

2.6 Non Wood Forest Products (NWFPs)

Overview

Summary of the Achievements under the Theme

Researches on Non Wood Forest Products have been covered extensively during the year. Focus has been given on species conservation, sustainable and non destructive harvesting procedures, post harvest treatments and processing techniques, bioactivity evaluation, resource development through forest enrichment with natural species, chemical profiling of wild edibles, gums and other useful NWFPs have been undertaken. Various works on biofuel carried out by the ICFRE Institutes include multilocational trials of different provenances and clones of *Jatropha curcas*, genetic improvement works, evaluation of superior clones and also bamboo charcoal and tree borne oilseeds. Works on treatment of wood and bamboos with preservatives have been taken up. Cultivation of NWFP bearing species, propagation, population assessment and identifying superior chemotypes of a number of medicinal plants have been undertaken.

Projects under the Theme

Project	Completed Project	Ongoing Project	New projects Initiated During the Year
Plan	12	26	22
Externally Aided	6	9	5
Total	18	35	27

2.6.2 Resource Development of NWFPs

Field trials for increasing NWFP Productivity using *Piper pedicellatum*: *Piper pedicellatum* plant which grows naturally in moist tropical and sub-tropical forest areas, has the potential to be profitably utilized to increase forest productivity. Domestication and cultivation of this wild species

is possible and so field trials at Dehradun area has been taken up. Nursery technique developed and standardized. Selected 2 sites for field trial- FRI Campus under *Prunus cearasoides* plantation and Lachhiwala RF area under *Dalbergia sissoo* plantation of Dehradun. Preparation for final plantation works in the field is also being carried out.



Vegetative Propagation and Seedling Production



Data Compilation of R & D in Medicinal and Aromatic Plants by ICFRE Institute and Other Institutional Projects funded by ICFRE: A lot of information on different aspects of medicinal and aromatic plant sector has been generated over the years, however, this information is scattered, and often inaccessible to less citation and also likelihood duplication of the works. They are also not fully disseminated to the stakeholders. Therefore, compilation of the large data generated under various research programmes for dissemination to stakeholders besides its application for easy reference, planning of new projects is being taken up. Works being done include screening of ICFRE funded final project reports and library search on R&D in MAPs by ICFRE Institutes for the last 50 years. Two JRFs are actively engaged in the work. Field visits made to HFRI, Shimla, AFRI, Jodhpur for R&D data collection. Consulted project completion reports (46 nos.), research papers (44 nos.) and up-dation of R&D information on 36 medicinal plants is in progress.

Standardization of Drying and Storage Protocol and Quality Assessment of Selected Commercially Cultivated Medicinal Plants of Uttarakhand: Standardisation of optimum drying and storage conditions for *Aconitum heterophyllum*, *Withania somnifera*, *Asparagus racemosus*, *Picrorrhiza kurroa* and *Rauwolfia serpentina* is being carried out in order to get quality products. Work on the evaluation of the effect of drying and storage conditions on the quality of selected cultivated medicinal plants is being carried out. The research is also to develop drying and storage package of practices for farmers and traders.

During the year, experimental differential drying and storage of five medicinal plants under cultivation has been undertaken and quality parameters like LOD, Total Ash, Acid Insoluble Ash, Water and Alcohol Soluble extractives have been assessed for up to 18 months of storage. The chemical markers specific to each species have

been estimated at different storage intervals. The project is in the final stages.

Under Integrated Approach of Bamboo Improvement, various works such as bamboo conservation, propagation and development of agroforestry models of selected Bamboo Species is being carried out at IWST, Bangalore. Collected offset cuttings/plants from CPCs of selected Bamboo species and maintained plants in nurseries. Planted 16 different bamboo species including 9 CPCs in germplasm bank, Gottipura. Carried out experiment on the effect of types (culm cuttings, branch cuttings and rhizomatous cuttings) on rooting in *Dendrocalamus brandisii*. Rhizomatous cuttings and culm cuttings proved better for rooting. Intercropping was done with horse gram, field bean and cow pea in Hoskote Devon plantations, Koppa, Chickmagalur District and in Bittangala, Virajpet, Coorg. Experiment was carried out to study the effect of different size (big, medium, small) and type of cuttings (branch cuttings and rhizomatous cuttings) on rooting in *Dendrocalamus brandisii*. Different growth hormones like; IBA, NAA, IAA and NOA were also tried. Initial results indicate that rooting was better in big size rhizomatous cuttings and growth hormones IBA and NAA enhanced rooting percentage. New agroforestry trials were established at Devon plantation Chickmagalur and Kodagu, management and observation on growth parameters recorded. Leaf litter traps carried out and litter decomposition trials carried out in Nallal, Hoskote for productivity studies and monthly observations were recorded.

Protection of Bamboo and Products: Experiments on bio-deterioration-pest and disease in nurseries, plantations, seed and culm storage, bamboo products, durability and integrated pest/disease management is being carried out at Bangalore. Surveys were carried out to investigate the pest and disease problems associated with cultivated Bamboos. The major bamboo species studied



were *Bambusa bamboos*, *B. nutans*, *B. balcooa*, *B. pallida*, *B. tulda*, *Dendrocalamus asper*, *D. brandisii*, *D. hamiltonii*, *D. stocksii*, *D. strictus*, and *Guadua angustifolia*. The pests include sapsuckers and defoliators. Aphids and Delphacids were the major pests on different species of bamboos. Collected diseased bamboo leaves and culturing of fungi was carried out. The following pathogens were isolated and identified. *Pestalotiopsis guepinii* (desm) Stey causing leaf spot on *B. bamboos*, *Fusarium* spp. close to *F. equiseti* (Corda) Sacc. causing leaf infection in *D. asper*, *Pseudofusarium* causing leaf-spot on *D. stocksii*. The following insect pests were identified and biological studies are being undertaken -*Eleamea* spp., *Tesserotoma javana*, *Purohita* spp., in *D. brandisii*, *Eucyrtus coccinus*, *Pseudoregma bambusicola* and *Gnamptoloma aventiaria* in *B. balcooa*, *M. notobitus*, *Astegopteryx bambusae*, *Purohita* spp., in *D. strictus*, *Astegopteryx bambusae*, *Morillia* spp., *Matapa acia* in *B. bamboos*, *Eleameasecurigera* spp., in *D. hamiltonii*. Commonly used insecticides were tested against major pest in the nursery. *Metarhizium* spp. were used as botanical and bio-control agents against aphids. Predatory potential experiment done with *Astegopteryx bambusae* and *Coccinella septempunctata*. The insecticide/preservative/botanical treated *B. bamboos* and *D. stocksii* were evaluated for durability under lab and field conditions. Six *Trichoderma* spp. were tested against the pathogens (*Fusarium oxysporum*, *F. verticilloides*, *Pestalotiopsis* spp. and *Dreschlera* spp.) *in vitro* by adopting methods like dual culture test and production of volatile and non-volatile compounds. The blocks of *D. asper*, *D. stocksii*, *D. strictus*, *B. pallida*, *B. balcooa* and *B. nutans* were treated with 1% and 2% concentration of Prosopis extract and Bark extract of *Cleistanthus collinus* by pressure treatment for the durability test against the rot fungus/borer and termites. Natural durability of *B. balcooa* and *B. pallida* was tested against two

white rot and brown rot fungus. Prepared checklist of pest and diseases on bamboos in India. Data on various experiments are compiled and report is under preparation.

Seasoning and Preservation of Bamboo:

Experiments on drying of Bamboo (*D. Stocksii* and *D. strictus*) using microwaves at different microwave intensity and exposure times are completed. Experiments on kiln drying and microwave drying of *Bambusa bamboo* carried out. Analysis of preservative absorption at different treatment parameters and along the length of the Bamboo (*D. stocksii*) completed. Analysis of preservative absorption in *D. strictus* completed. The results showed that the retention of preservative is significantly higher in MW dried than that in kiln and air dried samples. A research paper entitled "Microwave drying of Bamboo" published in European Journal of Wood and Wood Products.

Fuel Properties, Carbonization and Characterization of Charcoal from Selected Bamboo Species:

It was observed that the basic density ranges from 0.48 ± 0.03 to 0.61 ± 0.03 in four bamboos species. Its value was found to be highest (0.61 ± 0.03) in *B. bamboos*. Elemental analysis (ultimate carbon, hydrogen, nitrogen, oxygen and sulfur content determination) of *Bambusa balcooa* with age (1 to 4 years) and height (top, middle and bottom) was carried out. Proximate analysis of four bamboo species was carried out. The ash percentage of *B. bamboos* was found to be quite low (1.41 ± 0.002) whereas comparatively higher ash (3.02 ± 0.03) was found in *D. strictus*. The fixed carbon ranges among different bamboo species ranges from 17.61 to 18.14 percent. Calorific value of four bamboo species was determined using oxygen bomb calorimeter. Highest calorific value (4580 ± 0.04 kcal/kg) was found in *B. bamboos* and the lowest (4496 ± 0.02 kcal/kg) in *D. strictus*. The variation



in calorific values of two bamboo species may be due to difference in the ash content. Thermo-gravimetric Analysis (TGA) of selected bamboo species was also carried out. Preparation of charcoal at different carbonized conditions (temperature, heating rate and soaking time) is under progress. Ash elemental analysis of four selected bamboo species was carried out. Order has been given for fabrication of portable charcoal making kiln.

Integrated Approach of Bamboo Improvement Propagation, Agroforestry Models, Protection, Processing and Utilization:

A pamphlet on “sap displacement method of treating bamboo poles” was published in Kannada and English. A pamphlet on “infrastructure requirement and vegetative propagation of *Dendrocalamus stocksii* by culm cutting” has also been prepared. A video film on bamboo and institute activities of approximately 15 minutes each prepared. 19 demo Programmes has been organized in Karnataka, Andra Pradesh and Kerala as per the action plan. A National seminar on “Recent advances in Bamboo propagation, management and utilization” was organized by IWST on 17th and 18th February 2011.

Effect of Fertilizer Application on Growth and Yield:

Salvadora persica and *Acacia ampliceps* plantations, both 10 years old under silvipastoral system on arid salt affected soil is going on at AFRI, Jodhpur. Field trials were laid out of *Salvadora persica* and *Acacia ampliceps* in 1997 and 1998 on saline alkali sandy soil in Jodhpur. In case of *S. persica*, thirteen treatments viz; 1. Control; 2. FYM (10 Kg/plant); 3. FYM + Urea (500 g N) 4. FYM + ZnSO₄ (25 kg/ha) 5. FYM + K₂SO₄ (50 g K₂O) 6. FYM + SSP (500 g P) 7. FYM + Urea + ZnSO₄, 8. FYM + Urea + K₂SO₄ 9. FYM + Urea + SSP, 10. FYM + ZnSO₄ + K₂SO₄ 11. FYM + ZnSO₄ + SSP, 12. FYM + K₂SO₄ + SSP 13. FYM +

K₂SO₄ + SSP + Urea + ZnSO₄ and in case of *Acacia ampliceps* ten treatments viz. 1. Control; 2. FYM (10 Kg/plant); 3. Urea (500 g N) 4. SSP (500 g P) 5. ZnSO₄ (25kg/ha); 6. K₂SO₄ (50 g K₂O) 7. FYM + Urea 8. FYM + ZnSO₄ 9. FYM + K₂SO₄ 10. FYM + SSP were applied in January 2009 to study the effect of fertilizer treatments on growth and yield.

Salvadora persica

After deficient of monsoon, the fruit yield in April, 2010 was maximum (971g) in T₁₃(FYM+U+Zn+K+SSP) treatment, followed by T₄(FYM+Zn) 681g and T₇ (U+Zn) 670g. Yield in other treatments was ranging from 20 to 123g with no fruit yield in T₆ (FYM+SSP) with T₁₀ (FYM+Zn+K) treatments. Oil yielding was estimated and pink fruit's seed yielding with least 37.5%, while purple and white yielded 40.8 and 39.6%, respectively. Oil yield varied from 30.5 to



White



Mixed

Salvadora persica in Fruiting Stage



43.1% with no effect of treatments. Phenological observations in 2010, recorded and early flowering found in 93.6% plants in late October. Mostly multicolored fruits were observed, but only white fruits were observed on six plants. Immature fruit without seed were formed, but aborted and fresh flowering initiated in early December. A total of 93.1% tree flowered second time in February 2011. Fruit setting took place in March.

Annual growth data for the year 2009-10 indicated that treatments are significantly (P-0-00) influencing the height, crown and collar diameter as compared to control. T₁₂ was the best treatment recording, maximum overall growth -13.6, 26.6 and 40.1% for height, crown and collar diameter, respectively, followed by T₄ (FYM+Zn) 7.8, 26.5 & 35.3

Acacia ampliceps

Early flowering was observed in *A. ampliceps* and 90 % trees flowered in the first week of November 2010 and maintained upto January 2011 in a well distributed monsoon year with pod setting in 72.5 % plants, which was better as compared to 45% flowering in 2009 with no pod setting. Maximum pod setting was in T₇ (91.6%), followed by T₆ 88.8% and minimum (44.4%) was control in March 2011.

After deficient monsoon, *A. ampliceps* recorded a mean 18 % casualty in different treatments during summer of 2010, maximum (42%) mortality was in T₄ (FYM + SSP) treatment. The incremental tree growth showed that T₆ (32.2 & 34.2 %), T₈ (31.4 & 36.3%) and T₁₀ (26.4 & 29.4%) recorded maximum collar and crown diameter, respectively, however, height growth was maximum for T₁₀ (37.1%), followed by T₉ (28.8%) and T₈ (25.8%) treatments.

Grass Trial:

Field trial was laid with two grass species viz *Cenchrus ciliaris* and *Sporobolus diander* on

three soil structures (i) raised platform (ii) raised bund and iii) control for Silvipastoral study in three replications.

In a good monsoon year, soil structures influenced the green grass yield and it was 906 and 894 g/m² for the platform and slope soil structures, respectively as compared to control (465 g/m²) in *S. diander*. In case of *C. ciliaris*, slope was the best structure with 1104 g/m² and yield is 6.5% more than control (169 g/m²) indicating the positive effect of leaching.



1. Platform



2. Control
Sporobolus diander



3. Slope

4. Control
Cenchrus ciliaris

HFRI, Shimla

***Podophyllum hexandrum*:** Identification of Superior Chemotypes and *ex-situ* Conservation of the species from Himachal Pradesh and Jammu & Kashmir (Ladakh Valley) is going on. After extensive survey, 28 nos. sites were identified for collection of *Podophyllum hexandrum* species from different geographical locations of Himachal Pradesh (HP) and Jammu & Kashmir

Studies on *Podophyllum hexandrum* at Kargil (Ladakh), Jammu & Kashmir

(J&K). Each site was geo-referenced along with characterization of micro-habitat. The samples of *Podophyllum hexandrum* were collected from the identified sites and the same were sent to the Institute of Himalayan Bio-resource Technology (IHBT), Palampur for carrying out a/i (active ingredient) analysis for identification of superior chemotypes. By using the germplasm collected from 34 sites, Field Gene Bank (FGB) has been established at Field Reserach Station, Brundhar, Jagatsukh, Distt. Kullu, Himachal Pradesh (H.P.). Seed and vegetative propagation trials have also been initiated to develop user friendly propagation trials of *P. hexandrum*. After a/i analysis of samples, data have been statistically analysed to identify the superior chemo-types from most probable geographical locations of Himachal Pradesh and Jammu & Kashmir (Ladakh Valley).

***Picrorhiza kurro* and *Valeriana jatamansi*:** Population Assessment and Identification of Superior Genetic Stock of *Picrorhiza kurroa* Royle ex Benth and *Valeriana jatamansi* Jones by Screening Different Populations from North-western Himalayas (HP and Uttarakhand) is being carried out at Shimla. Extensive survey were carried out to select the sites by the



One of *P.kurrooa* site at Chamba (H.P.)

respective teams covering the most probable sites viz. Rampur, Shimla, Chamba, Dharamsala, Nahan, Kullu and Mandi forest circles of Himachal Pradesh. Geo-referenced the sites and carried out population assessment study along with characterization of the micro-habitat. Collected the medicinal plants samples (*P.kurrooa*-81 nos. and *V.jatamansi*- 40 nos.) for carrying out a./i. analysis for identification of Superior Genetic Stock. Sent the medicinal plants samples for a./i. analysis to the Institute of Himalayan Bio-resource Technology (IHBT), Palampur, District. Kangra, (*P.kurrooa*-75 nos., *V.jatamansi*- 84 nos.) and Jai Prakash Univeristy of Information Technology, District. Solan, Waknaghat (*P.kurrooa*-74 nos.). Preparation of field beds at Shillaru and Brundhar nursery for establishing FGB. Maintained the existing strains at FRS Shilly, Shillaru and Brundhar nursery.

Utilization Study of NWFPs: Mode of collection, processing, sale and utilization of NWFPs in tribal pockets of Jharkhand has been completed during the year by IFP, Ranchi and studied 320 samples of NTFPs and medicinal herbs collected from different markets. A consolidated list has been prepared of the suppliers of medicinal plants in the eastern region.

Conservation of Medicinal Plants: Commercial cultivation and value addition by Joint Forest Management Committees/panchayats and farmers in eastern Himalaya and its socio-economic impact is going on. Total QPM Created 280483 and QPM Distributed for cultivation 77200 to the JFMC member through State Forest Department and Farmers for cultivation commercially, free of cost to motivate the farmers for cultivation. Supplied 43800 QPM to the farmers for commercial cultivation at minimum rate i.e. ` 1.00 and utilized 30950 nos. of QPM for seed garden at Udai Singh Joth and IFP Ranchi, Lalgutwa and trail plot. Seven Workshop/Training programme were organized and motivated 113 farmers of Mangalkata Village, Banarhut; Angrabhasa Grampanchayat, Jalpaiguri District; Lingsay Village, Kalimpong Sub-division, Darjeeling District.; Rangbhang Village, Darjeeling District; for commercial cultivation of medicinal plants through NTFP Division, North Bengal; Divisional Forest Officer, Jalpaiguri. Technical assistant was provided to cultivator from time to time. Preparation and maintenance of 10 trail plantations of 6 species of medicinal plants viz. *Rauvolfia serpentina*, *Withamia somnifera*, *Stevia rebaudiana*, *Asparagus racemosus*, *Gymnema sylvestre* and *Abolmoschau moschatus*.

Medicinal plants garden and propagation centre in Chhotanagpur plateau for conservation and production of QPM for promotion of ex situ cultivation has been established where, 20 different species have been planted in 300 beds and 1,10,000 seedlings/plantlets produced and distributed. A National Conference of Medicinal plants was also organized by IFP, Ranchi.



Cultivation & Marketing : Standardization and dissemination of complete package in relation to principal active ingredient of ten selected medicinal plants of Jharkhand, Bihar, West Bengal and Orissa is being carried out. Companies based on medicinal plants have been approached and maximum of them have given the data asked for experimental trial seedlings have been prepared. Experimental plot has been laid in two States i.e. Jharkhand and West Bengal in open and agronet conditions. One awareness training on selected medicinal plants was organized in ERS, Sukna and a practical demonstration of cultivation of selected medicinal plants was given to the farmers, NGOs etc.

Nursery Technique: Nursery technique of highly exploited medicinal plants viz. *Celastrus paniculatus* and *Vitex peduncularis* has been initiated. Three natural sites of *Vitex peduncularis* in Ranchi and 2 sites of *Celastrus paniculatus* in Ramgarh identified. Three trees of *V. peduncularis* and one plant of *C. paniculatus* (climbers) have been selected with healthy, vigorously growing propagules. Shoot cuttings were obtained from *V. peduncularis*. Mature seeds of *C. paniculatus* have been collected and subjected to various physico-chemical treatments for germination experiments.

Multilocational Trial: Multilocational trial of *Jatropha* in different agro-climatic zones and study of agronomic practices were also initiated. Planting material collected from Hyderabad, Indore & Lucknow. Field preparation & planting is completed. Agronomy trial, MLT trial & Silviculture trial have been taken up. Established irrigation facility, casualty replacement and termiticide application and maintenance of plants in the field were also provided.

2.6.3 Sustainable Harvesting and Management

Creation of Seed Production Area and Commercial Cultivation Trials of *Uraria picta*:

The population of herbaceous dashmula plant, *Uraria picta* is falling into a threatening position in the natural forest areas. It is being collected from the wild. The future availability is at stake unless it is protected and conserved. Therefore work on establishment of seed bank, undertaking experimental cultivation and to estimate the economics of its cultivation has been taken up.

During the year, 450 mother plants collected and established at Mother beds at FRI campus collected (NWFP Garden). Collected Seeds from Uttarakhand and MP and nursery raising achieved. Seed Bank has been established and it is being enriched with more plants for seed production. Approximately 1.739 kg of seeds from the seed bank were produced. Seeds collected from UK and MP and Seed Bank established at FRI have been sown and nursery raised for cultivation trials. Over 2000 seedlings have been raised and maintained.

Testing of Vegetative Multiplication Technique of *Microstylis wallichii* in its Natural Habitat:

Vegetative Multiplication Technique of *Microstylis wallichii* is known but its' lab to land procedures has not been developed. Therefore, the developed techniques are being tried in its natural habitats in Dehradun hill areas. Surveys were conducted for occurrence of species in Mussoorie, Chakrata, Nanital, Almora, and Narendra Nagar Forest Division. Field testing of vegetative multiplication techniques of the species are in progress at 3 sites namely-Chakrata, Mussoorie and Danolti. Growth observation, data recording and maintenance of experimental plots are in progress.



Vegetative Multiplication Technique of *Microstylis wallichii*

Field Trial of Bore Hole Method of Resin Tapping for Chir Pine of Uttarakhand for Better Oleoresin Yield: Need for effective pine resin tapping technique is essential to increase the productivity and for protecting the trees from its harmful effect of traditional tapping methods.

Survey was conducted for taking up field trial. *Pinus roxburghii* growing areas of Mussoorie Forest Division were selected and three plots at different elevations marked. One site at FRI in Champion, Block was also selected for demonstration and extension purpose. Selection of trees for tapping and markings at Magra comp. No.2 was also done. A total of 195 trees were marked for tapping resin using bore hole method. The yield is compared with the prevailing rill method.



Selection of Trees



Rill Method



Bore Hole Method

Collection and Drying of *Thymus serpyllum* for Study of Essential Oils

Study of Essential Oils of *Thymus serpyllum* Grown in Different Altitudinal Locations at Different Stages of Harvesting: *Thymus serpyllum*, a wild plant of Lamiaceae family, bears important aromatic oils, made up of Lilanool and Linalyl acetate as major component. Oil content and composition depends on various factors effecting the growth of the plant. Therefore, estimation and analysis of essential oils from different stages of its development at different locations of Uttarakhand state were carried out. Field visits to know the occurrences were also made in different Districts. Result indicated that the oil per cent was not much different in wild and cultivated plants but the percentage of thymol and other compounds were highly increased in cultivated form. Findings have been sent for publication.

Results:- The oil obtained from dried aerial parts and analyzed by GC and GC-MS. Twenty two compounds were found from 88.46 to 93.95 % wild plants, and 93.63 % cultivated plants at High altitude area. In all the samples, Thymol (34.63-36.61%) was the most abundant component followed by p-cymene (10.74-13.68%) and -terpinene (7.94-13.4).

Development of Nursery Techniques of Fibre Yielding Himalayan Nettle: In order to ensure sustainable production and utilization of Himalayan nettle (*Girardinia heterophylla*) fibre, work relating to nursery development has been taken up. Nursery work such as seed sowing and germination trials, vegetative multiplication trials are in progress at Chakrata NWFP Nursery and NWFP Nursery FRI, Dehradun. Data recorded on seed germination in laboratory condition and in open nursery conditions.

Seed Germinated in Different Containers in Green House at FRI-NWFP Nursery

Plastic Trays



Root Trainers



Poly Bags





Seed Sown in Open Mother Lands at FRI-NWFP Nursery Experiment Site-I

Bed prepared for seed sowing



Seed germinated



Phytochemical Examination of *Acacia albida*:

Isolation of bioactive compounds from *Acacia albida* have been taken up. Research activities include isolation and structure elucidation of chemical compounds present in the leaves and bark of *Acacia albida* and then to carry out studies on the antifungal activity of extractives on the *Cylindrocladium quinqueseptatum*, *Aspergillus niger* and *Rhizoctonia solanii*. To achieve the target, bark and leaves of *Acacia albida* were procured and processed. Bark and leaves were extracted with solvents and crude extracts were sent for screening of antifungal activity. Isolation of compounds by column chromatography is in progress.

Marketing Mechanism : Commercially important medicinal plants were taken for study in selected districts of Eastern Uttar Pradesh were taken for study i.e. Allahabad, Varanasi, two

districts of Vindhya Plateau i.e. Mirzapur, Renukoot and two districts at Tarai region of Eastern Uttar Pradesh i.e. Baharaich and Basti. Questionnaire for market survey was prepared and tested on farmers, market and industry and modified where ever necessary. Survey of Allahabad district has been completed and Varanasi district is under progress.

Population Dynamics of Selected Threatened Medicinal Plant Species and Conservation Management Through Community Participation in Buffer and Transition zone of Achanakmar-Amarkantak Biosphere Reserve, Madhya Pradesh : Surveyed Amarkantak and East Karanjia ranges, located in buffer and transition zones of Achanakmar-Amarkantak biosphere reserve and baseline information such as potential habitat areas, village forest committees etc. are collected. Localities of selected target species of medicinal plants,



such as *Thalictrum foliolosum*, *Embelia tsjeriam cottam*, *Rubia cordifolia* and *Celastrus paniculatus* identified. Observations on population size, structure of target species, habitat characteristics and associate species of selected medicinal plants recorded. Extension materials, such as posters and questionnaire were prepared for awareness programme and interface with villagers. Two interface workshops conducted with villagers of Damgarh, Umargohan and Kharidih.

Development of Alternative Methods of Sustainable Harvesting of Medicinal Plants:

Experiments were laid out for standardization of alternative harvesting practices of designated species viz. *Bauhinia variegata* (Kachnar), *Holarrhena antidysenterica* (Kutaj), *Oroxylum indicum* (Sheonak), *Saraca asoka* (Ashoka) and *Terminalia arjuna* (Arjuna) in the forests areas of Jabalpur, Balaghat, Rewa, Bodla (M.P.), Chandrapur, Tadgaon, Allapally, Tadoba, Nasik (Maharashtra) and Keonchi, Pendra Road, Bilaspur, Raigarh, Marvahi, Gariyaband (Chhattisgarh), Harishankar, Champagarh, Khurda and Koraput (Odisha). Various harvesting methods such as $\frac{1}{2}$ and $\frac{1}{4}$ blaze size, longitudinal strip (alternate and opposite strips) harvesting were experimented. Different plant parts i.e. trunk bark, branch bark, twig bark, twigs, leaves, flowers and root bark etc. were collected and analyzed for their phytochemical constituents (tannins, alkaloids, flavonoids, phenols and phenolic acids). Regenerated bark was also collected and evaluated for major active ingredients. Regular observations were recorded



Terminalia arjuna Tree
Showing a Blaze on the Trunk



Terminalia arjuna Tree
Showing Regeneration of Bark

on bark regeneration. Results revealed that longitudinal strip harvesting method is superior to other harvesting methods. Data on bark regeneration revealed that bark recovery is faster in younger trees having GBH <80 cm. Complete bark recovery was observed in two years in trees having GBH <80 cm and three years in the trees having GBH >80 cm. Minimum harvestable girth varies from species to species. Bark can be harvested from the previously harvested trees after two years from opposite side of the blaze. Phytochemical analysis of various plant parts revealed that the trunk bark contained maximum amount of active ingredients but branch bark and leaves can also be used in place of trunk bark. Original bark contains higher amount of phytochemical constituents than regenerated bark. Antioxidant activity assay was also done in bark samples of above species in which *T. arjuna* was found to possess maximum antioxidant activity.

Sustainable Harvesting Practices for Arjuna (*Terminalia arjuna*) Bark:

Experiments were laid out for standardization of sustainable harvesting practices for *Terminalia arjuna* (Arjuna) in the forest areas of Keonchi, Pendra Road, Bilaspur, Marvahi, Gariyaband (Chhattisgarh). Various harvesting methods such as $\frac{1}{2}$ and $\frac{1}{4}$ blaze size, longitudinal strip (alternate and opposite strips) harvesting were experimented. Different growth regulators e.g., IAA, IBA; bordeaux mixture, leaf extracts of Neem, Aak and Karanja etc. were applied on harvested surface of tree trunk in order to study their influence on bark regeneration. Different plant parts i.e. trunk bark, branch bark, twig bark, root bark, twigs, leaves and flowers etc. were collected and analyzed for their phytochemical constituents (tannins, ash, oxalic acid, gallic acid, ellagic acid, cardiac glycosides, flavonoids, phenols and phenolic acids). Regenerated bark was also collected and evaluated for their major



active ingredients. Bark regrowth results revealed that longitudinal strip harvesting method is superior to other harvesting methods. Data on bark regeneration revealed that bark recovery is faster in younger trees having GBH <90 cm. Minimum harvestable girth should be >60 cm. Study on different growth regulator and insecticide application is under progress. Phytochemical analysis of original and regenerated bark revealed that original bark contains higher amount of active ingredients than regenerated bark. Plant samples were also analysed for their antioxidant activity which was found maximum in bark samples.

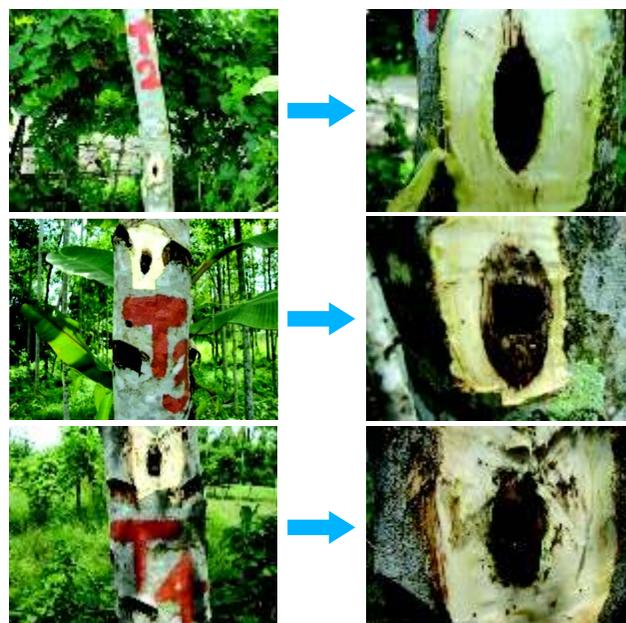
Sustainable Harvesting Practices of Bhui-aonla (*Phyllanthus amarus*), Sal-parni (*Desmodium gangeticum*) and Baichandi (*Dioscorea hispida*): Experiments were laid out to standardize sustainable harvesting of *Phyllanthus amarus*, *Desmodium gangeticum* and *Dioscorea hispida* in Chhattisgarh. Further studies for standardization of harvest regimes is under progress in which entire plants will be harvested as per treatments e.g. H1 (Control), H2 (40% harvest), H3 (60% harvest), H4 (80% harvest) and H5 (100% harvest) as well as cutting of plant up to collar level at all level of harvest.

Harvesting Time of Some Selected Medicinal Plants for their Natural Antioxidants Constituents: Survey was conducted in Tamia and Delakhari natural forest and Medicinal Plants Conservation Area, Delakhari for the availability of the selected species under study. *Gymnema sylvestre* species was available in Rainikheda beat, compartment no. P-36, Jhirpa range. *W. somnifera* and *Stevia rebaudiana* experimental beds were established in CFRHRD nursery and are being maintained. *M. oleifera*, *G. sylvestre*, *W. somnifera* and *S. rebaudiana* leaves samples were collected from existing plantations of the centre and natural forest at monthly time intervals. Method was standardized and

antioxidant constituents viz. ascorbic acid, total phenols, phenolic acids and macroelements estimated. Further analysis is under progress.

RFRI, Jorhat

Inoculation Technique for Agarwood Formation in *Aquilaria malaccensis* L: Artificial inoculations of fungi were carried out in Tezpur for inducement of agarwood in agar trees under the project entitled “Standardization of inoculation techniques for agarwood formation in *Aquilaria malaccensis* Lamk.” Fifteen trees were inoculated as per the technical programme. Inoculated trees were observed after 3 months for external symptom of agarwood formation, if any. Spread of formation of agarwood at the point of inoculation was measured. Samples were collected from the inoculated site and brought to the laboratory for laboratory studies. Isolation from the infected samples revealed the presence of the inoculated fungi.



Visual Observation for Formation of Agarwood after Inoculation with the Dominant Fungus After 3 Months

***Commiphora wightii*:** Network Research Project on Guggal *Commiphora wightii* is Goung on.

Clonal performance trial was established in September, 2007 in RBD design with 4 replications with each replication, having 8 plants per accession. The trial is 41 months old.



Survival varied from 44% of Jalore to 100% of Jaipur, followed by 94% of Barmer, Bikaner and Dausa. Mean Plant height varied from 112.14cm of Bharatpur to 192.22cm of Tonk, mean crown diameter varied from 104.64cm in Jalore to 183.98cm in Sikar source, nearly followed by 183.52cm of Tonk source and mean number of branches ranged from (3.09) in Bharatpur to (5.61) in Jhunjhunu source. The data were significant for all the growth parameters at <0.01 probability level. On the basis of DMRT, height of all the 21 clonal sources was divided into 10 groups, crown into 7 and branches divided into 6 groups.

The main effects of various irrigation (I_1, I_2, I_3 30, 45, 60 days) and fertilizer treatments (F_0 = No organic manure (FYM), F_1 = 2kg/pit; F_2 = 5kg/pit; F_3 = Urea 50g pit (46% Nitrogen); F_4 = SSP 50 g pit (20% Phosphorus); F_5 = 5kg FYM+ Urea 50g/plant; F_6 = 5kg FYM+ SSP 50g/plant; F_7 = Urea + SSP (50g each) applied in agri-trial of *Commiphora* after 40 months of planting in the field. Mean plant height (cm), number of branches and crown diameter (cm) ranged from 182.69cm in I_3 to 198.69cm in I_1 , 4.46 in I_1 to 5.05 in I_3 and 168.96cm in I_1 to 174.08cm in I_3 , respectively. The analysis of variance showed that irrigation intervals had high significant effect on mean plant height and number of branches, whereas, crown diameter was not affected by irrigation.

Application of fertilizer treatment showed significant effect on growth of *Commiphora* plants. The mean height, number of branches and crown diameter varied from 182.24cm in treatment F_7 to 205.82cm in F_2 , 3.98 in F_1 to 5.66 in F_7 and 160.97cm in F_5 nearly followed by F_1 (161.67cm) to 183.16cm in F_2 , respectively. Analysis of variance revealed that effect of fertilizer on plant growth with respect to number of branches was highly-significant. The plant height and crown diameter were also significantly affected by fertilizers.

Non-destructive Gum Production:

Experimental trials of *Commiphora wightii* were maintained in Kumatia enclosure, Kailana Forest Area, Jodhpur. Protection measures (application of termiticide and fungicide) were applied in June 2010 and Monthly spray of fungicide and termiticide to all the plants was done from January to March 2011, while, GA_3 was sprayed once on pruned plants. Growth data (height, crown and collar diameter) and vegetation status were recorded in October-November 2010. In the experiment 1, the growth data of height ranges from 150 to 216.6 cm, crown diameter 210 to 307.5 cm and collar diameter 4.84 to 6.83 cm with 3-8 number of branches/plant. In experiment 2, height ranged from 105 to 290 cm, crown diameter 175 to 345 cm and collar diameter 4.41 to 8.33 cm, having 3-7 number of branches/plant.

Percent moisture in thinner branches (post ethephone treated plants) was ranging from 57.2 – 69.1 % in various treatments in the month of November 2010. Pre-ethephone solvent extractions (2009) with petroleum ether, ethyl acetate and acetone extracts were 1.76 to 1.9%, 0.97 to 1.31% and 0.52 to 0.89%, respectively. The powdered material of thinner branches (post ethephone -2009) was collected after second consecutive gum extraction. It was extracted with petroleum ether (60-80°), ethyl acetate and acetone. The maximum per cent extractives were recorded with petroleum ether. It was maximum in control 3.0 per cent, followed by 2.42 to 2.64 per cent for different doses of ethephone. In case of ethyl acetate, the range was 1.3 per cent for control, while 1.47 to 1.86 per cent for ethephone doses indicated that ethephone application is increasing the yield. It is also found that Guggulsterone came in ethyl acetate fraction. In case of acetone, the range was 1.40 per cent in control, while in different ethephone doses it was 1.28 per cent.

**Table 1. Percent of Different Solvent Extracts of Guggul Branches (Post Ethephone, 2009)**

Chemical Doses		W/o Irrigation and w/o FYM (I)	With FYM			Mean
			I ₀	I ₁	I ₂	
C0	PE	2.30 %	2.57 %	3.02 %	3.41 %	3.0 %
	EtOAc	1.42 %	1.31 %	1.09 %	1.52 %	1.30 %
	Acetone	1.36 %	1.38 %	1.35 %	1.48 %	1.40 %
C1	PE	2.64 %	1.76 %	2.62 %	2.82 %	2.40 %
	EtOAc	2.26 %	1.97 %	2.55 %	1.07 %	1.86 %
	Acetone	1.25 %	1.26 %	1.20 %	1.35 %	1.27 %
C2	PE	1.87 %	1.31 %	3.52 %	2.68 %	2.50 %
	EtOAc	1.41 %	2.01 %	1.35 %	1.37 %	1.57 %
	Acetone	1.12 %	1.20 %	1.34 %	1.31 %	1.28 %
C3	PE	3.26 %	2.26 %	3.0 %	2.66 %	2.64 %
	EtOAc	1.58 %	1.79 %	1.16 %	1.48 %	1.47 %
	Acetone	1.40 %	1.10 %	1.32 %	1.42 %	1.28 %

I: Without irrigation and without FYM

I₀: One time irrigation with FYM

I₁: Irrigation at 20 days interval with FYM

I₂: Irrigation at 30 days interval with FYM

PE= Petroleum ether extract

EtOAc = Ethyl acetate extract

Acetone = Acetone extract

In the second experiment (2010), soil analysis of plant pit samples collected in summer 2010 after cessation of gum exudation has been carried out. The ranges of pH₂, EC₂, % SOC and phosphorus were 7.1 to 8.1, 0.20 to 0.84, 0.21 to 1.30 and 4.21 to 13.88 kg/ha, respectively. There is no significant difference in soil surface and soil depth (0-20 cm).

Phenological observations were recorded on monthly basis for all the plants in exp. 1 and 2. Flowering was noticed in February 2010 in all the plants with leaf initiation in some plants. Sporadic fruiting was observed in almost all the plants in March, 2010 and become dense in April 2010. Plants were lush green after rains in monsoon (July to October 2010) with occasional fruiting. Leaf started yellowing in early November and all the plants were completely leafless in late Nov, 2010 with fruiting. In the year 2011, fruiting was observed in February which was one month early as compared to that of last year.

Tapping experiments were initiated in last week of March 2011 with varying ethephone doses (0, 175 and 225 mg) and injected at one place in a plant, and 3-4 cuts were given. First gum has been collected. Oozing of gum was observed in treated plants. So far all the trees are healthy. Branch cuttings (1.5 cm to 3.5 cm dia) from these plants were taken after gum exudation and planted. Sprouting was observed in 85% of the cuttings.



Commiphora wightii Healed Plant Showing Gum Exudation for the Third Time



Demonstrated ethephone injection based gum-oleo-resin extraction technology at DMAPR, Anand from 8 to 12 March 2011 on 9 years old 12 plants with four ethephone dosages viz; 0, 150, 160 and 170 mg. Collar diameter of branches, range from 2.60 to 6.91 cm.

Tissue Culture Protocol of *Commiphora wightii*: More than three years old embryogenic callus was maintained continuously by subculturing. Secondary and tertiary somatic embryos were also obtained. Cyclic embryogenesis was established and stabilized.

Matured white somatic embryos were used for germination of SEs on different concentrations of gibberellic acid supplemented in modified MS medium. The highest germination percentage (62.25%) of SEs was observed on modified MS medium supplemented with 0.8 mg/l gibberellic acid as well as on control with least abnormal germination of somatic embryos. Plantlet derived from somatic embryo was termed as embling (plantlets).

Harvested mature embryos upon germination and formation of complete plantlets acclimatized to make them ready for transplantation to field conditions. These emblings, 4-5 cm in height were acclimatized in a two step manner. During *in-vitro* hardening step, the survival was 61.5% and during *ex-vitro* hardening step, it was 100%. Hardened plants (10-12 cm in height) were transferred to polybags filled with mixture of soil and FYM in the ratio of 2:1 and were kept in 75% shade in agro-net shade for one month and, then, under tree shade, where they gained height upto 80 cm.

Fifty tissue culture raised hardened plants were planted in field in July, 2010. Out of these, 42 plants were derived from somatic embryogenesis pathway, while 8 plants were derived from axillary bud based micropropagation

pathway. The plants are growing well in the field condition for the last 10 months with 100% survival. Six monthly growth data were collected.



Somatic embryogenesis (A- F)

A- Non-embryogenic Callus Turned in Embryogenic Callus;
B and C- Multiplication and Maintenance of Embryogenic calli;
D and E- Maturation of Somatic Embryos;
F- Germination of Somatic Embryos



Somatic Embryogenesis (G- M)

G- *In-vitro* Hardening of Emblings;
H, I, J, K- *ex-vitro* Hardening of Emblings;
L- Plantlets Under Green Shade House (Rajsamand district);
M- Plantlets Under Green Shade House (Ajmer district)



Field Plantation of Tissue Culture Raised Guggal Plants in July 2010

Sustainable harvesting: Harvest Limits of *Picrorhiza kurroa* & *Valeriana jatamansi* in Himachal Pradesh is being assessed at HFRI, Shimla. Reconnaissance survey was carried out in different forest divisions of the State and sites were selected for laying experimental harvesting trials. For *Picrorhiza kurroa*, two sites viz. Tino forests in Lahaul Forest Division and Banseru Dhar in Kullu Forest Division were selected for the study while for *Valeriana jatamansi*, three sites viz. Jagatsukh forests in Kullu Forest Division, Tikkar forests in Rampur Division and Chail forests in Chail Wildlife Sanctuary were selected. Population data of medicinal plants was collected following quadrat study in all the selected experimental sites. Experimental harvesting trials (control 25, 50, 75 and 100% harvest of selected medicinal plants) were established in all the five selected sites in July-August 2010 to determine optimum harvest limits of selected plants. The harvesting trials for both the selected medicinal plants were also replicated in nursery beds at Field Research Station (FRS), Brundhar of the institute. Population status, number of fruit/seed productions, growth, regeneration and the ability of the population to withstand the extraction is being monitored for the

selected medicinal plants. To create awareness on medicinal plants among the field staff of state forest department, training was imparted on identification, conservation and sustainable utilization of medicinal plants of Himachal Pradesh on 25th February 2011 at Forest Training Institute, Chail.

2.6.4 Chemistry of NWFPs, Value Addition and Utilization

Chemical Investigation: A simple and facile process has been developed to isolate Hederagenin from seed kernel extract of *Sapindus mukorossii*. Hederagenin is a potential bioactive compound known for its anticancer, anti-inflammatory, antidepressant, antihyperlipidemic, antityrosinase, skin lightening, cure of nephritis and prevention and treatment of bone diseases alongwith a number of other biological activities.

A novel green product named as “Samriddhi”- a silk productivity enhancer for sericulture industry has been developed from the weeds and tested at Regional Sericulture Research Station, Sahaspur, Dehradun on Silkworm, *Bombyx mori* L. The product is capable of exceptionally reducing the complete spinning time from



32-36 hours to 15-18 hours. Application of “Samridhi” reduces the cost of silk production in terms of feed cost (mulberry leaves), less mandays (Labour cost), space, infrastructure and time.

Chemical screening of *Diploknema butyraceae* seeds has indicated the presence of high fatty oil content i.e. 65% in the seeds. Phytochemical studies on medicinally important *Diploknema butyraceae* has also been initiated. Natural dyes and their different shades have been developed which are capable of dyeing different type of textiles (silk, wool and cotton). Twenty-five prospective plant species have been screened for extraction of dye for application on human hair.

Germplasm of *Eucalyptus tereticornis*, *E.* hybrid and six commercially used clones of eucalyptus was collected and analyzed for determination of marker constituents conferring CLSB resistance to the foliage. Results were indicative of the susceptibility of the germplasm to CLSB disease. Validation of chemical markers conferring *Cylindrocladium* leaf and seedling blight resistance in *Eucalyptus* germplasm has also been initiated. Refining of process for detoxification studies of *Jatropha* seed oil and chemoenzymatic saccharification of cellulosic biomass has been taken up by FRI, Dehradun.

Isolation and characterization of phytoecdysteroids from *Achyranthes aspera* and *Achyranthes bidentata* and their effect on economic traits of silkworm *Bombyx mori* L. has been completed. Ecofriendly PPD free natural hair colourants, utilization of economic potential of *Lantana camara* and pectic substances from the fruits of *Diospyros peregrine* have been studied at FRI, Dehradun.

Natural Dye: Development of commercially viable dye products from selected plants of North-east region has been taken up. Three species of North-East region were identified for development of natural dyes. The extraction of

dyes has been done after optimization of concentration and time for different samples. The extracted dyes were tested for parameters of natural dyes. The natural dyes were developed from aerial parts of three species of North-East region-*Aporosa dioica* Syn. *A. roxburghii*, *Baccaurea ramiflora* Syn. *B. sapida*, *Bischofia javanica*, which imparts different shades on silk, wool and cotton. The developed dyes qualify the various tests like different colour fastness properties such as washing, rubbing, perspiration and light. These developed dyes could be utilized for dyeing of different textile fabrics. The study, thus, established the target species as potential and easily accessible source of dye.

Pharmacological Investigations of *Aegle marmelos*: Successive extraction methods and fractionations of different tissues of *A. marmelos* leaves, ripened and unripened fruits were standardized and performed series of preliminary pharmacological evaluations. The combined extracts were evaluated for the three antioxidant activities, of which super oxide scavenging activity was found to be better. Three different tissues of *A. marmelos* were tested against organism to study the behavioural activity in two doses of 200 and 400 mg and found that leaves were having more behavioural activity. Haematological parameters like RBC, WBC, Hb, Haematocrit, McB, McHc, leucocytes, differential leucocytes counts with respect to cell analysis after the treatment (ripen /unripe fruits =100mg /100mg =200mg) and other related parameters were also measured. Chemical characterization of the preformulations of ripe and unripe fruit extracts with special focus on pharmacopoeial standards has been documented to support the above studies. Forced swim test to report on antidepressant activity of the preformulation of *A. marmelos* against the experiment organism showed promising results to develop a product with high medicinal qualities.



Non-edible Oils Derived from Tree Borne Oil Seeds as Potential Pesticides: Tree Borne oil seeds of *Sapindus emarginatus*, *Pongamia pinnata*, *Moringa oleifera*, *Calophyllum inophyllum* and *Hydnocarpus pentandra* were collected and processed by hot and cold extraction procedures using non-polar solvent for oil extraction. Overall, hot extraction yields more oil than cold method except for *S. emarginatus*. The preliminary bioassay studies of the TBO, against teak defoliator showed promising results after 24 hours of treatment. Antifungal activity of TBOs oils tested against *Alternaria solani*, *Fusarium oxysporum*, *Cylindro cladium*, *Rhizoctonia solani* and *Trichosporium vesiculosum* in comparison with fungicide revealed no antagonistic activity but found to have synergetic activity.

Essential Oil of *Lantana camara* a Noxious Alien Weed as Biopesticide: Survey was made in different parts of Tamil Nadu and leaves of *L.camara* differing in flower colour (orange, pink, white pink, pink yellow, orange yellow) were processed for oil extraction. Essential oil percentage varied from region to region and was high with rose colour flower compared with others. Bioefficacy of the essential oil was evaluated against teak defoliator (*Hyblaea puera*), and fungal cultures such as *Alternaria solani*, *Fusarium oxysporum*, *Cylindro cladium*, *Rhizoctonia solani* and *Trichosporium vesiculosum* and observed larval mortality but antagonistic activity against fungal pathogens was not seen. A successful attempt was made to prepare handmade paper from this noxious weed.

Biotransformation of Secondary Metabolites: *Frankia* strain isolated from the surface-sterilized root nodules of Casuarina seedlings was cultured and monitored for the culture characteristics at different intervals of 15 – 30 days to analyze the bioconversive reactions. Different days of (15, 25 and 30) homogenized cultures were lyophilized to analyze the variation of signalling compounds which will modulate root physiology

and root growth. The lipid and ethyl acetate extract of the lyophilized cultures were resolved in TLC and HPLC, and the HPLC fractions collected were analyzed in GC-MS-MS. The work is in progress for further characterization of secondary metabolites.

Bio-preservative: Synthesis of organo metallic complex replacing arsenic component in CCA and evaluate as semi bio-preservative has been taken up at IWST Bangalore. Effort has been made to develop eco-friendly wood preservative using naturally available plant by-products of *Cleistanthus collinus* and *Prosopis juliflora*. *Cleistanthus collinus* is known for being toxic which contains three identical compounds, viz. Cleistanthin A, B and C (diphyllin glycoside) in addition to other secondary metabolites. The *Prosopis juliflora* is known to possess two major chemical constituents viz. Juliflorine and julifloricine, the main alkaloids besides other minor compounds. Methanol extract of leaves and bark of these plants were tested for its anti fungal activity, termite and borers., both the extracts were found to be effective to inhibit the growth of white rot and brown rot wood decaying fungi. Lower doses of extracts were not effective to control borer and termite attack. Further, Methanol extract of leaves and bark plants have been reacted with Copper sulphate and Potassium dichromate solutions. Highly perishable rubber wood was treated with complex mixtures and exposed to wood decay fungi using standard method of “Laboratory testing of wood preservatives against fungi (IS- 4873)”. Perishable rubber wood was not infected by the wood decaying fungi, whereas control samples are completely attacked by fungi. Test for Insect borer was done on Bamboo culms by dip treatment of complex mixture as per IS 4873. Field testing of bamboo species and rubber wood against termites was done at IWST field station as per IS 401 (1982). The complex mixture of *Cleistanthus collinus* and *Prosopis juliflora* treated under pressure and dip on Rubber wood and *Bamboo* spp. were found to be effective to



control termites and borers where as control specimens are deteriorated.

Evaluation of the Performance of Steam Volatile Creosote (SVC) as a Wood Preservative has been Tried: Wood samples of seven tree species were procured from different places in Karnataka and Kerala. Crude creosote was procured and Steam Volatile Creosote (SVC) was obtained by steam distillation. SVC was applied to wood surface of four selected tree species and kept for standardization to know its effectiveness. Synthetic dye in various concentrations and combinations was treated with SVC as wood coating to four tree species. Natural dye (*Dalbergia latifolia*) was applied in various concentrations and combinations treated with SVC as wood coating. Coating schedule was worked out for the treated four tree species.

Fatty Oil: Oil composition and utilization of lesser known tree borne oilseeds- *Givotia rottleriformis* Griff., *Madhuca insignis*(Radlk.) H.J.Lam, *Shorea tumbuggaia* Roxb, *Poeciloneuron indicum* Bedd, *Hopea parviflora* Bedd, *Mesua ferrea* L. and *Balanites roxburghii* Planch has been taken up at IWST, Bangalore.



Madhuca insignis- An Endangered Species of Western Ghats

Survey was conducted in various parts of Karnataka and Andhra Pradesh, identified and collected seeds of seven tree species namely *Givotia rottleriformis* Griff., *Madhuca insignis* (Radlk.) H.J.Lam, *Shorea tumbuggaia* Roxb, *Poeciloneuron indicum* Bedd, *Hopea parviflora* Bedd, *Mesua ferrea* L. and *Balanites roxburghii* Planch. The seeds were processed and the fatty oil extracted. The physico-chemical properties of the oils like Acid value, Saponification value, Iodine value, Unsaponifiable matter and Refractive index were determined.

Pharmacological Evaluation: Pharmacological evaluation of the extract/active principle from *Garcinia indica* for anti diabetic property is under study. Fruits of *Garcinia indica* were collected from Subramanya and Puttur (Karnataka). The dry rind was subjected to sequential extraction with Petroleum ether, Chloroform, Ethyl acetate and Methanol. Methanol yielded highest amount (40% by weight) of extract. The crude extract of *Garcinia indica* fruit rind with methanol was further separated by column chromatography with different combinations of benzene and ethyl alcohol. Testing of two distinct fractions along with the crude extract for anti-diabetic property in mice by Streptozotocin induced model for Type-I and Type-II diabetes is in progress. Good results are obtained for acute studies using dosages of 400 and 200 mg of extract/kg body wt of mice.

Screening of Plants for Anti-malarial Activity: Selected members for Rutaceae from Southern India for anti-malarial activity is being screened. Survey was conducted in Devarayanadurga, Savandurga for collection of *Toddalia asicatica* plant material. All the plant parts viz. leaves, stem, root and root bark were processed dried and pulverized, then, extracted sequentially and quantified. The extracts were, then, tested for larvicidal activity against 3rd instar larva of



Aedes aegyptii and the chloroform extract of root has given good results. Experiments are repeated for concurrent results.



Toddalia asiatica

Quantitative Estimation of Sandal oil : Sandal oil content has been determined by non-destructive method by collecting core samples from standing trees from sandal bearing areas of Karnataka. Colour reaction has been standardised using living bark tissue of Sandal tree by reacting with Guaiacol Peroxidase Reagent (GPR) and



Collection of Sandal Wood Core Samples- A Non-destructive Method for Estimation of Sandal Oil

Benzidine Peroxidase Reagent (BPR) from IWST campus for field estimation of sandal oil content in standing trees to develop a field kit for on-site assessment of value of sandal tree based on oil content. Recorded data like girth, height, climatic factors to correlate with quality and quantity of sandal wood oil.

Nutritive Values and Value Addition of Bamboo: Fresh bamboo shoots of different species (*Dendrocalamus asper*, *D. strictus*, *Bambusa bamboos* and *B. tulda*) were analyzed for their nutritional constituents by TFRI, Jabalpure. Results revealed that there is a significant difference in the nutritional status among different species. *D. strictus* (commonly available species of central India) can be considered as a good edible species as it contains nutrients at par with *D. asper* (known edible species of Thailand) grown in Madhya Pradesh. Moreover, *B. tulda* and *B. bamboos* shoots have almost similar nutritional status as that of *D. asper*. Thus, all the three species have the potential to be explored for edible shoot production in central India. Simple, efficient and cost effective methods for processing of bamboo shoots were developed. The processing methods developed significantly reduce the amount of cyanogens and retain nutrients considerably, thus, may be utilized for pre-cooking processing of bamboo shoots to remove anti-nutrients. After processing of bamboo shoots, different products viz. bari, papad, crunches, sauce and pickle were made. The products made were good in taste and texture and, were accepted in terms of flavour, odour, appearance and taste. The nutrient contents of products (bari, sauce and crunches) showed a gradual decrease and should be consumed within 6 months from the date of preparation. However, in case of papad the carbohydrate content did not decrease much but the taste is not acceptable after 8 months, thus, they should be consumed within 8 months of preparation. Whereas, in case of pickles, nutrient



content decreased in 9 months but the product is acceptable in taste and good in texture even after one year of preparation. This study will popularize and increase the utilization of bamboo shoots. Being a lesser known food product, bamboo shoot processing has vast potential to be developed as a new, innovative and promising enterprise in central India.



Bamboo shoots



Bamboo Product (Bari)

Polysaccharides for the Development of Bioproducts: *Curcuma angustifolia*, *C. pseudomantana*, *Dioscorea bulbifera*, *D. hispida* and *Hyptis suaveolens* (seeds and aerial parts) were collected for isolation of polysaccharides. Physical and chemical properties of polysaccharides–starch and mucilage i.e. morphology, size, solubility, viscosity, extraction temperature, amylose,

cellulose and oil per cent of polysaccharides samples were determined. Polysaccharides–starch from different species were modified by acetylation, hydroxyl-propylation and carboxy methylation. The densities of unmodified starches were ranged 1.29-1.50 g/cm³ while modified starches showed significant variation. Degree of substitution of modified starches estimated 0.040-0.277. Starch polymers were prepared with native and modified starches and different additives. Physico-chemical properties i.e. solubility, swelling behavior, transparency and biodegradability test, FTIR, thermal, mechanical analysis and XRD analysis were then performed. The value of tensile strength of unmodified polyfilms was found to be 9.1 MPa, while significant variation i.e. 45MPa was found in modified polyfilm. Compatibility of starches with mucilage, polyvinyl alcohol, chitosan and bentonite and their effect on properties of polyfilms were also evaluated.

Polysaccharides were modified by different chemical treatments and evaluated compatibility of starches with different additives for the development of adhesives. Binding ability of adhesives with different substrate was evaluated. Properties of adhesives i.e. setting time, water resistivity, solubility in water and organic solvents and Thermal Gravimetric Analysis (TGA) were performed. Comparative efficiency of bioadhesives and synthetic adhesives were also screened.

Processing of *Aegle marmelos* (Bael) Fruits:

Bael fruits of different maturity were collected from Barha (Jabalpur), Saliwada, NWFP Nursery (Jabalpur, M.P.), Pandariya (Kawerda, CG). Samples of matured and immature bael were processed by different methods i.e. roasting in cow-dung, steaming, boiling in hot water at different duration and solar treatment for the extraction of pulp and dried in shade, sun, direct and indirect solar treatments. Assessment of



quality (riboflavin, carotene, carbohydrates, protein, fat, and fibre) of pulp samples, of matured fruits and immature processed fruits were undertaken. The edible portion and carbohydrate % of bael fruits pulp were found changed in different processing methods. Carotene and riboflavin % varied 25.6 mg/100 g to 55.45% and 2 to 8 mg/100g, respectively.

Physico-chemical properties of bael pulp samples, processed by tribals were also assessed. Samples were found to be damaged by fungal attack due to wrong processing. Stored samples of pulp were also analyzed and significant variation in carbohydrate, protein, minerals were recorded.

Food Products from *Madhuca indica* Flowers:

Collection of *Madhuca indica* flowers from available source in Central India was done. Method of standardization for extraction and quantitative estimation of *M. indica* flowers for their nutritional constituents was also done. Quantitative estimation of mahua flowers for their nutritional constituents was also done. Four value added food products viz. jam, squash, sauce and chikki were developed using mahua flowers. Consultancy was taken from LIT, Food Technology Dept., Nagpur University, Nagpur as and when required. Further work is under progress.

Optimum Treatment Time and Durability Test of Bamboo:

Commercially important bamboo species of North-eastern Region was studied. Freshly harvested 1 m long bamboos derived from top, middle and basal portions of *B. pallida* and *D. hamiltonii* were treated with Copper Chrome Boron (CCB) at 8%, 10% and 12% and instilled into the bamboo at 1 & 1.5 kg pressure using Boucherie Apparatus (Jagriti) with 5 replications each. During optimization, 360 bamboo samples of *B. pallida* and *D. hamiltonii* were treated and 5 replications of both the samples from top, mid and bottom regions of bamboo were kept for both the sites at Jorhat and Aizawl. Preliminary data showed that preservative treatment time required



Shooty Mould
Infection

Infection by
Schizophyllum commune

was from 25 to 90 minutes for completion of the treatment, depending upon the volume, moisture content, species and age of the bamboo. Completion of preservative treatment was ascertained by comparing the specific gravities of the stock solution with effluents coming out from the bamboo. The treated bamboo samples were dried under shade for fixing of the chemical preservative. Their weight, volume were recorded and tagged with unique identity number. Five replications of untreated (control) samples derived similarly were kept aside for the purpose of comparison. Five replications derived from all the samples including control, were powdered and kept for chemical analysis. Preliminary chemical analysis of the samples shows the average loading as Chromium=2.4 gm/sample; Copper=1.24 gm /sample and Boron=3.3gm/sample. Inspection of the test yard at Aizawl revealed that out of 105 samples of *Bambusa pallida* used in the test yard, 21% got infected by black sooty mould; 4.2% infected with *S. commune* and 12.6% infected with termite; 105 samples of *D. hamiltonii* used in the test yard were infected with 11.55% with black sooty mould, 27.3% with termite and there was no infection by *S. commune*.

Jorhat test yard inspection revealed: In *B. pallida*- Shooty mould 3.15%; Undetermined fungus 3.15%; *S. commune* 3.15% and Termite infection 2.1%. In *D. hamiltonii*-Black sooty mould 2.15%; Undetermined fungus 1.05%; *S. commune* 6.3% and Termite infection 1.05%.



Phyto-proteins from Plant: of North-East Region for the Production of Protein Concentrates with Greater Food Value

Leaf protein is bestowed with enormous nutrients almost equivalent to regular food sources and critical investigations of a number of researchers have provided evidence of it. An affordable alternative food source that can feed a large population who can spend too little for their living is definitely going to be welcomed around the globe. The unexplored plant leaves with greater food value and at minimum cost is the need of the hour. Besides, providing food with essential nutrients, “leaf proteins” have several other promises too. Therefore, with the aim to explore new plants as a potential source for Leaf Protein Concentrates (LPCs) and preparation of LPCs with high food values from selected species from NE region by RFRI, Jorhat, has been under taken. As the expected output of the project is to explore new plant/s for the production of LPC and evaluation of their food values, nine different plant species, viz. *Sambucus javanica* (Caprifoliaceae), *Antidesma bunius* (Euphorbiaceae), *Alocasia macrorhiza* (Araceae), *Cissus adnata* (Vitaceae), *Cissus repens* (Vitaceae), *Enhydra fluctuans* (Asteraceae), *Mimosa invasia* (Fabaceae), *Diplazium esculantum* (Athyriaceae) and *Samanea saman* from Assam has been selected for Nitrogen estimation. Selected plants have been screened for the N/protein content in leaves by using kjeldhal method. The nitrogen content has been determined in the range of 1.73-3.62 in these leaves. LPCs were prepared from fresh leaves of these species to find out LPC production potential. Leaves (100 g level) of the above reported species have been subjected to LPC preparation by following the method of Fellow (1987, Tropical Science, 27, 77-84). Maximum yield of LPC has been obtained in case of *Diplazium esculantum*, *Alocasia macrorhiza* and *Samanea saman*. Thus, these species have been selected for LM/LPCs

production and their physico-chemical analysis. Best temperature and pH conditions has been optimized for *Diplazium esculantum* to increase the yield of LPC. Best temperature has been optimized for the yield production of LPC from *Alocasia macrorhiza* leaves. Leaf protein concentrate from *Diplazium* sp. have been prepared at laboratory level and analysed for Moisture, Ash, Crude Fibre, Crude Protein, Ether extract, N free extract by using standard chemical methods.

Nutritional Status of Wild Edible Plants: To document the information on wild edible plants, a questionnaire was developed and used for the documentation of wild edible plants. Information on this account was collected from different regions of Himachal Pradesh like Kinnaur viz Baspa valley (Raksham, Chhitkul, Batseri, Chansu & Boring sarin), Nichar area (Nichar, Nengani, Kashpo, Garadeh, & Bari), Ropa Valley (Shyaso, Giabong), Rupi Valley (Majgaon, Naling-I, Gurguri, Shingarcha, Hurua) and Sutlej Valley (Kalpa, Pangi, Akpa, Jungi, Rispa, Lippa, Asarang, Rarang, Labrang & Pooh & Mabber) covering all three blocks of the district. To document the wild edible plants, 178 people in total were interviewed in the above villages and 110 wild edible plant species were documented. Within the edible plants, fruits (33%) and leaves (27%) were the most widely used plant parts followed by roots and fruiting body with 11% and 6%, respectively. Within the edible plants, herbs (58%) and shrubs (22%) are the most widely used growth forms followed by trees (16%). Among the plant families, Rosaceae (15 species), Polygonaceae (6 species) and Saxifragaceae (6 species) are the important wild edible plant families in Kinnaur district. For prioritizing the most preferred wild edible plant species, different weightages were assigned to parameters, such as, no. of people who use the plant, seasonal availability, abundance, scope of market and other



traditional usage and species were prioritized for nutritional analysis. Among the prioritized wild edible species, fruits samples of *Elaeagnus umbellata*, *Malus baccata* and *Rosa webbiana*, *Hippophae salicifolia* and *Berberis aristata* were collected for nutritional analysis. Total pH, Ascorbic acid, mineral nutrients, carbohydrate, total sugar and antioxidant activity were estimated. To disseminate the research findings to stakeholders, two interactive workshops on wild edible plants was organised and a pamphlet on wild edible plants was prepared to create awareness among the people.

Active Principles of Medicinal Plants: Studies on various factors effecting the quantity of active principles in some commercially important medicinal plants under cultivation was initiated at IFP, Ranchi. Two sites were identified for collection of propagules of *G. sylvestre* from natural sources. The dried leaves of *G. sylvestre* have been defatted with petroleum ether; Benzene and chloroform extracts have been prepared from the leaves of three years old plants. *G. sylvestre* plants have been raised under the shade of teak, sal and sissoo.

2.6.5 Biofuels and Bioenergy

Bioethanol Production: Effect of improved operational parameters on hydrolysis of lignocellulosic biomass to enhance total reducing sugar yield for bioethanol production has been taken up at FRI, Dehradun. Following the proximate chemical analysis and particle size optimization of *Lantana camara* and Pine needle, the raw materials were subsequently subjected to hydrolysis for the maximum extraction of total reducing sugars by using different acid/alkali concentration at the lower temperature. Total reducing sugars extracted during pre-hydrolysis was 9.27 g/l (5.69%) at 120°C, 90 min. reaction time with the charge of 1% NaOH in case of

Lantana camara while it was 8.27g/l (4.96%) in case of Pine needle under the same reaction conditions. The isolated wild strain of yeast from old contaminated *Lantana camara* hydrolyzate was cultured on Yeast Extract Peptone Dextrose Agar at 30°C and was tested against the glucose in order to determine the fermentation efficiency and fermentability. The experiments of fermentation resulted in 11.15 g/l of ethanol with 85% fermentation efficiency against previously used fermentative yeast (*Saccharomyces cerevisiae*) which produced 10.31 g/l of ethanol with 80% fermentation efficiency.

Production of Clean Producer Gas from Woody Biomass :Experiments were carried out at IWST, Bangalore with the “clean the producer gas” from the wood wastes and thereby increasing its fuel efficiency. Wood chips, bamboo chips and saw dust were oven dried for biomass gasification. Producer gas was produced from wood chips and



Gasifier



Producer Gas



bamboo chips were analysed. Tested results showed that as compared to wood wastes, bamboo wastes were having high yield of carbon monoxide and hydrogen (near about two times more than wood waste) which are main constituent of the producer gas. Also, gasification of bamboo produces a range of valuable by-products like charcoal and activated charcoal. Producer gas was cleaned using dolomite and olivine sand and these cleaned gases were also tested with GC.

Extraction and Transesterification of *Pongamia pinnata* (L.) Seed Oil: The effect of microwave irradiation on oil extraction from *Pongamia pinnata* seed was studied. It was observed that microwave irradiation reduces the time of oil extraction from the seeds significantly. The effect of microwave irradiation on the transesterification was also investigated and compared with conventional heating. The transesterification time under microwave reduces significantly. The optimization of reaction conditions i.e., catalyst concentration and temperature is under progress.

Charcoal Production from Bamboo: Charcoal production experiments in parts of Meghalaya, Mizoram and Manipur has been completed. Most of the sites visited revealed that the local people use traditional pit method or its variants to produce charcoal from timbers collected from the nearby forest areas. Unrestrained, heedless felling of timbers has led to shrinkage of the forest area and cover. Except for the report of bamboo charcoal from Tamenglong, Manipur everybody used any forest timbers for production of charcoal. Bamboo samples – *Bambusa tulda* and *Bambusa balcooa* has been collected, sized and readied for pyrolysis. For preliminary studies, some charcoal samples from *Bambusa bamboos*, *B. pallida*, *B. balcooa*, *B. tulda* and *M. baccifera* - were prepared at laboratory using aluminium method and calorific value of some charcoal worked out. Designs of Drum kiln, Brick kiln and Solar drying chamber have been finalized out of which drum kiln have also been fabricated.



Traditional Charcoal Making in Meghalaya



Wood Charcoal after Pyrolysis in Meghalaya

Bio-oil from *Jatropha*: National network programme on integrated development of *Jatropha curcas* has been taken up.

Networking Trial I : In field trials, genotypes Akola (PKVJ-MKU-1) and PJ Sel-2 performed well for seed yield attribute over others in multi-locational trial with oil content of 33.56 % and 30.66 % on degraded silica mining site of Allahabad in Vindhyan region. It was found that in zonal trial , CSFER-1 showed best performance followed by Jhansi (NRCJ-42).

Networking Trial II: CPTs CALD-13 and CALD-14 from Allahabad has performed well for growth as well as seed yield. In seed yield, two CPTs of Allahabad, one CPT of Deoria and three CPTs of Gorakhpur performed well with an average seed yield in the range of 323 – 385 kg/ha with good oil content. The canopy dia and collar



Wood Charcoal Market in Manipur



Newly Designed Drum Kiln for Charcoal

dia was highest in the CPTs of Allahabad over other progenies with a value of 211.13 and 45.46 cm.

Networking Trial III: Promising genotypes having more than 33% oil content were contributed by the participating institutes and centres. CSFER, Allahabad has received a total of 16 provenances from different institutes/centres. CSFER, Allahabad also contributed samples of CALD- 14 to member institutes. Seedlings were raised and field trial was carried out at Padilla. Weeding, hoeing and maintenance of networking trials are in progress. Pruning was carried out at the height of one feet. Growth, branching and fruiting data were recorded. Maintenance and management of field trials are being done as per the requirement.

Integrated Development of *Jatropha* and Karanj:

Jatropha: One hundred seventy five CPTs were selected from different agro-climatic regions of

Madhya Pradesh. Two Progeny trials comprising of 20 progenies each were established at Chhindwara and Baraha, Jabalpur. In progeny trials, Patna Satna, Khaerwani Tamrikala, Gesani Shivpuri-2, Gesani Shivpuri-3 and Gwalior-2 progenies have performed better. Multilocational trials in the form of national and zonal trials comprising of 22 and 14 accessions respectively were established at Institute campus. In National trial, TFRI-1& 2, IGAU-1, TNMC-22, PDKV-1 & 2, TNMC-7, Palampur-I, RJ-92, JCP-2, NRCJ-17 and TNJC-19 accessions were performed better on the basis of growth performances, fruits yield, seed characters and oil content. In zonal trial, TFRI-1, TFRI-2, PDKV-1, IGAU-2, PDKV-2 and PDKV-1 performed better. Plants planted in pits (30X30X30 cm) at the spacing of 2X2m and 3X2m in the month of July with fertilizer dose of 20gm Urea, 120 gm SSP and 120 gm MOP have shown better growth under tropical conditions of Madhya Pradesh.

Karanj: Eighty one CPTs were selected from different agro-climatic regions of Madhya Pradesh. Progeny trial comprising of 20 progenies was established at Balaghat, Madhya Pradesh. Kusmeli Chhindwara, Sikharpur, Chhindwara and Lalpur Satna progenies were found better. Flowering and fruiting was observed in Kusmeli, Chhindwara progeny. National and zonal trial comprising of 5 and 17 accessions respectively were established at Institute campus. In national trial TNMP-14 and RAK-5 accessions were performing better. In zonal trials IGAU-1, CCSHAU-1, IGAU-5, NRCAF-2, JNKVV-29 and JNKVV-15 were performing better. In Zonal trial-I flowering and fruiting was observed in NRCAF Jhansi accession. All the trials were maintained with regular weeding and hoeing practices and irrigation as and when required.

Multilocational Trials of *Jatropha curcas*: A multi-locational trial comprising of nine superior accessions of *Jatropha curcas* and half-sib



progeny trial comprising of nineteen accessions were established in October 2008 and July 2009 respectively at institute campus. The trials are performing well and survival is more than 85%. Regular observations on growth attributes like height, collar diameter, number of branches, flowering, incidence of pests and diseases has been recorded on quarterly basis and data are sent to Biotech Park, Lucknow for compilation. Minimal irrigation and maintenance was provided to the trials as and when required. In multilocal trial, two accessions HAP 41 and HAP 44 (HNB, Garhwal) have produced higher number of branches without pruning (indicating no requirement for pruning). Flowering was observed in all accessions in the month of September-October 2010. Fruits were formed in all accessions: JA-9, NBRI, Lucknow (109 fruits), JA-126, NBRI, Lucknow (85 fruits), JA-139, NBRI, Lucknow (33 fruits), BTP-U, BTP, Lucknow (4 fruits), HAP 41, HNB, Garhwal (130 fruits), HAP 42, HNB Garhwal (36 fruits) and HAP 44, HNB Garhwal (74 fruits). Oil percentage in different accessions varied between 25-38%. In half sib progeny trial, flowering has been observed in September-October 2010 in following accessions: JA-9, JA-18 (NBRI, Lucknow), MSSRF-10, MSSRF- 16, MSSRF-51 (MSSRF, Chennai), HAP-41 and HAP-44 (HNB, Garhwal). However, fruiting was observed only in three plants belongs to the accession JA-18, MSSRF-10, MSSRF-51. Second pruning of multilocal trial and first pruning of half-sib progeny was done in the month of February 2011. Mulching was done in both the trials in the month of March 2011 to prevent moisture loss. The experimental trials are managed and maintained properly.

A multi-local trial comprising of 100 superior accessions received from network partners was established in July- August 2010 at GRC farm house, Sita Pahad, Jabalpur. The experiment was established following RBD with

four replications. The experimental field was divided in 400 equal sized plots and 9 plants were planted per plot at a spacing of 3m x 3m. The trial is performing well and the survival is more than 90%. Regular observations on growth attributes like height, collar diameter, number of branches, flowering, incidence of pests and diseases has been recorded on quarterly basis and sent to Biotech Park, Lucknow for compilation. The experimental plantation is being maintained and managed intensively so as to raise a good crop leading to higher fruit production.

Survey selection performance trial and estimation of yield potential of *Jatropha curcas* in Rajasthan and Gujarat is being carried out. Two progeny trials, one with 5 replications at AFRI, Jodhpur and another with 15 replications at Haldughati, Udaipur having single plant per replicate in RBD of 30 CPTs were established in July 2008. At AFRI, Jodhpur site, the survival percent varied from 40 to 100. Maximum mean height, number of branches and collar diameter was observed as 247.5cm, 5.50 and 10.59cm in CSMCRI-1, while these were minimum 117.00cm, 1.80 and 3.98cm, in EL-19 AFRI-17 respectively. At Haldughati, Udaipur site, percent survival varied from 40 to 93%. Maximum plant height was 111.43cm in CSMCRI-3, whereas, number of branches and collar diameter were 2.50 and 3.89cm in EL-21 AFRI-15. Minimum plant height and collar diameter were 67.50cm and 1.81cm in 94 AFRI-8, and number of branches was 1.00 in 142-AFRI-12, respectively. The CPTs at AFRI, Jodhpur site only yielded fruit and seeds, whereas, at Haldughati, Udaipur there was no flowering/fruiting observed. Analysis of variance showed that the number of branches was significant at 0.01 probability level in AFRI, Jodhpur trial, whereas, remaining growth parameter were non-significant at both sites.

To develop seed yield equations, measurements were done in the two sample plots



of *J. curcas* laid out at Motiya Research Farm, Rajpipla (Gujarat) during 2010-11. Total mean height, mean collar diameter and mean crown width varied from 2.44m to 2.92m, 12.92cm to 14.2cm and 2.15m to 2.41m, respectively. Observation on the seed yield was also taken, which varied from 103.0g to 193g. Regression could produce relationship between seed yield and height and SY vs. CD. Two different relationships: one LN (SY) vs. 1/HT or 1/CD, other SY vs. HT or CD. Calculated estimated seed yield based on these equations. The equation which gave more close value to the observed data was only considered. It is clear that CSMCRI clones were better as compared to SRT and BCR. They were having more height and seed yield as compared to SRT & BCR though their age was only 4 years, while ART and BCR, were of 6 years old.

Based on the data recorded from two plots (4-6 years) at Motiya research Farm during 2010-11, the yield equation developed as follows:

$$SY(1) = -165.55 + 120.9868 * HT$$

$$SY(2) = 844.0604 - 51.8072 * CD$$

$$LNSY(1) = 7.145631 - 5.60393 * 1/HT$$

$$LNSY(2) = -0.13976 + 68.55505 * 1/CD$$

Multilocal Clonal Trial and Seedling Seed Orchard of *Jatropha curcas*: Two multi-local clonal field trials have been established at Haldughati, Udaipur by AFRI, Jodhpur. The first trial was established in the month of November 2007 with 12 accessions and the second clonal trial was established with 8 accessions in the month of September 2008 in RBD with four replications. Seedling seed orchards in Randomized Block Design (RBD) with 5 replications at Arid Forest Research Institute, Jodhpur and 15 replications at Haldughati, Udaipur were established.

Trial-I revealed that percent survival varied from 15 to 56%. Highest value of mean plant height and collar diameter were observed 124.17cm and 4.62cm, respectively in

TERI/DBT/Jat/04-05, whereas, mean number of branches was 1.69 in BTP-K, which was closely followed by 1.66 in TERI/DBT/Jat/04-05. While lowest value of mean plant height, number of branches and collar diameter were observed; 72.73cm, 1.03 and 1.87cm in TERI/DBT-Jat/06/10, TERI/DBT-Jat/06/05-06/12 and TERI/DBT-Jat/06/16, respectively after 40 months of growth period. Data were non-significant for all the three parameters.

In clonal trial-II, per cent survival varied from 0 to 22%. Maximum value of mean plant height and collar diameter were noticed 78.75cm and 2.94cm in NBRI-JA-126, whereas, maximum number of branches was 1.50 in J-2, Hisar. However, minimum value of plant height, number of branches and collar diameter were 47.50cm in J-2, Hisar & HS-42, 1.00 in HS-41 and 2.21cm in HS-44, respectively.

At AFRI, Jodhpur, percent survival varied from 0 (in 6 accessions) to 100% (in 6 accessions). The accession TERI/DBT/JATROPHA/01/15 showed maximum plant height and collar diameter; 260.00cm and 9.13cm, respectively. While minimum plant height and collar diameter was observed 136.70cm in accession TERI/DBT-JATROPHA/05/31 & TERI/DBT-JATROPHA/05/87 and 2.76cm in TERI/DBT-JATROPHA/05/58 accessions, respectively. Mean number of branches varied from 1.00 to 5.00. Amongst 116 CPTs, only 12 CPTs at AFRI, Jodhpur site were seeded during 2010-11 which ranged from 4.72g to 135.26g.

At Haldughati, Udaipur site, per cent survival varied from 20 to 80%. Maximum plant height, number of branches and collar diameter were observed; 140.71cm, 2.75 and 4.47 cm in accession TERI/DBT-JATROPHA/04/16, TERI/DBT-JATROPHA/05/53 and TERI/DBT-JATROPHA/07/05-06/37, respectively. Minimum plant height was shown by accession TERI/DBT-JATROPHA/04/31 (51.00cm), while accession



TERI/DBT-JATROPHA/05/26 showed minimum number of branches and collar diameter of 1.00 and 1.74cm, respectively. No fruiting was observed at Haldughati, Udaipur sites during 2010-11.

The observations showed that plantation at AFRI, Jodhpur site showed better performance than at Haldughati, Udaipur in term of growth parameters while, accessions planted at Udaipur site showed better survival than Jodhpur site. Data were non-significant for all the parameters.

Genetic Improvement of *Jatropha curcas* for Adaptability and Oil Yield: Survival of 18 selected elite accessions under arid conditions after 65 months of growth period varied from 6 to 69%. Overall mean plant height, number of branches and collar diameter varied from 135.00 to 226.67cm, 1.00 to 4.50 and 3.83 to 8.26cm, respectively. Seed yield ranged from no seed to 660.00g per plant.

Performance of 63 native accessions after 54 months of growth period under arid conditions ranged from 33 to 100%, whereas average plant height, number of branches and collar diameter varied from 155.0 to 295.0cm, 1.00 to 4.00 and 4.55 to 12.55cm, respectively. Seed production varied from 0.00 to 313.0g per plant. On the basis of across site performance, 14 accessions have been selected.

Percent survival in spacing trial after 44 months varied from 14% in 2m \times 2m to 39% in 3m \times 3m. Maximum mean plant height was observed (200.22cm) in 4m \times 4m spacing treatment, while number of branches and collar diameter was maximum 3.08 and 5.76cm in 3m \times 3m spacing. Minimum plant height, number of branches and collar diameter was observed 179.90cm, 2.00 and 5.24cm in 2m \times 2m spacing. Only two treatments seeded in 2010 which ranged from 225g per plant in 3m \times 3m to 319g per plant in 4m \times 4m spacing. Data were non-significant for all the parameters.

Percent survival in pollarding trial varied from 30% in T₂ to 46% in T(control). The mean plant height and collar diameter ranged from 151.81cm (T₂) to 158.58cm (T₃) and 5.42cm (T₂) to 5.59cm (T₀), respectively. Whereas, the mean number of branches ranged from 3.87 in control (T₀) to 8.96 in (T₂). No fruiting was observed during 2010-11. Analysis of variance suggested that effect of pruning is significant on number of branches, while non-significant on average plant height and collar diameter after 37 months of imposing treatments.

From the result of main plot analysis (irrigation effect), average plant height was 233.11cm in I₂ (30 days) and maximum up to 270.17cm in I₁ (15 days). Maximum number of branches and collar diameter was observed 4.45 and 9.65cm in I₂ and I₁, respectively, while these were noticed minimum 3.30 and 8.59cm respectively in control. Three irrigation treatments plant were seeded this year except control which was ranged from 31.8g per plant in I₃ (45 days) to 81.0g per plant in I₂ followed by 76.4g in I₁ treatment. Only plant height was significantly affected by irrigation treatment, whereas, number of branches and collar diameter remains unaffected by the irrigation. From sub-plot analysis for fertilizers (F₁ organic manure 2kg/pit; F₂ organic manure 5kg/pit; F₃ = Nitrogen 10g+ P, 20g, K, 10g per pit; F₄ = 2kg organic manure + Nitrogen 10g+ P, 20g, K, 10g) per pit results revealed that mean plant height ranged from 237.50cm in F₂ to 253.85cm in F₃. The mean number of branches and collar diameter were observed maximum 4.00 & 10.31cm in F₄ and minimum 3.62 & 7.69cm in F₁, respectively. All the fertilizer treatments plants were seeded which ranged from 22.5g in F₀ to 58.0g in F₂ treatment. Plant growth performance was not significantly affected by fertilizer. Interaction of irrigation and fertilizer does not show any significant effect on the growth performance of *Jatropha* after 49 months of the planting.



Database on Tree-Borne Oilseeds: The demand and prices of petroleum products are growing by leaps and bound. The planning commission is examining the possibility of producing blended high speed diesel with 20% *Jatropha* and other TBO's based diesel. This project was initiated to contribute to the knowledge base of TBO's with an aim to estimate their current availability and future supply, demand analysis and estimation of their contribution to the rural economy of India. The objectives of the project is documentation of the scattered plantations of TBO's in Rajasthan and Gujarat done by Government organizations, research institutions, etc. and to develop a database for its fast retrieval.

In order to estimate state wise acreage of cultivation of seven tree borne oilseed species from Gujarat and Rajasthan, a detailed list of Government departments/Institutions viz; State Forest Department, Horticulture, Agriculture Departments, Railways and NGO was prepared by AFRI, Jodhpur. Proforma for data collection was developed and sent to the various departments. Under this study, information regarding seven TBOs viz; *Jatropha curcas*, *Karanja (Pongamia pinnata)*, *Neem (Azadirachta indica)*, *Mahua (Madhuca indica)*, *Mango (Mangifera indica)* kernel as feed, *Jojoba (Simmondsia chinensis)* and *piloo (Salvadora spp.)*, falling in the jurisdiction of AFRI was collected and compiled.

Seed Sources of *Jatropha curcas* L: Seeds from Lower and Mid Himalayan Regions of Himachal Pradesh were studied by HFRI, Shimla. Seeds were collected from the 29 seed sources and 19 individual trees in Himachal Pradesh and sent to The Tata Energy Research Institute, (TERI), New Delhi for estimation of oil per cent. Passport data of all the collections recorded as per standard format provided by National Bureau of Plant Genetic Resource (NBPGR), New Delhi. After the result of oil contents, the plants were raised from the seeds of superior accessions i.e. >30% oil contents. Identified 21 nos. seed sources having seed oil contents >30% from various parts of

Himachal Pradesh out of which 9 nos. seed sources have oil content >35%. Established demonstration plantations with approximately 57,000 plants planted at various places of Himachal Pradesh on 23 ha. area namely Thakurdwara (Nalagarh), Joharji (Solan), Majhouli (Solan), Brahpukher (Bilaspur), Bhojnagar (Solan), Samloe (Sunni), Devidhar (Sunni), Dharja (Solan) Samati (Solan), Narag (Sirmour), Sarahan (Sirmour), Nalagarh (Solan). At the end of the project, demonstration plantations on 16 ha. were surviving. The various growth parameters were recorded regularly in those demonstration-cum-experimental plantations. Subsequently, seeds were also collected from the various demonstration plantations and recorded seed yield. The seeds from some progenies were also sent to TERI, New Delhi for oil estimation. Conducted nursery studies for raising *Jatropha curcas* in lower and mid Himalayan regions of Himachal Pradesh. Seeds from various seed sources were also submitted to NBPGR, New Delhi for getting IC#No of the seed sources. Cuttings of different accessions were provided to network partners at different stages of the project. Frost seems to be an important factor in fruit setting in *Jatropha curcas* as frost prone areas produced very less seed per plant. Seed maturity was also reported as a serious problem owing to early winters in some areas of Himachal Pradesh. Altitude & aspect found to considerably affect growth & survival in *Jatropha curcas* plantations in lower & mid Himalayan regions. Establishment of *Jatropha* in Lantana infested areas was proved to be a very difficult task. However, the project has been completed successfully during March 2011 and, now, the demonstration plantations will serve as source of experimental material for future research activities as well as for training purposes.

Field Evaluation of *Jatropha curcas*: Multilocation experimental trial of rooted cuttings of 10 superior accessions of *Jatropha curcas* has been done in 0.5 ha area at Solag village



(N 31°21.356', E 76°49.737' Altitude: 938m) in Bilaspur District of Himachal Pradesh. The actual plantation in this trial was carried out during October 2008 and some accessions were planted in 2009 as per the statistical design provided by Department of Bio-technology (DBT): Jatropha National Coordinator. However, due to frost injury followed by drought like conditions and heavy mite attack, the survival of *Jatropha* plants fell abruptly at that site during 2009 & 2010. Therefore, the similar trial with same accessions has been re-established at Jawalaji area (N 31°52.947', E 76°18.880' Altitude: 546m) of Kangra district of Himachal Pradesh during September 2010. The trial also covered 0.5ha area and recorded very good initial survival. The growth and survival data is being recorded regularly.



Demonstration Plantation of Jatropha at Thakurdawara, Nalagarh (H.P.)

For establishing half-sib trial, seeds of *Jatropha curcas* representing 20 accessions obtained from NBPGR, New Delhi as per the instructions of the funding agency and were sown in Institute's nursery at Bir Plassi Nalagarh, District, Solan, Himachal Pradesh, during 2008-09. The germination behaviour of these seeds was recorded in the nursery. The plantation of this half-sib trial of superior accessions of *Jatropha curcas* was carried out at village Jawalaji of Kangra district of Himachal Pradesh (N 31°52.947', E 76°18.880', Altitude: 546m) in 1ha area during August 2009. Total 523 number of plants of *Jatropha* planted at Jawalaji which includes plants from superior accessions of half-sib trial and plants from local accessions. *Jatropha* experimental plantation at Jawalaji was being maintained intensively. Growth and survival data of experimental plantations as well as nursery stocks was recorded regularly. The survival is more than 80% till date. Plants are growing vigorously in the trial and flowering is also recorded in the second year of plantation. Pruning of plants has been done in the month of February 2011 as per the guidelines provided by Jatropha National Coordinator. After pruning, vigorous branching has been recorded in the trial which may help in increasing the seed yield during current year.



Pruning of Jatropha Plant at Half-sib Trial