality as biological control agent against insect pest species, viz. *Hyblaea puera* (Teak defoliator), *Eutectona machaeralis* (Teak skeletonizer), and shisham defoliator, *Plecoptera reflexa*. $27^{\circ}\text{C} \pm 1$ in RH $70 \pm 5\%$ was the most suitable for mass-multiplication. Rice moth, *C. cephalonica* was found as the best host. *C. cephalonica* larvae were used for the first time, and its eggs were used for rearing the predator.

The predatory insect, which feeds on egg and larvae, proved promising biological control agent against major insect pest like *Hyblaea puera*, *Eutectona machaeralis* and *Plecoptera reflexa*. It could consume 7-8 larvae or 80-90 eggs per day in case of first instar larva of *Hyblaea puera* and with others. Laboratory experiment on life cycle of predator was completed.

Benefits of the research: The data generated will help understand occurrence of predator, *Chrysoperla carnea* in central India along with standardization of its mass-multiplication method. The information generated will help eventually in utilizing predatory potential of this predatory insect in biological control.

Biology and Management of Insect pests of seeds of *Juniperus polycarpos* C. Koch and Evaluating the Insect-pests Resistance Performance in the Nursery (HFRI)



Homaloxestis cholopis was recorded for the first time on berry and seeds of the Juniper causing maximum damage during the month of June and thereafter ceased its activities up to the arrival of favorable conditions (May-June) next year. The insect was found to be uni-voltine, which took 45-56 days to complete a life cycle. Heavy damage to the berry and seeds of Juniper was observed in the field and in stored conditions last year. The seeds/berries showed little or no symptom during seed development and the insect remained involved in oviposition during seed maturation. Two micro-moths (Lepidoptera) were found feeding on the berries. Taxonomy and biology of seed borer, *Homaloxestis cholopis* of *Juniperus polycarpos* (Devidyar), was completed in the lab. *Plodia interpunctella* was also observed on the seeds during storage. Fursa treatment followed by Robust was found most effective and had shown maximum control of insect-pests damage. It was also most effective in the control of insect-pests damage in nursery trials.

Benefits of the research: Technologies pertaining to effective management of juniper seeds for their long term storage including improvement in survival percentage in nurseries against insect-pest incidences developed. It is being disseminated to the user groups. The research outcome will directly benefit the state forest department during the seed storage and also during raising of the planting material in nurseries.

Study on the Influence of Climate on Bionomics of *Pityogenes scitus* Blanford in Himachal Pradesh (HFRI)

The bionomics of *Pityogenes scitus* (Borer) revealed that this insect passes through four



generations in a year and the fifth remains partial. The beetle was found boring into the green bark of the living branch / stem of young or old trees. The larva of the beetle makes the galleries in the cambium stratum between the bark and the sapwood. Once the grub destroys the cambium, the green needles start drooping and wilting and turns brown in color. Impact of seasonal climatic variation on population of egg, larva, pupa and adult stage of the insect was found statistically significant in their abundance and survival.

Benefits of the research: The detailed life cycle of *Pityogenes scitus* were correlated with various weather parameters and beetle abundance, which revealed the pattern of population distribution of the insect across the different altitudinal zones. Outcome of the study may provide a warning signal to the field functionaries of the state forest department so as to minimize/ manage the insect incidences in field conditions.

Biological Control of *Thysanoplusia orichalcea* F.: a Potential Insect-Pest of *Saussurea costus* in North-Western Himalayas and Extension of Protection Technology to Local Communities (HFRI)

Females were recorded laying eggs varying from 200 - 400 in numbers, singly or in group on the lower leaf surface of the hosts after 2 to 5 days of emergence. Fecundity has been found to be adversely affected by the high temperature and low humidity. The maximum parasitization was obtained to be 25% in July, *Enicospilus* sp. being the most important and responsible for the 15% larval mortality. In other months, the parasitization was as low as 5%. Periodic collection of larvae from the field was completed and kept for emergence of parasites/parasitoides. The larval and egg parasitoids belonging to order Hymenoptera and Diptera were identified as *Apanteles ruficrus* and *Trichogramma japonicum* (Trichogrammatidae) and *Voria edentata* respectively. From diseased and dead larvae, microbial infection have been reported and the cultured entomo-pathogen has been submitted for identification at IMTECH.

Benefits of the research: The study will lead to exploration of biological control agents of *Thysanoplusia orichalcea* and their subsequent use in pest management. On completion of the project, outcome will help the farmers of

Saussurea costus (kuth) growing areas in management of the insect-pest incidences on their cash crop.

Distribution, field biology and integrated pest management of major white grub species infesting teak seedlings in Madhya Pradesh (TFRI)

29 forest nurseries falling under different agro-climatic zone of Chhattisgarh and Madhya Pradesh were surveyed during the period of emergence of the white grub adults. Observations were recorded in teak nurseries and the adjacent crop fields for host range and their distribution in different host plant species. Culture of *G. mellonella* (Greater wax moth or Honey comb moth) larvae was maintained throughout the year on artificial diet in laboratory for EPN culture. Six populations of entomopathogenic nematodes were maintained in the laboratory. Field experiments were laid out in nurseries at different locations.

Benefits of the research: The data generated will help understand field biology of the white grubs along with its distribution in different agro-climatic zones in Madhya Pradesh and help develop locality-specific and species-specific Integrated Pest Management models against teak nursery pests.

Insect pest complexes on medicinal plants and the influence of pest damage on their active principles (IFGTB)

Documentation of insect pests of medicinal plants viz. *Aloe vera*, *Cassia angustifolia* (senna), *Gloriosa superba* (gloriosa), *Mentha arvensis* (mint / pudinah) and *Withania somnifera* (ashwagandha / amukkura) was carried out. Pest population levels in relation to biotic and abiotic factors were correlated. A Pest Calendar has been updated based on the spectrum of pests for each species. Plant based extracts were also identified for safe management of selected insect pests of the reported medicinal plants. Comparative biochemical analysis was carried out and showed variation in the level of metabolites with insect damaged and undamaged medicinal plant species.

Benefits of research: Results will help farmers involved in medicinal plant cultivation to identify insect pests associated with the species cultivated and manage them through eco-friendly methods. Understanding of the



variation in active principles due to insect attack will help farmers in collection of plant parts during the right time. High cost involved in

pesticide application in medicinal plants can be avoided.

2.7 Bio-Oils and Bio-Diesel

Study on microwave assisted direct biodiesel production from *Pongamia pinnata* (Karanj) L. seed oil by two phase solvent extraction (IWST)

Study on microwave (MW) assisted two phase solvent extraction (TSE) of *Pongamia pinnata* seed was carried out at different temperature (40°C and 50°C) and oil extraction time (3, 5, 7, and 10 min). Prior to oil extraction, seeds were MW -treated (30sec and 1.0min) and converted into different particle sizes. Effect of MW-pretreatment and seed particle size on yield and quality of oil was studied. The result shows that MW assisted seed pretreatment had positive effect on yield and quality of oil. Results of MW assisted TSE shows higher oil yield in less extraction time in case of pretreated seeds as compared to untreated seeds. Oil yield varied significantly with size of seed used for extraction. Optimum condition for MW assisted TSE process was found to be-30 sec of Mw-treatment, 40°C extraction temperature and 3 min extraction time. The quality parameters evaluated were specific gravity, refractive index, acid value, peroxide value and iodine value. Result shows significant improvement in the quality of oil under MW assisted TSE. Acid value of TSE oil was found to be 1.1 mg KOH/g as compared to acid value of untreated soxhlet extraction oil i.e., 5.0 mg KOH/g. Compared to conventional heating, significant reduction in oil extraction time was observed in MW induced TSE.

Benefits of the research: Rapid oil extraction as compared to conventional oil extraction, there is improvement in quality of oil (reduction in acid value, peroxide value) and biodiesel can be produced in single step.

Tree Borne Oil seeds (TBOs) in community lands for improved livelihoods of vulnerable

groups of Jharkhand (IFP)

Five year old plantations of Karanj were converted into TBOs demonstration plots. Growth data were collected. Spraying of insecticide was done to demonstration plots for protection from insect pest attack. Clones of Karanj were also multiplied from 5 plus trees. The clonal trial established at Mandar was evaluated and growth data recorded.

Benefits of the research: During the production of clone of mature trees, grafting methods as well as stem cutting methods were used and improved. Supply of genetically improved clonal planting stock of karanj and kusum will revolutionize productivity and profitability of their plantations. The seed oil of these species has a great potential for the production of bio-diesel. After evaluation, best clone of these species will be identified. The seed oil produced from plantation of identified clones will directly support the rural economy.

Studies on chemo-enzymatic treatment of black liquor recovery of reducing sugars for bio-ethanol production (FRI)

Studies on chemo-enzymatic treatment of black liquor recovery of reducing sugars for bio-ethanol production were undertaken. The effluent samples from different sections of the sugar mill were procured from Dhampur Sugar Mill Distillery at Dhampur, Bijnour (U.P.).The procured black liquor samples were analyzed for total reducing sugar (TRS) content and the recovery of the sugars from the samples is under process.

Benefits of the research: The findings on sugar content in black liquor sample can be utilized for producing ethanol that will benefit the paper industries for exploring alternate way of black liquor utilization.