Vol. II

# Forestry Research

## Essence for Outreach

(1986-2018)


**Indian Council of Forestry Research and Education**
P.O. New Forest, Dehradun – 248 006

Vol. II

# *Forestry Research: Essence for Outreach*

## *(1986-2018)*

**Indian Council of Forestry Research and Education**

P.O. New Forest, Dehradun – 248 006

© Indian Council of Forestry Research and Education 2020

**Published by :**
Indian Council of Forestry Research and Education
P.O. New Forest, Dehradun – 248 006

**Printed at :**
Saraswati Press,
2, Green Park, Niranjanpur (Opp. Sabzi Mandi),
Dehradun, Uttarakhand 248001

डॉ. सुरेश गैरोला, भा.व.से.
**Dr. Suresh Gairola, IFS**

कुलाधिपति, व.अ.सं. विश्वविद्यालय
**Chancellor, FRI University**

महानिदेशक
भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद्
डाकघर न्यू फॉरेस्ट, देहरादून–248006
(आई.एस.ओ. 9001:2008 प्रमाणित संस्था)

**Director General**
**Indian Council of Forestry Research and Education**
P.O. New Forest, Dehra Dun - 248 006
(An ISO 9001:2008 Certified Organisation)

## FOREWORD

Research is an integral part of activities performed by Indian Council of Forestry Research and Education (ICFRE), Dehradun, a pioneer Council in the field of forestry in India. The scientists at 9 Institutes and 5 Centres of the Council are conducting research through various projects in the fields of Entomology, Pathology, Silviculture, Genetics, Tree Breeding, Forest Products, Soil, Ecology, Climate Change etc. through its Plan Projects (funded by ICFRE) and Externally Aided Projects (funded by other agencies).

On completion of the projects the scientists submit their results/outcomes as Project Completion Reports (PCRs). PCRs depict outcome of research. Since, research is a continuous process; these PCRs are of immense importance for researchers as these provide scientific status of the work in a particular field upto a point of time. These PCRs find place in the library for ready reference as well as extending their outcomes to the stakeholders. These serve as reference points and also are stepping stones for young scientists.

There are 660 PCRs of plan funded projects in ICFRE under different thrust areas and the number is increasing year by year. Therefore, with a view to provide researchers an easy access to the PCRs, it has been envisaged to provide a brief review of each PCR classified appropriately in subject areas and indexed suitably. For this, subject experts were nominated on the basis of their experience for screening the PCRs under 13 themes for providing a summary of research outcome and future course of action, if any, expected for exploring new horizons in the field.

In the present volume 335 PCRs classified in 8 themes is presented. I hope that this compilation will successfully provide the status of research done in specific subjects at ICFRE since 1986 which will pave the way for further research.

**Dr. Suresh Gairola**

**श्रीमती कंचन देवी,** भा.व.से.
उप महानिदेशक (विस्तार)
विस्तार निदेशालय
**Mrs. Kanchan Devi, IFS**
Deputy Director General (Extension)
Directorate of Extension

दूरभाष : 0135-2224830 (का.) (O)
फैक्स नं./Fax.No. 0135-2750693
ई.मेल/E-mail. ddg_extn@icfre.org

**भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद्**
(पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार की एक स्वायत्त परिषद्)
पो.ओ. न्यू फॉरेस्ट देहरादून – 248 006 (उत्तराखण्ड)
**INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION**
(An Autonomous body under the Ministry of Environment, Forest and Climate Change, Government of India)
P.O. New Forest, Dehradun – 248 006 (Uttarakhand)

# PREFACE

Research outcomes of a research organization are valuable assets on the one hand which need to be preserved in appropriate manner for ready reference of future researchers as baseline data. On the other side, these outcomes are also required for extension and education purposes. Therefore the idea of publishing the outcomes of completed projects of ICFRE is going to serve both the purposes and will become a stepping stone for further publication of such outcomes.

The present volume contains outcomes of 335 research projects presented under 8 themes. This is a compilation of comments of subject experts including summary of the outcome along with suggestions for future endeavours on the topic. This is going to be a continuous process as the third volume is on the way and further compilation of outcomes since 2019 will appear in future.

I would like to state that while going through the editing and publication process of this document, I found that the task was very meticulously planned by former DDG (Extension) Shri Vipin Chaudhary, IFS (Retired) which was aptly executed by my team at Media and Extension Division. I hope that future researchers will find this publication useful in planning and execution of research projects.

**Kanchan Devi**

**श्री विपिन चौधरी,** भा.व.से.
पूर्व उप महानिदेशक (विस्तार)
विस्तार निदेशालय
**Shri Vipin Chaudhary, IFS**
Former Deputy Director General (Extension)
Directorate of Extension

दूरभाष : 0135-2224830 (का.) (O)
फैक्स नं./Fax.No. 0135-2750693
ई.मेल/E-mail. ddg_extn@icfre.org

**भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद्**
(पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार की एक स्वायत्त परिषद्)
पो.ओ. न्यू फॉरेस्ट देहरादून – 248 006 (उत्तराखण्ड)
**INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION**
(An Autonomous body under the Ministry of Environment, Forest and Climate Change, Government of India)
P.O. New Forest, Dehradun – 248 006 (Uttarakhand)

# PREFACE

The research in Indian Council of Forestry Research & Education (ICFRE), Dehradun is being conducted in project mode. The outcomes of the research are documented in the form of Project Completion Reports (PCRs). It has been observed that over the years the number of PCRs is on increase and there is a need to provide some basic information about these at one place for the benefit of researchers as well as policy makers. With this objective these PCRs are being scrutinized by the subject experts and being presented to the stakeholders.

While, going through the process of compilation and selection of subject experts it has been noticed that research themes and thrust areas of ICFRE have been revised from time to time to get these updated to meet the challenges in the field of environment and forestry. Therefore, it has become difficult to place these PCRs in any of the present thrust areas and themes. Therefore, the following 13 themes have been identified on the basis of themes and thrust areas of ICFRE in the yesteryears for the purpose of proper indexing of the PCRs. The themes identified are Agroforestry, Biodiversity & Climate Change, Biofuel & Bioenergy, Chemistry, Ecology, Soil & Land Reclamation, Extension, Forest Botany, Hydrology, Forest Products, Forest Protection, Silviculture and Tree Improvement, Non Wood Forest Products, and Genetics & Biotechnology.

The present volume contains 335 projects covering 8 themes i.e. Agroforesty, Silviculture and Tree Improvement, Hydrology, Protection, Forest Botany, Biodiversity and Climate Change, Forest Products and Genetics and Biotechnology. The remaining themes will be covered in the next volume. I hope that it will provide a baseline for researchers and policy makers for conducting further research.

**Vipin Chaudhary**

**डॉ. शामिला कालिया**
सहायक महानिदेशक
मीडिया एवं विस्तार प्रभाग
विस्तार निदेशालय
**Dr. Shamila Kalia**
Assistant Director General
Media & Extension Division
Directorate of Extension

**भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद्**
(पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार की एक स्वायत्त परिषद्)
पो.ओ. न्यू फॉरेस्ट देहरादून – 248 006 (उत्तराखण्ड)
**INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION**
(An Autonomous body under the Ministry of Environment, Forest and Climate Change, Government of India)
P.O. New Forest, Dehradun – 248 006 (Uttarakhand)

दूरभाष : 0135-2224814 (का.) (O)
Phone : 0135-2755221 (का.) (O)
फैक्स नं./Fax.No. 0135-2750693
ई.मेल/E-mail. adg_mp@icfre.org

## ACKNOWLEDGEMENT

At the Council level researchers as well as policy makers are in need to have information about the research done on desired topics. Therefore, this publication has many contributors who need special mention and acknowledgement. On the outset, I would like to express my deepest appreciation to Dr. Suresh Gairola, Director General, Indian Council of Forestry Research & Education (ICFRE) who has the attitude and a substance of a genius. He continually and convincingly conveyed a spirit of research and excitement in regard to the outcomes of various projects. His persistent help and guidance needs special mention for completion of the job.

I would like to express my gratitude to Mrs. Kanchan Devi, DDG (Extension) for her guidance & support in designing and publishing of this important document.

Besides, it is extremely important to acknowledge Shri Vipin Chaudhary, Deputy Director General (Extension), ICFRE who was a guide throughout the compilation. His idea of identification of themes and subject experts needs mention which was aptly dealt with finesse. The same is thankfully acknowledged.

I express my sincere thanks to Dr. R.K. Tiwari, IFS, Secretary, ICFRE, Dehradun, Dr. Kishan Kumar V.S., Scientist-G, FRI, Dehradun, Dr. Amit Pandey, Scientist-G, FRI, Dehradun, Dr. A.N. Singh, Scientist-F, ICFRE, Dehradun, Dr. Santan Barthwal, Scientist-F, FRI, Dehradun, Dr. Ajay Thakur, Scientist-F, FRI, Dehradun, Dr. Charan Singh, Scientist-E, FRI, Dehradun, Dr. Sas Biswas, Scientist (Retd.), FRI, Dehradun, Shri V.R.S. Rawat, Scientist (Retd.), ICFRE, Dehradun and Dr. Ombir Singh, Scientist (Retd.), FRI, Dehradun, for their invaluable comments after due scrutiny of a huge number of Project Completion Reports (PCRs) which have taken a lot of their time.

I am also thankful to Dr. Sadhana Tripathi, Scientist-G and Chief Librarian, National Forest Library and Information Centre (NFLIC), Dehradun, Shri N.C. Sarvanan, Assistant Director General (Monitoring and Evaluation), ICFRE, Dehradun and Shri Manish Kumar, Scientist-B, ICFRE, Dehradun for providing PCRs.

Special thanks are due to the team and personnels of Media & Extension Division, ICFRE for assisting in various ways in dealing with this important task in addition to their regular duties.

**Dr. Shamila Kalia**

# THEMES

# CONTENTS

# Agroforestry

1. **Evaluation of productivity of maize in *Dalbergia sissoo* (shisham) and *Zea mays* (maize) agroforestry system**

**Principal Investigator:** Dr. Nanita Berry, TFRI, Jabalpur
**Co Principal Investigator:** Shri Rambir Singh, TFRI, Jabalpur

**Duration:** 2008 – 2011

**Critical analysis of the research theme and summary of the study**

The study conducted in Tropical Forest Research Institute campus, Jabalpur which is located at $23^0$5'37" to $23^0$6,10"N latitude and $79^0$58, 49" to $79^0$ 59, 42" on long rotation agroforestry species *Dalbergia sissoo* in combination of a Kharif crop *Zea mays* (Hybrid) for evaluation of comparative outcome from three spacing of *D. sissoo* viz 4x4m, 5x5m and 6x6m block plantation. Parameters of tree-crop combination were fixed as trees with crops with 60cm and 120cm line spacing between maize crop. The same pattern of spacing was also followed in pure crops and pure tree plantation. The *p*H of experimental plots was ranged from 7.52 to 8.14 showing slightly alkaline nature. The data recording was done only for 3 years.

The study reveals that *D. sissoo* attains highest growth of 4.96m with 7cm DBH in plantation of 5x5m spacing and the maize crop (cobs with cover) yield was maximum 40.15qha$^{-1}$ with tree spacing of 5x5m. The productivity of maize decreased near tree line. There were slight changes in soil fertility and *p*H value towards alkaline nature. The NPK contents were found increased in sole tree plantation having 6x6m spacing. The study also indicated that incorporation of leaf biomass of different tree species like *Indigofera*, *Flemingia* and *Tephrosia* helps in higher productivity and improves the fertility of the soil.

**Scientific findings and contents**

The findings of the study show that *D. sissoo* is a suitable species for plantation in rainfed conditions in sandy loam soil in tropical region. The species has no shade effect on under-storey crop like maize up to 3 years and shows a rapid growth at spacing of 5x5m. However the under storey crop of maize shows some decrease in yield near tree line. Biomass of other tree species may increase the productivity of under-storey crop and soil fertility as well. In study, it is assessed that *D. sissoo*-Z. Mays silvi-agri system can generate Rs. 289550 /- only for selling of Maize cob and Rs. 82840/- stalk (straw) and fuel wood cost Rs. 25300/- at the 3$^{rd}$ year of system with improvement in soil fertility (according to PCR 2011-12). Overall, it is indicated in the study that interspaces of *D. sissoo* can be utilized for agriculture crop like maize up to 3 initial years of plantation.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Shisham is a long rotation tree crop and shisham based Silvi-agri system study needs a long term study.

2. **Evaluation of superior planting stock of *Acacia mangium* in agroforestry systems at different eco-climatic zones of Kerala and Tamil Nadu**

**Principal Investigator:** Dr. C. Bhuwaneswaran, IFGTB, Coimbatore

**Duration:** 2003-2008

**Critical analysis of the research theme and summary of the study**

The study was conducted in western and southern zones of and Tamil Nadu and central and southern zones of Kerala. The study area in western zone of Tamil Nadu located between $9^0$ 30' and $12^0$N latitudes and $77^0$30' and $78^0$E longitude and an altitude ranging from 160m – 270m above sea level. The study site in Southern zone of Tamil Nadu located between $8^0$ 10' and $55^0$N latitudes and $77^0$30' and $79^0$E longitude. The study area in central zone of Kerala located at Palakkad district and Pathanamthitta district in southern zone of the state (geographical location not mentioned).

The seedlings were raised by seed collected from seed orchards of Acacia mangium in Panampalli, Kerala along with ramets of superior trees of mangium procured from Mysore paper Mills situated in Tamil Nadu and Kerala. The spacing of plantation done in 2004 was 3x4m, 4.5x4.5 and Homestead scattered at four places in central and southern zone in Kerala. In 2005, plantation done at 6 places i. e. 1 in Kerala and 2 in Tamil Nadu with different spacing.

Observations on growth at the age of three years revealed that growth of *A. mangium* was maximum in Southern zone in Kerala registering girth at breast height (gbh) of 36.0cm total height of 15m. The mean commercial bole height was 12.7m in this zone. Volume production was also highest southern zone of Kerala registering 79.12$m^3ha^{-1}$ while estimated wood yield at 3 years was 54MT $ha^{-1}$ which was 4-6 times more than that of central zone of Kerala. The suitable intercrops with A. magnium were black gram, horse gram, sorghum and beans and the best agroforestry system was A.magnium+Beans+Topioca/Yam/Peper based system for Kerala.

**Scientific findings and contents**

The scientific contents in the report are growth parameters of *A. mangium* seedling and plantation produced from seeds of superior trees procured from Mysore Paper Mills of Tamil Nadu and Kerala. It is recommended in the report that the best suitable zone for proper growth of *A. mangium* is southern zone of Kerala. While comparing of the performance of seedling of A. *mangium* with that of hybrids *A. mangium* it is mentioned that A. mangium hybrid is not suitable for inter cropping with agriculture crops specially, in Blocks as it has profuse branching. The suitable agroforestry model recommended is black gram, horse gram, sorghum and beans and the best agroforestry system was *A. magnium*+Beans+Topioca/Yam/Pepper based system for Kerala.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

*A. mangium* is a fast growing species and suitable as an intercrop with Beans, Topioca, Yam and Pepper but long term study is required to evaluate the volume of full matured trees.

3. **Effect of pine and oak forests on agriculture crops**

**Principal Investigator:** Omkar Singh, Head Extension Division, FRI, Dehradun
**Duration:** 2005-2008

**Critical analysis of the research theme and summary of the study**

The study was conducted in Pauri and Garhwal area of Uttarakhand on yield of wheat (*Triticum aestivum*) and paddy (*Oryza sativa*) nearby oak and pine forests and away of these forests to compare the effect of these forests on both crops keeping the distance from each forest in view. The 1st site was taken near village Gwad situated nearby oak (*Quercus leucotrichophora*)forest and located at N30$^0$10,347-523"E78$^0$52, 137 – 205" at an altitude of 1650 – 1720m. The aspect of hill was North-South and comes under the Block Khirsu, Garhwal Forest Division of district Pauri. The 2nd site was selected in Bisti village near chire pine (*Pinus roxburghii*) forest in Purola district at N30$^0$'651 – 721" E78$^0$6, 293-351" at an altitude of 1775 to 1976m. The aspect of the site was South – West and comes under Tons Forest Division Purola. In study it was concluded that biomass in irrigated field near oak forest was 35q/acr and the biomass production 4 km far from oak forest was 33.16/acre while at the same locations in rainfed conditions the green yield was 33.72q/acre and 31.88q/acre near and 4km away from oak forest. In chire pine forest area, the biomass production near and 4 km away from pine forest in irrigated field was 23.00/q/acre and 2200q/acre respectively. In rainfed conditions, the biomass production near pine forest was 22.00q/acre while it was 18.00q/acre 4 km away from forest.

**Scientific findings and contents**

There is no remarkable difference in yield of wheat and paddy near both Oak and Chir pine forest areas. The condition of irrigation is always a factor in crop yield. In other words, it can be said that the crop yield significantly more in irrigated area at both sites.

4. **Development of model of some important medicinal plants with *Melia composita* and *Emblica officinalis* in degraded land of Punjab and Uttarakhand**

**Principal Investigator:** Shri Rambir Singh, Extension Division, FRI, Dehradun
**Duration:** 2011 – 2016

**Critical analysis of the research theme and summary of the study**

The study was undertaken to access the effect of *Melia composita* Willd.(*M. dubia*) and *Emblica officinalis* on medicinal plants and agriculture crops on degraded land at Naukra grant $30^0$2'49" to $30^0$6'10"N at 264msl in Uttaarakhand and Handesara at $30^0$48,25" to $30^0$52'10"N at 299msl in Punjab. Among under storey crops Sarpgandha (*Rauvolfia serpentina*) and Ashwagandha (*Withatnia somnifera*) were tried as medicinal crops with spacing of 60X60cm under *Melia composita* panted at 4x6m. Both medicinal crops were also tried with *Emblica officinalis* (Var. NA-7) with same spacing. Agriculture crops like wheat and ground nut were also tried as under storey crops with both tree species.

**Scientific findings and contents**

It was observed that fresh yield of *R. serpentina* (135.30q/ha at 90% survival) under Aonla and *W. somnifera* (41.57q/ha at 50% survival) under *M. composita* show synergic effect. Likewise, masoor (8.0q/ha) and Ground nut (13.75q/ha) under *E. officinalis* at Naukragrant (Haridwar district) and *M. composita* without any agriculture crop at Handesara (SAS Nagar district) performed better (ht. 9.38m and 41.78cm girth) at 3 year age. *Emblica officinalis* showed better (height 3.06m and 24.7 girth) performance at Naukragrant. Overall the study reveals that in slightly alkaline soil and rainfed conditions *M. composita* and *E. officinalis* with medicinal plants and different seasonal agriculture crops based Agri-silvi-medicinal agroforestry system is suitable and beneficiary practice for farmers. It is also recommended that species like *M. composita* and *E. officinalis* are suitable tree species under agroforestry with synchronization of medicinal plants like *R. sepentina* and *W. somnifera.*

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

It is well known that *M. composita* (*M. dubia*) is a fast growing species and almost free from any pest and pathogen attack. However, the species shows significant weight and volume at 8 years rotation. To get desirable results from tree species *M. dubia* should be retained on farmland at least for 8 years in combination of different crops. On the other hand, Aonla is a fruit yielding tree species having different phenological nature and utilization. Hence, the model may be expressed separately.

5. **Introduction and performance trials of *Gmelina arborea* for agroforestry in lower hills of Himachal Pradesh and Jammu & Kashmir**

**Principal Investigator:** Dr. Vijendra Panwar, Scientist, HFRI, Shimla (Now in FRI, Dehradun)
**Duration:** 2007-2012

**Critical analysis of the research theme and summary of the study**

The study was conducted in lower hills to evaluate performance Gamhar (*Gmelina arborea*) under agroforestry in villages namely Puruwala (Sirmour district at latitude $30^0$ 27'49.61"N and $77^0$33'06.10E and 430m above msl) and Kot (Hamirpur district at latitude $31^0$ 43'18.24"N and $76^0$33'10.24E and 842m above msl) and in Jammu & Kashmir the study was conducted in Basanterbela, district Sama lying between $32^0$ 34'25.44"N and $75^0$06'55.32E at an altitude of 347m above msl and Nud in same district lying between $32^0$38'29.85"N and $75^0$09'52.46E at an altitude of 536m above msl. Seed of G. arborea was collected from Amjharia (Jharkhand district), Nagdi (Ranchi district), Chiro (Palamu district) of Jharkhand and Katsira (Korba district) of Chhattisgarh and Netaipur (Birbhum district) of West Bengal. Seed germination, growth and survival of seedling and was recorded in Jorhan and Birplasi nursery. Growth performance was recorded annually at all experimental sites. The study revealed that seeds should be shocked in water for about 24 to 40 hours before sowing to get 50 % germination. To get more than 75% germination, seed should be treated for 40 hours in 100 ppm solution of $GA_3$. The study also indicates that location and altitude plays an important role in seed germination, seedling growth and performance of plants. Seed collected from Katsira locality in district Korba of Chattisgarh showed maximum growth of 26.84 cm with 89.59% survival. The maximum height of *G. arborea* plants raised from the seed source Netaipur in (Birbhum district of West Bengal i. e. 228.11cm in second year was recorded in Nud of samba district of J&K. Overall, it was observed that *G. arborea* is a fast growing species and can be easily grown in the lower hills of Himachal Pradesh and Jammu & Kashmir through proper site selection.

**Scientific findings and contents**

The study contains altitudinal consideration for collection of seeds, raising of nursery and plantation of *G. arborea*. It is noticed that altitudinal variation more than 350m may affect the germination, seedling and plantation performance. Soaking of seed in water for 24 to 48 hours may enhance the germination up to 50% but to get 75% and more germination seed requires 40 hours treatment of 100 ppm solution of $GA_3$. The maximum height of *G. arborea* plants raised from the seed source Netaipur in (Birbhum district of West Bengal i. e. 228.11cm in second year was recorded in Nud plantation site of samba district of Jammu & Kashmir.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

*G. arborea* being a fast growing species is suitable for sub tropical zone agroforestry in Himachal Pradesh and Jammu & Kashmir. Further the species is deciduous in nature and comes even under hard and dry conditions. However, the rotation of the species is about 11 years. Hence, the species may be beneficial at the rotation of 11 years. Best source of seed i. e. Netaipur (in Birbhum district of West Bengal) can be utilized for further study.

6. **Managing resources to enhance productivity of agroforestry system in dry areas of Rajasthan**

**Principal Investigator:** Dr. Vilas Singh, Scientist
**Duration:** 2012- 2016

**Critical analysis of the research theme and summary of the study**

The study was conducted to know the effect of pruning and root barriers on the growth of *Hardwinkia binata* and *Colophospermum mopane* and yield of under storey crops like *Cymopsis tetragonobola* and *Cenchrus ciliaris*. The experimental trial was alid in 17 years old plantations of H. binata and C. mopane at Forest Ecology Division, AFRI, Jodhpur situated at $26^0$45'N latitude and $72^0$03'E longitude thinned to 5 x10m spacing. The under storey crop C. tetragonoloba (cluster bean of Guar) was grown under *H. binata* trees. Likewise, C. ciliaris grass was grown along with C. mopane as silvi-pastoral trial. In the experimentation, five different silvicultural treatments were included. These were: intact tree, tree branches removal up to 70% of total tree height, root barrier in 2.0 m diameter around tree, both tree branches removal and root barrier and sole crop/ grass plot. Root barrier treatments affected incremental growth in height and dbh (Diameter and Breast Height) of *H. binanata C. mopane* tree more adversely than the lopping treatments. Incremental growth reduction was more in H. binata than *C. compane* tree due to root barrier treatment. Soil water depletion was highest in intact tree plot whereas the depletion was lowest in lopped and root barrier treatment in both systems. Soil organic carbon was 8.1% and 10.6% higher in *H. binata* and *C. mopane* tree integrated plot than sole crop. This indicated that *H. binata* is more favorable species in enhancing nutrient availability and carbon sequestration than *C. mopane* based agroforestry system. Growth and grain yield of C. tetragonoloba and C. ciliaris grass dry matter were highest in lopped tree with root barrier but lowest yields were under unlopped trees in the both tree species. Increased crop and grass yields with increasing distance from tree indicate competitive antagonistic effects of these species with companion vegetation.

**Scientific findings and contents**

The study revealed that effect of lopping and root barrier both is beneficial to enhance agricultural crop production. On the other hand lopping and root barrier affect growth of tree species antagonistically. It is suggested that antagonistic effects can be minimized through silvicultural practices.

**Suggestions regarding follow up patenting possibility, utilization aspects prototype**

The study conducted is synchronizes with studies conducted on other tree species and under storey crops on same pattern in different parts of the country. As, the study is part of agriculture practices, nothing is patentable. The system may be adopted in the area to enhance productivity of a land with improved canopy management of trees to minimize the shade effect and selection of suitable under storey crops at different ages of trees. Shade bearing crops may be optionally grown under trees having dense canopy.

7. **Tree crop Interactions: Effect of *Melia composita* on crops**

**Principal Investigator:** Dr. Charan Singh, Scientist-E, FRI, Dehradun

**Duration:** 2005-2011

**Critical analysis of the research theme and summary of the study**

The study was conducted at two places namely Handesra located at 30.417$^0$N and 76.8959$^0$E in SAS Nagar district (Mohali) and Hukran at 31.4208$^0$N and 75.8817$^0$E in Hoshiarpur district of Punjab. The plantation was done at 4X5, 5X5 and 4X6m in blocks. Crops of wheat and maize were taken in all space plantations and growth of trees and yield under storey crops was recorded. Resultantly, *Melia composita* significantly showed a fast growth in all three spacing done during the study. The species has a capacity to grow under rainfed conditions also. A plantation on community land near funeral house as shanti van is an evidence of the performance in rainfed condition.

**Scientific findings and contents**

It was noticed that trees do not pose a remarkable adverse effect on growth of under-crop only the reduction up to 2 quintal/ha in yield was noticed which can be compensated by the growth of tree species. The study revealed that combination with wheat and maize is best with spacing of the plantation at 4x6m. As per estimation of production, it is emphasized that the production of timber from 400 trees may be 1360.00 quintal in one ha (value is calculated at the diameter of 30cm on the basis of volume table). Fuel wood production comes 554.60 quintal from these trees in 8 years. From wheat crop grains and straw production from one ha estimated as 371.31 and 482 quintal respectively in 8 years. In the case of maize production of grains and straw estimated as 327.29 and 818.22 quintal respectively in 8 years. The estimated expenditure on harvesting of agriculture crops and *Melia composita* including pruning etc. comes Rs. 354939.00. Total sale price of the tree and crop product as per estimation of 8 years is Rs. 2797111.00 and over all the total benefit in 8 years period comes Rs. 2437172.00.

8. **Multipurpose trees for agroforestry (World Bank FREE Project)**

Sub Project- Studies on any allelopathic effect of tree growth on agriculture crops, root growth pattern under different plantation geometry and development of suitable agroforestry model by Agroforestry Division, TFRI, Jabalpur

**Duration:** 1994-2001

**Critical analysis of the research theme and summary of the study**

The study was carried out at Barha experimental plot of Tropical Forest Research Institute, Jabalpur to analyze the allelopathic effects of tree growth on agricultural crops, root growth pattern under different plantation patterns and development of suitable agroforestry models. To realize the stated objectives, various experiments (eight tree-crop combinations) were laid for the tree crops i.e. *Dalbergia sissoo, Pongamia pinnata* and *Sesbania sesban* with two agricultural crops namely *Cajanas cajan* and *Zea maize*; and two fodder crops namely *Panicum maximum* and *Pennisetum pedicellatum*. *D. sissoo* and *P. maximum* were planted at 5x5 meter spacing, *S. sesban and C. cajan* at 5x5 meter while with *Z. maize,* it was planted at 2x2 meter spacing with three cutting heights i.e. 0.5, 1.0 and 1.5 meter. The agricultural crops were raised at 5 blocks; 4 in intercrops and 1 as sole crop. The data were analyzed in RBD. Growth parameters (height, girth, CBH, crown length, crown width) and total above ground biomass along with total phenolic content, tannin per centage of the species were also estimated. The effects of aqueous and alcoholic extracts were employed to establish how the allelochemicals influenced the process of germination, radicle, plumule length and their dry weights. The nature of agroforestry systems was initiated in pot culture experiments including competition; their growth were monitored and cross compared with field interactions. While identifying certain synergistic and antagonistic combinations for agroforestry practices, several management recommendations were brought out based on studies besides.

**Scientific findings and contents**

*D. sissoo* with *P. maximum* caused 42.8% growth reduction of all growth parameters while guinea grass flourished at the rate of *D. sissoo* producing 30.5., 86.0 and 60.5% biomass in II, IV and VI years than its sole crop estimation. Pot culture experiment indicated best total biomass of fodder (10.28t/ha.). The growth of *P. pinnata* was reduced by 33% in IV year, when intercropped with *P. pedicellatum*. The litter treatment added 3.01g of total phenols, 0.83 g of tannins and 0.6 g of saponins to the pot cultures of the grasses. Total biomass of *C. cajan* with *P. pinnata* was reduced by 24% compared to the sole crop, though there was an overall increment of 5.6% in total biomass yield of sole crop. Pot culture showed 17% grain yield increment in one year over control plot, which further reduced to 7.5% by II year and become 6.5% less than sole crop in III year. Maximum dry weight of redicle, plumule were recorded in 5% concentration and minimum in 10% concentration. Total phenolic content in *D. sissoo* was found lowest (1.32%) in I year to highest (9.52%) in VIII year. P. maximum tried to compete well with *D. sissoo* or other trees due to its extracted deep root system as against superfied root system of *P. pedicellatum.* Organic matter of *P. pinnata* produced a stimulatory effect on *P. pedicellatum* in pot culture. The alcoholic extracts of *D. sissoo* exhibited totally negative effects upon C. cajan due to higher concentration of harmful substances.

**Suggestions regarding follow up, patenting possibility, utilization aspects and prototype**

On basis of study outcomes; *P. maximum* + *D. sissoo* can be tried with more than 400 and up to 600 trees/ha density if the grass productivity is the main objective. Potential allelochemicals must remain active in soil to have an allelopathic effect. To reduce the shade effects and competition, *D. sissoo* may be harvested at 8 to 10 years rotation age.

9. **Bio-fertilizers (World Bank FREE Project)**

**Principal Investigator**: Dr. Jamaluddin, Scientist & Head, Pathology Division, TFRI, Jabalpur

**Duration:** 1994-2001

**Critical analysis of the research theme and summary of the study**

Different biofertilizers were collected from M.P., Maharashtra., Chhattisgarh and Orissa, VAM fungi for teak from M.P. and Maharashtra., VAM fungi and Rhizobium for *Albizia procera* from M.P. and Chhattisgarh, VAM fungi and Frankia for *Casuarina* sp. from Puri, Orissa. Different biofertilizers were isolated, identified and their germplasm were maintained at the institute. Nursery experiments were conducted to select the effective species/stains of different biofertilizers. Techniques were developed for production of inocula in bulk for field uses. Different substrate and trap (host) plants were produced in bulk. Techniques for field applications of fertilizers were demonstrated to the farmers, SFDs NGOs etc. Field experiments on teak, bamboo and *A. procera* were conducted at Katni, Jabalpur, Chhanbila and Bilgna to study the field performance of biofertilizers. In field experiments, results have indicated that VAM fungi has shown superiority over Azospirillum for teak. VAM+ Azotobactor +PSB (Phosphate Solubilizing Bacteria) showed satisfactory resulted for bamboo, hence considered best for bamboo. VAM+Rhizobium +Azotobactor+ have exhibited best results for *A. procera*.

**Scientific findings and contents**

The combination of VAM+Rhizobium) produced maximum biomass (dry weight as 73.39 g) followed by Rhizobium treatment (dry weight as 65.0 g) and VAM (dry wight as 52.3 g) as compared to control (dry weight as 39.1g). From field experiments, it is concluded that VAM in combination with Azospirillum is best for teak, VAM+ Azotobactor +PSB is best for bamboo and VAM+ Rhizobium+ Azotobactor is best for *A. procera*. Further, techniques for bulk production of VAM fungi, Rhizobium and associated $N_2$ fixers were developed and demonstrated.

**Suggestions regarding follow up, patenting possibility, utilization aspects and prototype**

Development of germplasm bank of biofertilizers namely VAM fungi, Rhizobium, Azospirillum, Rhizobia and Phosphate Solubilizing Bacteria (PSB) should be done at the institute also with their field application.

10. **Entomology (World Bank FREE Project)**

**Principal Investigator:** Dr. K. C. Joshi, Entomology Division, TFRI, Jabalpur

**Duration:** 1994-2001

**Critical analysis of the research theme and summary of the study**

The study was done to identify key insect pests of target tree species, to accesses the damage caused by the key pests and to develop techniques for control of key pests. For this purpose, a survey was carried out in selected localities of M.P., Maharashtra and Orissa. Pests of teak, *A. procera* and bamboos were identified. A number of pests were identified minimizing production and viability of teak seeds which included soil insects, sap sucking insects, borers and defoliators. The larvae of *E. machaeralis* were found as a cause behind poor seed production from teak trees. Termite or white ants of two species namely *H. birmanine* and *O. xenotermitis* were recorded to be fed upon roots and rootlets of teak seedlings in nurseries. Overall, seven species of insects namely *Celosterna scabrator, Nupserha variabilis, Cossus cadambae, Indarbela quadrenotata, I. tetraonois, Sahyadrassus malabariens and Zeuzera coffeae* were occasionally observed to damage teak in some of the areas of Maharashtra and M.P. the defoliator identified for teak were *Diascrisia oblique, Eutectona machaeralis, Hyblea purea, Hypesidra tala* and Grasshoppers. *S. retorta* was observed as a key pest of young seedlings and saplings in nurseries, plantations and forests. The pathogenicity of some microbes was tested against both the pests (*H. purea* and *E. machaeralis*). The efficiency of Bt toxins was evaluated in terms of CD at 5% level for 5$^{th}$ instar larvae of both pest species. The toxicity of five synthetic pesticides namely Endosulfan, Malathoin, Alphamethrin, Deltamethrin and Monocrotophos against *H. purea* larvae was tested. Potential parasitoids and predators were collected from different locations. All of which were tried to be reared at laboratory but none of them could be reared successfully. 11 provenances of *A.procera* were collected from different localities of which 1 was found highly susceptible, 7 were reported as susceptible and rest 3 were reported as resistant (value of SE and CD at 5% as 1.307-0.594 and 3.664-1.323 respectively). The study reveals that Key pests of teak and bamboos identified can be controlled in an integrated way consisting of selecting resistant seeds/ seedlings/ sapling for plantation and foliar spray of 1.0% Bt. for teak and 1.5 % Bt. for *Albizia* sp. foliage feeder and bamboo leaf roller. Also, 5% water extract of leaves of *Annoa squamosa* or commercially available neem extract can be used against all sustained key pests.

**Scientific findings and contents**

Total 49 insects were recorded so far. The larvae of teak defoliator (*H. purea* and *E. machaeralis*) were found as key pest leading to poor teak seed production causing 54.77% and 39.71% loss in annual growth. Production of large number of larvae in next generation may be due to availability of sufficient quantity of teak leaves with high moisture, N and Polyphenol content. Out of three species of Bruchid borer, B. bilineate was proved as a pest damaging seeds of *A. procera*. The beetle may survive up to 70 days depending upon weather conditions. For biopesticides, the experiments proved that 5% water extract and 1% methanolic extract of *A.squemosa* are equally effective to neem product (Amrutguard) against teak defoliator and skeletonizer. In bamboos, out of 7 insects, leaf roller (*C.coclesalis*) damage 18 species of bamboos in nurseries, forests and plantations.

# Silviculture and Tree Improvement

1. **Collection of quantitative field data through rapid assessment of population, growing stock and natural regeneration status of *pterocarpus santalinus* l. for CITES not-detriment findings study**

**Principal Investigator:** Dr. Maheshwar Hegde, IFGTB, Coimbatore

**Duration:** 2010-2011

**Critical analysis of the research theme and summary of the study**

*P. santalinus* was classified as endangered in the 1997 *IUCN Red List of Threatened Plants* based on results of Conservation and Assessment and Management Plant (CAMP) workshops for plants of Southern India in 1995 and 1997. The species was similarly assessed as *Endangered in the World List of Threatened Trees* due to its small range, fragmented populations and continuing decline (IUCN 2006). The CITES Secretariat has directed India to carry out "a preliminary inventory of standing stock *P. santalinus*, establish estimates of sustainable off take, establish a revised conservative export quota based on the inventory of standing stock, and estimate of sustainable off take and unharvested populations" (based on recommendation of 59$^{th}$ Standing Committee Meeting held on March 2010).

So the quantitative data in respect of area, distribution, population & regeneration status, harvest etc. need to be collected in the state of Andhra Pradesh. The population structure and regeneration studies were carried out in Chttoor, Kadapa, Nellore and Prakasham districts of AP by laying stratified random sampling and data was collected using standard formats. The Red Sanders (*P. santalinus*) is found distributed in 30 forest ranges and 171 beats in eight forest divisions (Chittoor East, Tirupati Wildlife Management, Rajampet, Kadapa, Nellore, Proddatur, Nandyal and Giddalur) with a total area of about 3.98 lakh hectares in the state of AP. The red sanders require specific ecological niche. The total growing stock of red sanders trees above 30 cm girth was estimated to be 45, 73, 406.51 $m^3$ in all eight divisions. Out of this growing stock 33, 52, 694.44 $m^3$ was contributed by trees below 70 cm girth classes i.e. about 73 % of total growing stock is contributed by trees below 70 cm girth class. Among all the forest divisions, Chittoor division had lowest regeneration of red sanders. The seedlings < 45 cm found higher numbers in comparison to >90-137 cm height class seedlings in all the divisions. The data on seized Red Sander logs in Andhra Pradesh and all over India at various points indicated that high level of removal is taking place in the natural populations.

1. It is suggested that to arrive; at exact extent of Red Sanders area and proper demarcation new technologies like GIS may be used in future. The canopies of Red Sanders trees give distinct color from other vegetation and trees and therefore, they can be very easily identified from a distance. Therefore, the species specific GIS techniques may be used for mapping the distribution of Red Sanders, demarcate the areas and monitoring the populations in future.
2. A systematic breeding programme should be initiated after studying intra specific variations using morphological and molecular markers, provenance identification, selection of superior genotypes through Candidate Plus Tree Selection and progeny trails and establishments of seedling seed orchards which will become source of genetically superior quality seed source for planting outside forests by State Forest Departments as well as tree growers.
3. Since the regeneration of the species is suffering from biotic and abiotic factors as reflected by

regeneration survey and skewed distribution the lower girth class population structure, efforts are required to augment regeneration by removal of grasses before seed fall, preparation of ground to facilitate germination and control of grasses.

4. Assisted natural regeneration supplementing with stumps or nursery grown seedlings would boost the growing stock.
5. The whole forest area under Red Sanders may be declared as "Red Sanders National Park" under Wildlife (Protection) Act, 1972 to afford better protection to the species. This will also augment fund availability for protection and enhance the punitive measures against offenders.

**Scientific findings and contents**

- The data on seized Red Sander logs in Andhra Pradesh and all over India at various points indicated that high level of removal is taking place in the natural populations.
- The natural Red Sanders areas are highly prone to summer fires because of thick cover of dried Botha grasses (*Cymbopogon coloratus*). Summer high temperature, thick dry grasses and difficult terrains make the task of controlling annual fires very difficult. During the fires most of the small seedlings, saplings and sometimes un-established poles (10-20 cm girth class) get dried up.
- The Red Sanders areas are surrounded by villages which have large number of cattle. Cattle's grazing is observed in most of the areas.
- The illegal felling for highly priced heartwood is one of the main threats for natural population of Red Sander. The trees of above 70 cm girth class are selectively harvested for heartwood.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Such studies should be carried out at regular intervals to assess the changes in population structure and other factors.

2. **Evaluation and characterization of clones of casuarina with reference to yield, tree form, biomass, pulping characteristics and key nursery pests**

**Principal Investigator:** Dr. Kannan C.S. Warrier, IFGTB, Coimbatore

**Duration:** 2007-2012

**Critical analysis of the research theme and summary of the study**

*Causuarina equisetifolia* is one among the widely accepted tree species by farmers in South India due to its fast growth, multiple end uses and suitability in the agrarian ecosystem. Considering the ever –increasing demand for supply of raw materials for the pulp industries, there is an urgent need to increase the area under superior planting stock and enhance the productivity. Clonal strategy is an excellent approach to eliminate inbreeds, provide adapted in predicting yield in plantation programmes. Eighty seven clones of *C. equisetifolia* were evaluated for growth traits, tree form and wood characteristics in three locations over a period of three years at IFGTB.

Significant difference was observed for tree height, diameter at breast height and biomass index among 87 casuarinas clones in all the three locations namely, Mayiladumparai, Moorthipalayam and Sirugramam. Among the two primary characters, DBH showed higher degree of variation than height in all the three locations. Application of Mahalanobis' $D^2$ statistics and Tocher's clustering method grouped the 90 accessions into 10, 15 and 14 clusters at Mayiladumparai, Moorthipalayam and Sirugramam respectively. Five male clones namely, TNVM 2, CE 2003/4, CE 2003/3 CE 219 and CE 347, and 10 female clones TNPP 2, TN 111, CE 2002/1, CE 220, CE 268, CE 243, CE 9, CE 303, CE 281 and CE 2003/5 can be selected for further breeding programmes. Five monoecious clones namely, CE 2002/2, CE 329, CE 327, CE 224 and CE 83 also were found to be productive and divergent. They could be used as pollen parents in the breeding programme. The results on genetic divergence have got an immediate application in the establishment of clonal seed orchards. GxE interaction was analysed using stability parameters. Five clones namely, CE 220, CH 3001, CE 243, CE 224 and CE 2003/5 proved to be stable across the three locations with respect to volume index. Clones CE 243, CE 9 and TNPP 1 were found suitable for planting in sites with stress or favourable conditions. Five resistant clones (PY-157, APKKD-11, TNKP – 2, APKKD -3 and TNIPT-6) remained free of the targeted pest *Icerya purchasi* for the entire study period.

**Scientific findings and contents**

- Significant difference was observed for tree height, diameter at breast height and biomass index among 87 casuarinas clones in all the three locations namely, Mayiladumparai, Moorthipalayam and Sirugramam.
- Among the two primary characters, DBH showed higher degree of variation than height in all the three locations.
- Five male clones namely, TNVM 2, CE 2003/4, CE 2003/3 CE 219 and CE 347, and 10 female clones TNPP 2, TN 111, CE 2002/1, CE 220, CE 268, CE 243, CE 9, CE 303, CE 281 and CE 2003/5 can be selected for further breeding programmes.
- Five monoecious clones namely, CE 2002/2, CE 329, CE 327, CE 224 and CE 83 also were found to be productive and divergent. They could be used as pollen parents in the breeding

programme.

- Five clones namely, CE 220, CH 3001, CE 243, CE 224 and CE 2003/5 proved to be stable across the three locations with respect to volume index. Clones CE 243, CE 9 and TNPP 1 were found suitable for planting in sites with stress or favourable conditions.
- Five resistant clones (PY-157, APKKD-11, TNKP – 2, APKKD -3 and TNIPT-6) remained free of the targeted pest *Icerya purchasi* for the entire study period.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Such studies should be carried out at regular intervals to assess the performance of clones under field conditions.

3. **Assessment of the impact of forest fire on the regeneration of forests in Andhra Pradesh**

**Principal Investigator:** D. Jaya Prasad, IFS, IFB, Hyderabad

**Duration:** 2004- 2007

**Critical analysis of the research theme and summary of the study**

To evaluate the impact of forest fires on the regeneration of different species, physical and chemical characteristics of the soil, experiments were conducted in dry deciduous forests of Mancheriyal Forest Division and Jannaram Wild Life Division of Adilabad District of Northern Telangana Zone of Andhra Pradesh. Two Vana Sarakshana Samithies (VSS) in each division, one is protected by brushwood fencing and by regular patrolling against fire & grazing, while adjacent area is considered as unprotected. Regeneration and vegetation analysis was done by quadrate sampling method and soil samples were analyzed for pH, electrical conductivity, nitrogen, phosphorus and potassium.

The forests in the region are characterized by ground fires only and a regular annual phenomenon. Crown fires seldom occur in this region; therefore the fire has little effect on community structure of trees. However, the herbs and seedlings are affected by fire significantly in respect of species richness etc. Regeneration of the seedlings and new recruits are observed more in the fire protected sites. Electrical conductivity and Ph of the soil is found increased as a result of fire in the region. Nitrogen, phosphorus and potassium are also found more in fire affected areas.

The pioneer species in fire affected areas are *Cyprus, Panicum, Phyllanthus,* while fire indicator species like *Sida, Cassia spp* in the region. When forest subjected to openness most Gramineae species dominates the ground floor. In protected forests where the fencing or the protects from grazing is provided there is significant regeneration of the tree species, especially *Tectona, Lagerstroemia, Azadiracta, Anogeissus spp, Someida* and *Terminalia spp* are observed. *Dendrocalamus spp* is showing more regeneration in protected forests.

**Scientific findings and contents**

1. The forests in the region are characterized by ground fires only and a regular annual phenomenon.
2. Crown fires seldom occur in this region; therefore the fire has little effect on community structure

of trees. However, the herbs and seedlings are affected by fire significantly in respect of species richness etc.

3. Regeneration of the seedlings and new recruits are observed more in the fire protected sites.
4. Electrical conductivity and Ph of the soil is found increased as a result of fire in the region. Nitrogen, phosphorus and potassium are also found more in fire affected areas.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The research findings have utility to study the effect of the ground fire in the dry deciduous forests of the Adilabad district. This indicates that the forest ecosystem sustains the biotic interferences like fire and immediately recoups every year. Since the natural forests compose different species it has sustenance to the environmental impact when damage due to the ground fire is insignificant.

4. **Studies to evaluate impact of ban on green felling on regeneration of conifer species (deodar)**

**Principal Investigator:** by Dr. Rajesh Sharma, HFRI, Shimla

**Duration:** 2002- 2005

**Critical analysis of the research theme and summary of the study**

Deodar is the climax species in temperate Himalayas and forms the bulk of vegetation. The decision to ban green felling apparently seems good to prevent illicit felling but it inherits certain demerits also. So studies were carried out to assess population structure and regeneration pattern in undisturbed and disturbed areas in Theog, Chopal, Kullu and Dalhousie forest divisions in the state of HP.

After conducting surveys in various Forest Divisions of HP, it was found that there were various factors affecting regeneration of Deodar as an impact of ban on green felling and this includes heavy biotic interferences due to Timber distribution and Grazing, Fire etc. Canopy closure resulting into poor seed formation and undergrowth altering moisture regimes. Wide opening of canopy resulted into excessive water evaporation. Heavy litterfall in areas caused difficulty in penetration of seed into soil, change in pH of soil and moisture contents in the soil.

Based on these studies, it could be inferred that the areas where Silvicultural operations have been done in past such as clear felling especially Cheyog compt. I, profuse regeneration has taken place. Also the stands where salvage has been removed or anything like fire which opened canopy enough to allow sunlight to pass through it on cooler and moist sites e.g. Bajraundi and Cheyog Compt. VII, the evidences of good regeneration were seen. However, certain sites despite opening due to salvage removal do not support this hypothesis, probably the areas were too exposed resulting into reduced soil moisture with excessive evaporation. Further compactness of soil due to biotic interferences has reduced the population of seedlings and saplings in such forest areas.

**Scientific findings and contents**

The surveys in various Forest Divisions of HP, evident that there were various factors affecting regeneration of Deodar as an impact of ban on green felling and this includes heavy biotic interferences due to Timber distribution and Grazing, Fire etc. Canopy closure resulting into poor seed formation and undergrowth altering moisture regimes. Wide opening of canopy resulted into excessive water evaporation. Heavy litterfall in areas caused difficulty in penetration of seed into

soil, change in pH of soil and moisture contents in the soil.

These studies suggests that the areas where Silvicultural operations have been done in past such as clear felling especially Cheyog compt. I, profuse regeneration has taken place. Also the stands where salvage has been removed or anything like fire which opened canopy enough to allow sunlight to pass through it on cooler and moist sites e.g. Bajraundi and Cheyog Compt. VII, the evidences of good regeneration were seen. However, certain sites despite opening due to salvage removal do not support this hypothesis, probably the areas were too exposed resulting into reduced soil moisture with excessive evaporation. Further compactness of soil due to biotic interferences has reduced the population of seedlings and saplings in such forest areas.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Such studies should be carried out at regular intervals to assess the changes in population structure and other factors.

5. **Seed studies on some of the economically important species of Western Ghats**

**Principal Investigator:** Dr. Geeta Pandey, IWST, Bengaluru

**Duration:** 2003- 2007

**Critical analysis of the research theme and summary of the study**

Western Ghats harbor number of timber yielding species, LKTS and non timber forests species. The study was aimed at generating basic data on seed variability, desiccation sensitivity, storage and extent and course of infestation in the four economically important species of the area. The species taken for this study were *Garcinia gummi-gutta*, *Dysoxylum malabaricum*, *Myristica fragrans* and *Dipterocarpus indicus.* The studies on desiccation sensitivity and storage has revealed that *Garcinia gummi-gutta* is tropical dormant recalcitrant while other three species viz., *Dysoxylum malabaricum*, *Myristica fragrans* and *Dipterocarpus indicus* are recalcitrant in nature. Seed viability of *G. gummi-gutta* and *D. malabaricum* can be prolonged by storing the seeds at 15°C. This information on variability, germination and insect infestation would help in estimating the quantity of fruits/seed that can be collected before undertaking any seed dependent trial. It would also help in restocking of these species in their native habitat. Since all the four species are desiccation sensitive the data on desiccation sensitivity and seed storage would help in devising methodology for ex-situ conservation of these species.

*G. gummi-gutta* has a peculiar germination pattern. The primary root (PR) emerges first at the distal end of the seed followed by emergence of shoot from the proximal end. Subsequently, prior to leaf differentiation, an adventitious root (AR) originates from the base of the shoot. This pattern resembles the already described 'garcinia type' of seed germination. The PR along with the seed gradually disintegrates by six months and ultimately the adventitious root takes over as the main root of the plant. This study shows that fractions of seeds of G. gummi-gutta posses unique regeneration capacity.

The seed of *D. malabricum* are recalcitrant, as viability loss rapid ~34% MC and at 15°C viability was retained for longer time. Whereas, seed of *M. fragrans* seeds are also recalcitrant, as viability loss rapid below 21-22% MC. Viability of this species could not be prolonged under any of the tested conditions.

**Scientific findings and contents**

- *Garcinia gummi-gutta* has a peculiar germination pattern. The primary root (PR) emerges first at the distal end of the seed followed by emergence of shoot from the proximal end. Subsequently, prior to leaf differentiation, an adventitious root (AR) originates from the base of the shoot. This pattern resembles the already described 'garcinia type' of seed germination. The PR along with the seed gradually disintegrates by six months and ultimately the adventitious root takes over as the main root of the plant. This study shows that fractions of seeds of G. gummi-gutta posses unique regeneration capacity.
- The seed of *D. malabricum* are recalcitrant, as viability loss rapid ~34% MC and at 15°C viability was retained for longer time.
- Whereas, seed of *M. fragrans* seeds are also recalcitrant, as viability loss rapid below 21-22% MC. Viability of this species could not be prolonged under any of the tested conditions.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The study was aimed at generating basic data on seed variability, desiccation sensitivity, storage and extent and course of infestation in the four economically important species of Western Ghats, which would help in devising methodology for Ex-situ conservation of these species.

6. **Studies on seed germination and longevity of *Abies Spectabilis* (D.Don) SPACH**

**Principal Investigator:** Dr. P.S. Negi, HFRI, Shimla

**Duration:** 2011- 2016

**Critical analysis of the research theme and summary of the study**

The natural populations of *Abies spectibilis* in the state of HP are not well documented; hence studies were carried out in addition to develop its seed protocol.

To identify natural population of *Abies spectabilis* in Himachal Pradesh survey was conducted in nine Forest Divisions viz. Shimla and Sarahan Wildlife Divisions, Kinnaur Forest Division, Rampur forest Division, Rohru Forest Division, Seraj Forest Division, Parvati Forest Division, Great Himalayan National Park and Kullu Forest Division and the species is recorded to have 39 natural populations in the state of HP. The study further reveals that it grows mainly in cool, moist and shady locations mostly in northern aspects. It is also observed that *Abies pindrow, Picea smithiana, Pinus wallichiana, Acer caesium* and *Acer acuminatum* at around 3000m elevations and with *Betula utilis, Corylus jacquenmontii, Quercus semicarpifolia, Taxux wallichiana, Rhododendron campanulatum* above 3000m elevations.

The germination studies conducted to find the effect on time of collection on germination of seeds revealed that optimum time of collection is 2nd fortnight of October as seed collected during this period recorded maximum 42.00% germination where as seeds conducted to find out the appropriate pre-sowing treatment in *Abies spectabilis* seeds revealed that seeds of *Abies spectabilis* do not possess any seed dormancy and it requires no pre-sowing treatments before sowing in the nursery. The poor germination of seeds is primarily due to presence of large number of empty/ unfilled seeds. The germination studies conducted to find the effect of seed size on germination of *Abies spectabilis* revealed that large sized seeds recorded maximum 40% germination where as medium seed size recorded 32% germination and small seed size recorded only 12% germination. The germination

studies conducted to find the effect of seeds collected from trees having different diameter classes on germination of seeds revealed that seeds collected from trees having 40cm-50cm diameter classes recorded maximum 46.40% germination where as seeds collected from trees having diameter classes of 30cm -40cm, 20cm -30cm and 10cm-20cm recorded comparatively less germination (<39.00%). The germination studies conducted to find the effect of depth of seeds sowing on germinating of seeds revealed that seeds sown at a depth of 1.50cm recorded germination (<34.00%) in the nursery. The seed storability studies conducted to find the suitable storage container and storage temperature (environment) for enhancing seed longevity during storage revealed that air tight moisture-proof polysac containers under low temperature (-<5°C) in deep freezer in the best storage container and storage environment for maintaining seed longevity. The seed stored in air tight Polysac container in deep freezer (<-5°C) retains more that 21.00% viability even after 18 months of storage whereas other storage containers/storage environment showed less seed viability.

**Scientific findings and contents**

- *Abies spectabilis* have 39 natural populations in the state of HP.
- The optimum time of collection is 2nd fortnight of October each year.
- The seeds of *Abies spectabilis* do not possess any seed dormancy and it requires no pre-sowing treatments before sowing in the nursery.
- The seed stored in air tight Polysac container in deep freezer (<-5°C) retains more that 21.00% viability even after 18 months of storage.

7. **Development of techniques for raising deodar (*Cedrus deodara*) plantations through tall plants**

**Principal Investigator:** Dr. Sandeep Sharma, HFRI, Shimla.

**Duration:** 2008-2013

**Critical analysis of the research theme and summary of the study**

Now a days, there is a need to develop technology to produce tall plants of deodar for quick re-greening and landscaping in addition to explore the possibilities to use wildlings of the species in n various plantation programmes.

The study suggests that in natural forest of Deodar especially in moist localities, lot of wildings are present, however the present study do not recommend utilizing this resource for field planting/nursery purposes as the uprooting and transplanting shock was no severe that wildings could not resume normal growth even after two years of replanting.

For producing tall plants of deodar, the seedlings were first raised in nursery beds for 2.5 years then these were transferred in gunny begs of suitable size during rainy season. These plants should be kept in shade house (50 % shade) and about 50 % of lower branches were pruned for better success. Application of Vermiwash dose of 20 ml / plant at 15 days internal during March to May enhanced the height and diameter growth over control in the tune of 8.67% and 10.64%, respectively.

The pit size of 75cm$^3$ was found to be better for survival and growth of gunny bag raised stock in the field. It is further found that gunny bag raised stock can be planted anytime in the field except summer season.

**Scientific findings and contents**

- The study do not recommend utilizing this resource for field planting/nursery purposes as the uprooting and transplanting shock was no severe that wildings could not resume normal growth even after two years of replanting.
- For producing tall plants of deodar, the seedlings were first raised in nursery beds for 2.5 years then these were transferred in gunny begs of suitable size during rainy season. These plants should be kept in shade house (50 % shade) and about 50 % of lower branches were pruned for better success. Application of Vermiwash dose of 20 ml / plant at 15 days internal during March to May enhanced the height and diameter growth over control in the tune of 8.67% and 10.64%, respectively.
- The pit size of 75cm$^3$ was found to be better for survival and growth of gunny bag raised stock in the field. It is further found that gunny bag raised stock can be planted anytime in the field except summer season.

8. **Determination of nursery requirements and initial planting performance of *Diploknema butyracea* (Roxn.) H.J. Lam and *Myrica esculenta* Buch. Ham. under mid hill conditions of Himachal Himalayas**

**Principal Investigator:** Dr. Sandeep Sharma, HFRI, Shimla

**Duration:** 2012-2017

**Critical analysis of the research theme and summary of the study**

Studies were carried out to develop nursery and plantation technology of *Diploknema butyracea* (Cheura) and *Myrica esculenta* (Kaphal) for the use of farmers and also to use these species as additional source of income in mid hill conditions of Himachal Himalayas.

The present study revealed that the Cheura nursery stock can be easily grown in the nursery in the foot hills of Himachal Himalayas provided nursery stock during winters kept in polyhouse for three months (15$^{th}$ December to 15$^{th}$ March) to avoid frost damage. Establishment of Cheura plants in the field pose problems and require special protection during winter months in Himachal Himalayas. It was found that this plant is heavily damaged by the porcupine in the field. For future field studies, porcupine free sites should be selected or steps should be taken in advance to protect plants from porcupine damage in field.

The breakthrough in Kaphal seed germination has been achieved depending upon seed year, time of sowing and pre-sowing treatment in this study. Production of Kaphal stock in the nursery from seed after giving one weed soaking in water followed by one weed drying and again repeating the weekly treatment once and subsequently sowing in sand beds in polyhouse during June-July resulted in breaking dormancy and getting around 70% germination. Seed treatment, time of sowing and good seed year affects seed germination in this species.

**Scientific findings and contents**

- The present study revealed that the Cheura nursery stock can be easily grown in the nursery in the foot hills of Himachal Himalayas provided nursery stock during winters kept in polyhouse for three months (15$^{th}$ December to 15$^{th}$ March) to avoid frost damage.

- Establishment of Cheura plants in the field pose problems and require special protection during winter months in Himachal Himalayas. It was found that this plant is heavily damaged by the porcupine in the field. For future field studies, porcupine free sites should be selected or steps should be taken in advance to protect plants from porcupine damage in field.
- The breakthrough in Kaphal seed germination has been achieved depending upon seed year, time of sowing and pre-sowing treatment in this study. Production of Kaphal stock in the nursery from seed after giving one weed soaking in water followed by one weed drying and again repeating the weekly treatment once and subsequently sowing in sand beds in polyhouse during June-July resulted in breaking dormancy and getting around 70% germination. Seed treatment, time of sowing and good seed year affects seed germination in this species.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The nursery and plantation technology of *Diploknema butyracea* (Cheura) and *Myrica esculenta* (Kaphal) for the use of farmers and also to use these species as additional source of income in mid hill conditions of Himachal Himalayas.

9. **Productivity enhancement through selection of superior clones of *Dalbergia sissooo***

**Principal Investigator:** Dr. Rajesh Sharma, HFRI, Shimla

**Duration:** 2012- 2013

**Critical analysis of the research theme and summary of the study**

Increase in productivity of tree species including *Dalbergia sissooo* can be achieved through selection of the best genotypes. The intensity of the selection in turn determines the genetic gain attainable at the end. In the present studies selection of the clones for their genetic variation and ability to resist stress and insect attack has helped in selection of clones which are expected to give higher genetic gain. The study was material from first generation clonal seed orchard of *D. sissooo* at Bir Plasi, Nalagargh. HP and genetic variation in clones was measured using isoenzyme analysis by Horizontal Starch Gel Electrophoresis..

*Dalbergia sissooo* clones selected initially based on their performance in the orchard were subjected to genetic variation studies through isozymes along with studies for stress and insect resistance. These investigations have revealed genetic variation in the selected clones of Shisham with regard to number of alleles, allelic frequencies and also with regard to allelic diversity, heterozygosity and genetic distances. Some of the clones like 204, 236, 36 and 260 showed greater diversity, while others showing variation have tendency of grouping. Clones tested for stress resistance based on water potential and regulated irrigation schedule have shown clone no. 204, 58, 203, 260 and 200 were found to be more resistant to stress while in insect resistance studies clone no. 260 was found to be more resistance followed by clones 215, 49 and 204 and clone 6 to the least resistive. The field performance of the selected clones at two different locations further confirms the selection of the clones based on genetic variation and stress and insect-resistance.

**Scientific findings and contents**

- These investigations have revealed genetic variation in the selected clones of Shisham with

regard to number of alleles, allelic frequencies and also with regard to allelic diversity, heterozygosity and genetic distances. Some of the clones like 204, 236, 36 and 260 showed greater diversity, while others showing variation have tendency of grouping.

- Clones tested for stress resistance based on water potential and regulated irrigation schedule have shown clone no. 204, 58, 203, 260 and 200 were found to be more resistant to stress while in insect resistance studies clone no. 260 was found to be more resistance followed by clones 215, 49 and 204 and clone 6 to the least resistive.
- The field performance of the selected clones at two different locations further confirms the selection of the clones based on genetic variation and stress and insect-resistance.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

*Dalbergia sissooo* clones selected initially based on their performance in the orchard were subjected to genetic variation studies through isozymes along with studies for stress and insect resistance.

10. **Comparison of hydrological regime of a micro-watershed having dense oak forest with a degraded micro-watershed**

**Principal Investigator:** Dr. S.P.S. Rawat, FRI, Dehradun

**Duration:** 2007- 2012

**Critical analysis of the research theme and summary of the study**

The study was carried out in two micro-watersheds; Arnigad having dense Oak forest vegetation and Bansigad having degraded forest cover. Both watersheds are in Garhwal Himalayas near Mussoorie. The study suggests that dense forested micro-watershed plays much better role as compared to degraded micro-watershed by regulating several hydrological parameters e.g. (i) Soil moisture was found 3% more in dense forested micro-watershed as compared to degraded micro-watershed, (ii) Annual base flow was 19% more in dense forested micro-watershed than degraded one, (iii) annual direct runoff was 45% less in dense forested micro-watershed than degraded one, (iv) Annual total flow was 13% less in dense forested micro-watershed than degraded one, (v) annual SSL was 61% less in dense forested micro-watershed than degraded one, (vi) Annual TDS was 43% more in dense forested micro-watershed than degraded one, (vii) Annual BL was 83% less in dense forested micro-watershed than degraded one and (viii) Annual TL was 44% less in dense forested micro-watershed than degraded one.

The results showed that the forest cover can be considered as main reason for changes in soil moisture regime, infiltration rate, runoff, sediment load and other hydrological parameters of study micro-watersheds. It also altered the rainfall-runoff and rainfall-sediment relationships and other hydrological links which may lead to proper understanding of planning, management and control measures, can be a part of watershed development plan in the future. The knowledge about rainfall – runoff relationship may contribute in flood prediction analysis. Changes in both quality and quantity of surface waters that occur through watershed management can often generate recreational benefits. Present research analysis/knowledge of soil moisture levels for proper management of watershed and bring local environmental benefits. The present findings offer a reference for hydrological flow paths in different forest covers but still there is an urgent need to understand all other hydrological paths in details like geology, evapotraspiration etc which have been limitations to the present study.

**Scientific findings and contents**

The study suggests that dense forested micro-watershed plays much better role as compared to degraded micro-watershed by regulating several hydrological parameters e.g.

- Soil moisture, Annual base flow and Annual TDS (Total Dissolved Solids) were found 3%, 19% 43% more, respectively, in dense forested micro-watershed than degraded micro-watershed.
- Annual direct runoff, Annual total flow, Annual SSL (Seasonal Sediments Load), Annual BL (Bed Load) and Annual TL(Total Load) were found 45%, 13%, 61%, 83%, 44% less, respectively, in dense forested micro-watershed than degraded one.
- The results showed that the forest cover can be considered as main reason for changes in soil moisture regime, infiltration rate, runoff, sediment load and other hydrological parameters of study micro-watersheds.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Comparison of Hydrological Regime of a Micro-Watershed having Dense Oak Forest with a Degraded Micro-Watershed provide current hydrological responses of watersheds at micro level in Mussoorie – lesser Himalayas. Such studies are also required to be carried out in other water sheds.

11. **Impact of invasive species on plant diversity in selected forest sites of Uttarakhand, Haryana and Punjab**

**Principal Investigator:** Dr. Anoop Chandra, FRI, Dehradun

**Duration:** 2012- 2015

**Critical analysis of the research theme and summary of the study**

Present study was carried out to know the impact of invasive species on the plant diversity of Uttarakhand, Haryana and Punjab. Phytosociological studies were conducted using quadrate method (10x10m for trees; 3x3m for shrubs and 1x1m herbs) at suitable representative locations in all three states. Control was taken in the site where comparatively less impact of invasive species was observed.

It is concluded from the study that in Uttarakhand, there is intense invasion of *Lantana camara* in the low areas whereas in hilly reasons *Eupatorium adenophorum* posing a great threat to indigenous flora. There was no significant difference in diversity index (H), species richness and evenness of control and lantana invaded sites of tree and shrub layer. Concentration of dominance (cd) showed inverse relationship with diversity index. Herbaceous species diversity index (H), species richness and evenness declined in the invaded sites. It indicates that there is tremendous pressure by *Lantana camara* on indigenous species.

In Haryana, there is heavy invasion of *Lantana camara. Parthenium hysterophorum, Acharymthus aspara, Bidens pilosa* etc. are also evading the area. The indigenous flora such as *Azadirchta indica, Bomabax ceiba, Albizzia lebbeck, Holoptia integrifolia, Diospyros montana, Balanites aegyptica* etc. are under tremendous pressure and their density and total basal cover is declining. There was no significant difference in diversity index (H), species richness and evenness of control and lantana invaded sites of tree and shrub layer. Concentration of dominance (cd) showed inverse relationship with diversity index. Herbaceous species diversity index (H), species richness and evenness declined in the invaded sites. It indicates that there is tremendous pressure by *Lantana camara* on indigenous species.

Similarly, in the Punjab, sites were identified by infestation with invasive species. Species richness

of tree and shrub layer was higher in the control site than the infested sites. Plant density was also higher in control than infested sites. Tree diversity index (H) and tree species richness was higher in the control site than threatened sites. Herbaceous species diversity index (H) was also observed higher in control sites. Concentration of dominance (cd) showed inverse relationship with diversity index. It indicates that canopy closing in invaded site prevent emergence of new species of herbs.

It was observed that seedling and sampling stages in the invaded sites in Uttarakhand, Haryana and Punjab are declining. It reveals that canopy closing and effective utilization nutrients by invasive species are the reason for decline in the regeneration of tree species. Spread of invasive species can only be controlled or minimized, if these species can be used for making useful products. Substantial dry biomass is produced by these species. Study reveals that *Lantana camara* can be utilized for paper making.

**Scientific findings and contents**

- In Uttarakhand, there is intense invasion of *Lantana camara* in the low areas whereas in hilly reasons *Eupatorium adenophorum* posing a great threat to indigenous flora. There was no significant difference in diversity index (H), species richness and evenness of control and lantana invaded sites of tree and shrub layer. Concentration of dominance (cd) showed inverse relationship with diversity index. Herbaceous species diversity index (H), species richness and evenness declined in the invaded sites. It indicates that there is tremendous pressure by *Lantana camara* on indigenous species.
- In Haryana, there is heavy invasion of *Lantana camara. Parthenium hysterophorum, Acharymthus aspara, Bidens pilosa* etc. are also evading the area. The indigenous flora such as *Azadirchta indica, Bomabax ceiba, Albizzia lebbeck, Holoptia integrifolia, Diospyros montana, Balanites aegyptica* etc. are under tremendous pressure and their density and total basal cover is declining. There was no significant difference in diversity index (H), species richness and evenness of control and lantana invaded sites of tree and shrub layer. Concentration of dominance (cd) showed inverse relationship with diversity index. Herbaceous species diversity index (H), species richness and evenness declined in the invaded sites. It indicates that there is tremendous pressure by *Lantana camara* on indigenous species.
- In Punjab, sites were identified by infestation with invasive species. Species richness of tree and shrub layer was higher in the control site than the infested sites. Plant density was also higher in control than infested sites. Tree diversity index (H) and tree species richness was higher in the control site than threatened sites. Herbaceous species diversity index (H) was also observed higher in control sites. Concentration of dominance (cd) showed inverse relationship with diversity index. It indicates that canopy closing in invaded site prevent emergence of new species of herbs.
- It was observed that seedling and sampling stages in the invaded sites in Uttarakhand, Haryana and Punjab are declining. It reveals that canopy closing and effective utilization nutrients by invasive species are the reason for decline in the regeneration of tree species. Spread of invasive species can only be controlled or minimized, if these species can be used for making useful products. Substantial dry biomass is produced by these species. Study reveals that *Lantana camara* can be utilized for paper making.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The study was carried out to know the impact of invasive species on the plant diversity of Uttarakhand, Haryana and Punjab.

12. **Development of suitable propagation technologies of three *Terminalia* species**

**Principal Investigator:** Dr. S. Nautiyal, FRI, Dehradun.

**Duration:** 2004- 2007

**Critical analysis of the research theme and summary of the study**

The experiments were conducted to standardize vegetative propagation techniques of *Terminalia* Arjuna*, T. bellirica* and *T. chebula* using hard wood cutting of about 15-20cm long and 5 to 10 mm dia. Cutting were taken from one-year healthy shoots of selected mother plants and each cutting had at least 2 to 3 nodes. Experiments were also conducted using juvenile cuttings.

Vegetative propagation technology through juvenile shoot cuttings of *Terminalia* Arjuna*, T. bellirica* and *T. chebula* is developed. In rooting response of juvenile shoot cuttings (mononodal cutting) of *Terminalia* Arjuna*, T. bellirica* and *T. chebula* for mass propagation, the maximum rooting response was observed in case of IBA 4000 (*Terminalia* Arjuna and *T. chebula*) and IAA 400 (*T. bellirica*) treated cuttings. The Branch cutting collected from mature tree of *T. bellirica* failed to root whereas, the branch cuttings of *Terminalia* Arjuna and *T. chebula* favourably responded to rooting.

All three *Terminalia* species are difficult to root. Comparatively *T.* Arjuna and *T. chebula* responded to rooting of hard wood cuttings, however, *T. bellerica* did not root at all. Hence, production of planting stock by hard wood cuttings is not recommended.

Rooting response of juvenile shoot cuttings in all three species have responded well up to 80% cuttings were rooted. Hence, production of planting material by rooting of Juvenile shoot cuttings is strongly recommended. The rooting of cuttings during summer and rainy months is recommended.

**Scientific findings and contents**

- Vegetative propagation technology through juvenile shoot cuttings of *Terminalia* Arjuna*, T. bellirica* and *T. chebula* is developed. In rooting response of juvenile shoot cuttings (mononodal cutting) of *Terminalia* Arjuna*, T. bellirica* and *T. chebula* for mass propagation, the maximum rooting response was observed in case of IBA 4000 (*Terminalia* Arjuna and *T. chebula*) and IAA 400 (*T. bellirica*) treated cuttings. The Branch cutting collected from mature tree of *T. bellirica* failed to root whereas, the branch cuttings of *Terminalia* Arjuna and *T. chebula* favourably responded to rooting.
- All three *Terminalia* species are difficult to root. Comparatively *T.* Arjuna and *T. chebula* responded to rooting of hard wood cuttings, however, *T. bellerica* did not root at all. Hence, production of planting stock by hard wood cuttings is not recommended.
- Rooting response of juvenile shoot cuttings in all three species have responded well up to 80% cuttings were rooted. Hence, production of planting material by rooting of Juvenile shoot cuttings is strongly recommended. The rooting of cuttings during summer and rainy months is recommended.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Vegetative propagation techniques of *Terminalia* Arjuna*, T. bellirica* and *T. chebula* using branch cutting have been developed.

13. **Assessment of seed quality in unimproved populations, seed production areas and seed orchards of *Tectona grandis* L.**

**Principal Investigator:** Dr. Geeta Joshi, IWST, Bengaluru.

**Duration:** 2005-2009

**Critical analysis of the research theme and summary of the study**

Investigations were carried out to assess seed quality of teak from different sources i.e. unimproved stands, seed production areas (SPAs) at Virnoli, Birchi, Bhagwati, Titimathi, Chandrapur, Adilabad and Kzagnarar and clonal seed orchard (CSO) at Adilabad and Jakaram, A.P., Thithimatti, Karnataka and Chandrapur, Maharashtra and seedling seed orchard at Tirupathi, A.P.

Seed germination studies were carried out for 17 seeds lots. Seed germination was more in seeds collected from SPA compared to corresponding unimproved populations for all the populations. Among all populations, maximum germination was 65% for SPA Titimathi and minimum of 3.66% from unimproved population from Vernoli. Among unimproved populations maximum germination of 55% was recorded for unimproved population form Titimathi followed by 38% germination for seeds from unimproved population Chandrapur and minimum of 3.66% from Vernoli. Similarly among SPAs maximum germination of 65% percent was recorded for SPA Titimathi followed by 62% from SPA Chandrapur and minimum of 9.33% from SPA Virnoli. Among CSOs Titimathi CSO had maximum germination of 62% followed by 42% from CSO Chandrapur and minimum of 12% from CSO Adilabad. Seeds from SSO Tirupati had 19% germination.

Assemblage of plus trees in CSO did not have impact on seedling growth as compared to SPA. Height and collar diameter recorded for CSO Chandrapur, Titimathi and Jakaram was lees as compared to SPAs. Seedlings from SSO Tirupathi had height and collar diameter more than the CSOs. But less as

This study provides insight into the effect of Thee Improvement activities like conversion of unimproved populations to SPAs and establishment of CSO and SSO on quality of the seed produced and on early growth performance of the seedlings. This study reveals the importance of SPAs as a source of "quality seeds", as based on morphological characters and seed germination, fruits collected from all Teak SPAs had better as compared to unimproved populations.

**Scientific findings and contents**

- Seed germination studies showed that seed germination was more in seeds collected from SPA compared to corresponding unimproved populations for all the populations.
- Assemblage of plus trees in CSO did not have impact on seedling growth as compared to SPA. Height and collar diameter recorded for CSO Chandrapur, Titimathi and Jakaram was lees as compared to SPAs. Seedlings from SSO Tirupathi had height and collar diameter more than the CSOs. But less as
- The study provides insight into the effect of Thee Improvement activities like conversion of unimproved populations to SPAs and establishment of CSO and SSO on quality of the seed produced and on early growth performance of the seedlings.
- The study also reveals the importance of SPAs as a source of "quality seeds".

14. **Standardization of nursery techniques of raising containerized seedlings of conifers and their broadleaved associates**

**Principal Investigator:** Dr. Sandeep Sharma, FRI, Dehradun

**Duration:** 2000- 2007

**Critical analysis of the research theme and summary of the study**

The gestation period of silver fir, spruce and deodar is 4½, 3½, and 2½ years, respectively, in nursery. This period can be reduced by one year for all three species using root-trainer seedling production system.

- Root-trainer of size 500cc or 300cc with vertical length more than 20cm should be used.
- Potting media comprised of compost: soil: sand in the ratio of 3:1:1 should be filled in the root –trainer. Compost should be preferably prepared from nursery weeds or Deodar, Kail needles. Soil must be obtained from natural zone of Silver fir to facilitate mycorrhizal association of root-trainers raised seedlings.
- Before filling potting media in to root-trainers, it should be treated with Formaline to disinfect it and to protect germinating seedlings from damping off diseases.
- The sowing should be done in the month of March directly in the root –trainers.
- Agro –shade net that provides 50% shade is required for Silver fir nursery stock.
- The shade is required from April to October to protect the seedlings from scorching Sun during entire nursery period of the root trainer grown stock. The shade should be removed during last 1-2 months of nursery period i.e. just before out planting.

In addition experiments were shown that root trainer of 500 cc single cell found good in terms of varied growth parameters for production of nursery stock of *Alnus nitida* and *Grewia optiva*.

**Scientific findings and contents**

The gestation period of silver fir, spruce and deodar is 4½, 3½, and 2½ years, respectively, in nursery. This period can be reduced by one year for all three species using root-trainer seedling production system.

- In addition experiments were shown that root trainer of 500 cc single cell found good in terms of varied growth parameters for production of nursery stock of *Alnus nitida* and *Grewia optiva*.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The gestation period of silver fir, spruce and deodar is reduced by one year using root-trainer seedling production system in nursery.

15. **Enhancement of seed germination in *Anogeissus latifolia* through various seed technological inputs**

**Principal Investigator:** Dr. Ombir Singh, FRI, Dehradun

**Duration:** 2009- 2012

**Critical analysis of the research theme and summary of the study**

Experimentation was carried to improve seed germination and overcome seed emptiness of *Anogeissus latifolia* by studying seed maturity indices, seed handling, seed pretreatment, seed germination and seed storage following ISTA and DANIDA protocols. The seeds of *A. latifolia* mature in second fortnight of March each year when the colour of fruits turns to blackish green with a moisture content of about 12 % of seeds. The weight of mature fruits varies between 0.110 to 0.313 g with average weight of 0.196g/fruit, while weight of seeds (100 seed) varies from 0.30 to 0.92 g with mean weight of 0.57g/100 seeds.

Keeping in view the problem of emptiness in seeds and presence of insect larvae in seeds, efforts were made to control the insect problem in seeds of the species which seems to be the cause of emptiness of seeds in *A. latifolia.* Systemic insecticides were applied in trees of the species in consultation with the Entomology Division of FRI to control the suspected insect responsible for fruit/ seed emptiness in the species. Application of systemic insecticide improves the presence of half filled seeds (about 10 %) in the species, hence, seeds of *A. latifolia* have some entomological problem and require more entomological inputs to deal with the insect by working with a separate independent project on the species to control the insect attack on seeds and also to enhance the filled and viable seeds, thereby, solving the seed problem in *A. latifolia*.

**Scientific findings and contents**

- The seeds of *A. latifolia* mature in second fortnight of March each year when the colour of fruits turns to blackish green with a moisture content of about 12 % of seeds.
- The weight of mature fruits varies between 0.110 to 0.313 g with average weight of 0.196g/fruit.
- *A. latifolia* seed neither require any pre-treatment for germination nor specific seed handling practices.
- Seeds of this species can easily be stored at $15^0$ C in refrigerator in polythene bags at a moisture content of 9% with slight decrease in viability up to two years and is orthodox in nature.
- Number of empty seed is 95% with 5% filled seeds only, which is the real problem in the species.
- Keeping in view the problem of emptiness in seeds and presence of insect larvae in seeds, efforts were made to control the insect problem in seeds of the species which seems to be the cause of emptiness of seeds in *A. latifolia.* Systemic insecticides were applied in trees of the species in consultation with the Entomology Division of FRI to control the suspected insect responsible for fruit/ seed emptiness in the species.
- Application of systemic insecticide improves the presence of half filled seeds (about 10 %) in the species, hence, seeds of *A. latifolia* have some entomological problem and require more entomological inputs to deal with the insect by working with a separate independent project on the species to control the insect attack on seeds and also to enhance the filled and viable seeds, thereby, solving the seed problem in *A. latifolia*.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The entomological findings give new direction in providing solutions and control the problem of seed emptiness in *A. latifolia*. However, the seed technology protocols have been developed for *A. latifolia* as per ISTA guidelines through this project.

16. **Allelopathic Influences in regeneration of silver fir (*Abies pindrow*) and spruce (*Picea smithiana*) forests - Effect of natural leachates on seedling growth in nursery**

**Principal Investigator:** Dr. Ombir Singh, FRI, Dehradun

**Duration:** 2010- 2014

**Critical analysis of the research theme and summary of the study**

To solve the regeneration problems in these forests, allelopathic research is undertaken to ascertain whether compounds released from litter, humus and under-storey species could negatively affect regeneration of *A. pindrow* and *P. smithiana.* Accordingly, allelopathic inhibitions of leachares of Litter, Humus, *Sarcococca saligna, Viburnum nervosum* and fern have been studied on nursery growth of *Abies pindrow* and *Picea smithiana*. Results showed that these leachates have inhibitory effects on nursery growth. The phenolic compounds viz. *p*-coumaric acid, *m*-coumaric acid, trans-5-p-coumaroylguinic acid, neochlorogenic acid, flavanol and others present in various leachates may be responsible of inhibition of various physiological processes of the receptor species (Silver fir and Spruce).It seems that the dynamics of Tree- under storey interactions creating unfavorable conditions for *Abies pindrow* and *Picea smithiana* regeneration on the forest floor in western Himalayas.

**Scientific findings and contents**

- Litter and Humus leachates have inhibitory effects on early nursery growth but intensity of inhibition is more in case of Humus.
- Foliage extracts of under-storey plants *Sarcococca saligna, Viburnum nervosum* and fern has inhibitory effects on nursery growth. The inhibition in nursery growth is also validated by calculating the response index (RI) of various parameters in the study.
- Allelopathic interactions of under storey plants may explain the poor seedling establishment and growth of seedlings of fir and spruce on the forest floor in these temperate forests.
- The phenolic compounds viz. *p*-coumaric acid, *m*-coumaric acid, trans-5-p-coumaroylguinic acid, neochlorogenic acid, flavanol and others present in various leachates may be responsible of inhibition of various physiological processes of the receptor species (Silver fir and Spruce).
- The active substances/allelochemicals present in green foliage and decomposing litter are leached out by rainfall and other means and reach the soil underneath the canopy and hamper the regeneration process in these species.
- It seems that the dynamics of Tree- under storey interactions creating unfavorable conditions for *Abies pindrow* and *Picea smithiana* regeneration on the forest floor in western Himalayas.
- Knowing such tree/under storey interactions can help the foresters in regenerating theses forests by manipulating silvicultural practices.
- Plantation areas of *A. pindrow* and *P. smithiana* should be devoid of Litter, Humus, *Sarcococca saligna, Viburnum spp* and Ferns for better survival and growth.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Allelopathic inhibitions of leachates of litter, humus, *Sarcococca saligna, Viburnum nervosum* and fern have been studied on nursery growth of Abies *pindrow* and *Picea smithiana* in this project.

17. **Developing seed technology and propagation techniques for germplasm conservation of *Buxus wallichiana* Linn. – An important alternative species for the woodcraft industry**

**Principal Investigator:** Dr. Manisha Thapliyal, FRI, Dehradun

**Duration:** 2009- 2012

**Critical analysis of the research theme and summary of the study**

The study used the fruits of *B. wallichiana* collected from Matkangra block near Jadi village in Chakrata forest division and near Kanchula Kharak in Kedarnath WLS, Mandal. At maturity the colour of the fruit was brown with mean length of 8.57, 8.66 and 8.98 mm in the year 2009, 2010 and 2011, respectively. Fruits were more or less round (globular) in shape as their width was marginally less than the length. The differences in seed parameters of Chakrata source were not significant over the years. It was observed that seeds of *B. wallichiana* both from Chakrata and Mandal yielded highest germination at $25^0$C which was 45 and 40%, with mean germination time of 21.40 and 18.20 days, respectively. $30^0$C proved to be high for the germination of seeds from both the sources. At ambient room temperature 42.5% germination was recorded in seeds from Chakrata whereas it was only 15% in seeds from Mandal. Thus, $25^0$C was found to be best suited for laboratory germination of seeds of *B. wallichiana*.

Seeds of *B. wallichiana* are known to exhibit shallow physiological dormancy, so the seeds were subjected to moist pre-chilling treatment for overcoming the dormancy. In seeds from Chakrata pretreatment with $KNO_3$ while in seeds from Mandal $GA_3$ pretreatment was more effective in enhancing the germination of seeds probably due to the fact that GA treatment has been used as replacement for moist prechilling for short duration, which was required more for seeds from higher altitude. Seeds of *B. wallichiana* are reported to have viability of 5-6 months in nature, due to this reason they do not form long term but transient seed banks in soil. Overall erratic seed germination behaviour was observed in seeds of *B. wallichiana* and trends of enhancement or decline in germination were not consistent.

Vegetative propagation through stem cuttings (after giving treatment with various IBA and NAA combinations) has also been developed for the species.

**Scientific findings and contents**

- At maturity the colour of the fruit was brown with mean length of 8.57, 8.66 and 8.98 mm in the year 2009, 2010 and 2011, respectively. Fruits were more or less round (globular) in shape as their width was marginally less than the length.
- The differences in seed parameters of Chakrata source were not significant over the years. It was observed that seeds of *B. wallichiana* both from Chakrata and Mandal yielded highest germination at $25^0$C which was 45 and 40%, with mean germination time of 21.40 and 18.20 days, respectively.
- Seeds of *B. wallichiana* are known to exhibit shallow physiological dormancy, so the seeds were subjected to moist pre-chilling treatment for overcoming the dormancy. In seeds from Chakrata pretreatment with $KNO_3$ while in seeds from Mandal $GA_3$ pretreatment was more effective in enhancing the germination of seeds probably due to the fact that GA treatment has been used as

replacement for moist prechilling for short duration, which was required more for seeds from higher altitude.

- Seeds of *B. wallichiana* are reported to have viability of 5-6 months in nature, due to this reason they do not form long term but transient seed banks in soil. Overall erratic seed germination behaviour was observed in seeds of *B. wallichiana* and trends of enhancement or decline in germination were not consistent.
- Vegetative propagation through stem cuttings (after giving treatment with various IBA and NAA combinations) has also been developed for the species.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Seed and propagation technology of *Buxus wallichiana* has been developed in this project.

18. **Role of allelopathy on regeneration in silver fir (*Abies pindrow*) and spruce (*Picea smithiana*) forests – Effect of natural leachates on seed germination**

**Principal Investigator:** Dr. Ombir Singh, FRI, Dehradun

**Duration:** 2007- 2010

**Critical analysis of the research theme and summary of the study**

The allelopathic research in the project is undertaken to observe the influences of litter, humus, *Sarcocoocca saligna*, *Viburnum nervosum,* fern, fir and spruce on the seed germination and early growth of silver fir and spruce in laboratory conditions. The various concentrations (5-20%) of leachates were tried to investigate their effects on seed germination and growth of radicle and plumule.

The results showed that leachates of humus have reduced and deteriorated radicle growth completely but some stimulation in germination at higher concentrations; however, litter leachates have no such pronounced effect. Foliage leachates of *Sarcocoocca saligna, Viburnum nervosum* and ferns (under-storey plants) also has inhibitory effects on germination and radicle growth but less inhibition in germination by Viburnum leachates at higher concentrations. This research concludes that humus and foliage of specific plants are responsible for regeneration failure in these conifers and not litter as supposed till date.

**Scientific findings and contents**

- Decomposed Litter/Humus as a whole has inhibitory effects on seed germination, radicle and plumule growth not litter as supposed till date.
- Foliage extracts of Under-storey plants *Sarcocoocca saligna , Viburnum nervosum* and ferns has inhibitory effects on regeneration of silver fir and spruce.
- Foliage extracts of Fern and *Viburnum nervosum* is mainly responsible for very less germination in fir and spruce on forest floor as reported.
- There is no self intoxicity on germination and early growth in silver fir and spruce.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Allelopathic inhibitions of leachares of Litter, Humus, *Sarcococca saligna, Viburnum nervosum* and fern have been studied on germination and early growth of *Abies pindrow* and *Picea smithiana* in laboratory conditions in this project.

19. **Allelopathic potential in regeneration of Sal (*Shorea robusta)* forests**

**Principal Investigator:** Dr. Ombir Singh, FRI, Dehradun.

**Duration:** 2011- 2016

**Critical analysis of the research theme and summary of the study**

Allelopathic interactions of one of the under-storey species (*Ardisia solanacea*), three invasive species (*Eupatorium adenophorum, Lantana camara* and *Ageratum conyzoides*), one tree species (*Mallotus philippensis*), litter and humus with the keystone species – *S. robusta* is undertaken to understand the natural regeneration failure in these forests. The foliage leachates/litter/humus (0, 5%, 10%, 15%. 20%) of the species were investigated to observe their effect on seed germination, root and seedling growth of *S. robusta* in laboratory as well as in nursery. The leachate concentrations of foliage extracts of *A. solanacea*, *E. adenophorum, L. camara, A. conyzoides* have inhibitory effects on seed germination, root and seedling growth, which causes yellowing of leaves and weakening of the seedlings in due course of time. However, very less inhibition on seed germination, seedling height and collar diameter was observed with the leachates of *M. philippensis,* litter and humus in this study. The inhibition in germination and nursery growth is also validated by calculating the response index (RI) of various parameters in the study. The allelochemicals present in foliage leachates, litter, humus and soil were also analyzed using HPLC technique.

The rate of inhibition by various leachates on seed germination, root and shoot growth of *S. robusta* seedlings in laboratory and nursery observed in this study is in following order:

*Ardisia solanacea* > *Eupatorium adenophorum* > *Lantana camara* > *Ageratum conyzoides* > *Humus* > *Litter* > *Mallotus philippensis*

**Scientific findings and contents**

- Regeneration survey in Sal forests showed that there is no sal regeneration in areas having either *Eupatorium adenophorum* or *Ardisia solanacea,* and less regeneration in *Lantana camara* and *Ageratum conyzoides* infested areas.
- Foliage extracts of Under-storey plants has inhibitory effects on seed germination, root and shoot growth of *Shorea robusta* in laboratory and nursery as well.
- These findings may explain the problems of seedling establishment in sal forests infested either with invasive or under-storey associates.
- By knowing which trees are particularly susceptible and which plants are most likely to produce toxic effects, these allelopathic problems can be avoided or dealt with by site preparation and weed control in plantations and assisted natural regeneration in these forests.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Allelopathic interactions of one of the under-storey species (*Ardisia solanacea*), three invasive species (*Eupatorium adenophorum, Lantana camara* and *Ageratum conyzoides*), one tree species (*Mallotus philippensis*), litter and humus with the keystone species – *S. robusta* is undertaken to understand the natural regeneration failure in Sal forests.

20. **Enhancement of seed longevity of *Diploknema butyracea* Roxb. H.J. Lam**

**Principal Investigator:** Dr. Manisha Thapliyal, FRI, Dehradun

**Duration:** 2009- 2012

**Critical analysis of the research theme and summary of the study**

The seeds of *D. butyracea* are reported to be short-lived because of which the propagation of this economically very important species has become difficult. A survey was conducted in the Pithoragarh Forest division (Uttarakhand) to identify and mark the population of the species. The fruits/seeds of *Diploknema butyracea* were collected for 4 years (2008 to 2011) either in June end or July first week, depending upon the fruit maturity and production. Due to high moisture content of seeds and ambient temperature, almost 8-10% seeds germinated during transit from places of collection to Seed laboratory of FRI. Seeds with above 30% moisture content exhibited high germinability (>80%) while it was low for seeds with lower moisture content (50-60%). Seeds from Matela (Pithoragarh Forest Division) were collected during all four years and it was observed that seeds had high germinability (>90%) in 2008 while it was low (55%) the next year which was poor seed year for the species.

The seeds of *D. butyracea* with high (36%) initial moisture content were desiccated to lower levels (30, 25, 20 and 15%) to store it at lower temperatures. The seeds could be desiccated to 25% mc without appreciable fall of viability, but below 25% mc there was drastic decline in viability from 63 to 33%, which proved that seeds did not tolerate desiccation below 25% moisture content. Thus, the least safe moisture content of the seeds of *D. butyracea* was observed to be 25%. The seeds tolerated $20^0$C storage temperature but none of the seeds were viable at $15^0$C, which proved that seeds were both desiccation and chilling sensitive and were tropical recalcitrant in storage behavior. Ambient room temperature was best for storage and longevity of seeds.
Nursery technology of species was also developed in this project.

**Scientific findings and contents**

- Due to high moisture content of seeds in *D. butyracea* and ambient temperature, almost 8-10% seeds germinated during transit from places of collection to Seed laboratory of FRI. Seeds with above 30% moisture content exhibited high germinability (>80%) while it was low for seeds with lower moisture content (50-60%). Seeds from Matela (Pithoragarh Forest Division) were collected during all four years and it was observed that seeds had high germinability (>90%) in 2008 while it was low (55%) the next year which was poor seed year for the species.
- The seeds tolerated $20^0$C storage temperature but none of the seeds were viable at $15^0$C, which proved that seeds were both desiccation and chilling sensitive and were tropical recalcitrant in storage behavior. Ambient room temperature was best for storage and longevity of seeds.

- Nursery technology of species was also developed in this project.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Seed and nursery technology of *Diploknema butyracea* has been developed in the project.

21. **Regeneration of Kharsu Oak (*Quercus semecarpifolia)* and Chamkharik (*Carpinus viminea*). Sub-Project 3- Germination Eco-physiology of Seed of *Carpinus viminea***

**Principal Investigator:** Dr. Manisha Thapliyal, FRI, Dehradun

**Duration:** 2005- 2008

**Critical analysis of the research theme and summary of the study**

Emptiness in the seeds of *Carpinus viminea* is one of the important causes of the poor regeneration of the species. Reasons for the seeds not getting filled can be investigated through studies on floral and seed biology, pollination process and predation pressures, genetic variability which can indicate whether inbreeding depression is leading to production of low number of viable seeds, *etc*. Fresh seeds that are filled yield good but slow germination and practically are difficult to completely separate filled seed from the empty ones.

Seeds acquire physiological dormancy during storage which further reduces the germination in seeds The seed coat of the seed is hard which impedes the uptake of water during germination and some simple scarification (filing of seed coat at one end) of the seed coat helps in improving the germination. The initial seed lot quality has a direct bearing on longevity and viability of seeds during storage. Seeds should not be stored at room temperature as the seed lose viability faster and within six months it is lost completely. $5^0$C and $15^0$C were found suitable for storage of seeds of Chamkharik as 6-10% seeds retained viability even after one year. Moist chilling helped in enhancing the germination of seed by reducing the inhibitory effects of endogenous chemicals in the seed. Stratified seeds exhibited a rhythm of increase and decrease in germination during alternate months which may be due to the endogenous rhythms in metabolic activity of the seed, this needs elaborate study.

Seedlings grown in the nursery can be transplanted in the natural forest to restock the forest with the species and promote its regeneration as after nine months 100% seedling survival was observed. These seedlings performed better than natural seedlings as their height gave them advantage over naturally regenerated small seedlings.

**Scientific findings and contents**

- Emptiness in the seeds of *Carpinus viminea* is one of the important causes of the poor regeneration of the species. Seeds acquire physiological dormancy during storage which further reduces the germination in seeds
- The seed coat of the seed is hard which impedes the uptake of water during germination and some simple scarification (filing of seed coat at one end) of the seed coat helps in improving the germination.
- The initial seed lot quality has a direct bearing on longevity and viability of seeds during storage. Seeds should not be stored at room temperature as the seed lose viability faster and within six months it is lost completely. $5^0$C and $15^0$C were found suitable for storage of seeds of Chamkharik as 6-10% seeds retained viability even after one year.
- Moist chilling helped in enhancing the germination of seed by reducing the inhibitory effects of

endogenous chemicals in the seed. Stratified seeds exhibited a rhythm of increase and decrease in germination during alternate months which may be due to the endogenous rhythms in metabolic activity of the seed, this needs elaborate study.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Initial germination and storage protocol of seeds *Carpinus viminea* has been developed in the project.

22. **Establishment of multilocation clonal trial and study of wood anatomical properties and cellulose content of promising clones of *Populus deltoides***

**Principal Investigator:** Dr. Dinesh Kumar, FRI, Dehradun

**Duration:** 2010- 2014

**Critical analysis of the research theme and summary of the study**

Standard methods of propagation, wood anatomical and cellulose estimation were adopted in this project. The multilocational trials of *Populus deltoides* suggested that:

There was significant variation among clones *Populus deltoids* for all anatomical and physical characteristics of wood including fibre length (μ), fibre diameter (μ), wall thickness (μ), vessel length (μ) and vessel diameter (μ). There was siginificant variation in holocellulose content of the clones.

The best clones at two years of age in the field for different site in respect of $D^2H$ (i.e. volume index) are: FRI-AM-95 (0.119) for Site1, FRI-AM-30 (0.118) for Site 2, FRI-AM-21 (0.093) for Site 3, FRI-AM-91 (0.119) for Site 4, FRI-AM-95 (0.112) for Site 5, FRI-AM-121 (0.128) for Site 6, FRI-AM-95 (0.104) for Site 7 and FRI-AM-13 (0.106) for Site 8.

The values of various growth traits for clone G-48 at the eight sites were intermediate values between the best and the worst clones. The trials need to be continued till rotation age to draw valid conclusion.

**Scientific findings and contents**

- There was significant variation among clones of *Populus deltoides* for all anatomical and physical characteristics of wood including fibre length (μ), fibre diameter (μ), wall thickness (μ), vessel length (μ) and vessel diameter (μ). There was siginificant variation in holocellulose content of the clones.
- The best clones at two years of age in the field for different site in respect of $D^2H$ (i.e. volume index) are: FRI-AM-95 (0.119) for Site1, FRI-AM-30 (0.118) for Site 2, FRI-AM-21 (0.093) for Site 3, FRI-AM-91 (0.119) for Site 4, FRI-AM-95 (0.112) for Site 5, FRI-AM-121 (0.128) for Site 6, FRI-AM-95 (0.104) for Site 7 and FRI-AM-13 (0.106) for Site 8.
- The values of various growth traits for clone G-48 at the eight sites were intermediate values between the best and the worst clones.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The multilocational trials of *Populus deltoids* were carried out and best clones are screened for further use in field in this project. There is a patenting possibility of best performed clone in this PCR.

23. **Evaluation of *Bombax ceiba* for seed sources in Northern India**

**Principal Investigator:** Dr. Dinesh Kumar, FRI, Dehradun

**Duration:** 2011- 2015

**Critical analysis of the research theme and summary of the study**

Identification of seed sources of *Bombax* ceiba (semal) for plantation forestry has been done in the project. As per survey done in region of Lakhimpur and Bahraich districts in Uttar Pradesh during year 2011, suggests that wood consumption of semal in this region is estimated at 1.75 lakh quintal /month which or Rs. 7.50 crore/month at the present market rate. A total of 52 CPTs were selected in the field, their seed was collected and tested for germination. On the basis of seed germination, significant differences were found among CPTs as well as seed sources. The best five seed sources of this species from standpoint of seed germination were found to be as follows: Lakhimpur Kheri (82.20%), Bahraich (81.55%), Meerut (77.93%), Shahjahanpur (77.06%) and Bijnore (76.85%).

Branch cuttings of mature trees did not root, however, maximum 68.9% rooting was observed with application of 8000 ppm IBA in juvenile cuttings. Provenance progeny trial was established; based on $D^2H$ index at 1½ years of age, among the 19 seed sources tested under this project the best five seed sources of *Bombax* ceiba in decreasing order of growth rate were as follows: Lakhimpur Kheri, Bahraich, Dehradun, Haldwani and Shravasti. Of these, Lakhimpur Kheri and Bahraich were particularly better than others recording about 1½ times greater growth rate than average of the seed sources. The form of these seed sources was also very good with no incidence of forking.

A germplasm bank was established with seed of promising seed sources. Combining the results of seed germination studies as well as early field performance of seed sources, Lakhimpur and Bahraich emerged as the best seed sources of this species.

**Scientific findings and contents**

- A total of 52 CPTs were selected in the field, their seed was collected and tested for germination. On the basis of seed germination, significant differences were found among CPTs as well as seed sources. The best five seed sources of this species from standpoint of seed germination were found to be as follows: Lakhimpur Kheri (82.20%), Bahraich (81.55%), Meerut (77.93%), Shahjahanpur (77.06%) and Bijnore (76.85%).
- Branch cuttings of mature trees did not root. However, maximum 68.9% rooting was observed with application of 8000 ppm IBA in juvenile cuttings.
- Provenance progeny trial was established; based on $D^2H$ index at 1½ years of age, among the 19 seed sources tested under this project the best five seed sources of *Bombax* ceiba in decreasing order of growth rate were as follows: Lakhimpur Kheri, Bahraich, Dehradun, Haldwani and Shravasti. Of these, Lakhimpur Kheri and Bahraich were particularly better than others recording about 1½ times greater growth rate than average of the seed sources. The form of these seed sources was also very good with no incidence of forking.
- A germplasm bank was established with seed of promising seed sources. Combining the results of seed germination studies as well as early field performance of seed sources, Lakhimpur and Bahraich emerged as the best seed sources of this species.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Various seed sources of *Bombax ceiba* has been evaluated in the project for further use by stakeholders.

24. **Evaluation of seed orchards of *Dalbergia sissooo* for seed quality**

**Principal Investigator:** Dr. Ombir Singh, FRI, Dehradun

**Duration:** 2006- 2009

**Critical analysis of the research theme and summary of the study**

The seed orchards of *D. sissooo* were evaluated in respect of seed traits, seed vigour, storage potential, nursery performances and results are as:

**CSO, Bithmera, Hissar, Haryana:** Best clones - 12, 255, 262 (Uttarakhand), 86, 94, 101 (Rajasthan), 192, 194, 199 (UP). Poor clones – 20 (Uttarakhand) and 57 (Haryana), rest clones perform moderately. Out of the best clones, clone 194 (Uttar Pradesh) also found resistant to Ganoderma disease, while clone 101, 94 (Rajasthan) found susceptible to this disease as reported by pathology division of FRI.

**CSO, Hoshiarpur, Punjab:** Best clones- 12, (Uttarakhand) 83, 87, 94 (Rajasthan). Poor clones – 198 (UP), 85, 90 (Rajasthan) and 66 (Haryana), rest clones perform moderately. The best clone 94 (Rajasthan) found susceptible to Ganoderma disease.

**SSO, Bithmera, Hissar, Haryana:** Best progenies- 288, 289, 293, 294, 295, 300, 302, 304 (Uttarakhand). Poor progenies - 281, 298, 305, 306 (Uttarakhand), rest progenies perform moderately. The best progeny 304 (Uttarakhand) found resistant to Ganoderma disease, while 288, 289,293 and poor progenies 281,298, 305,306 found susceptible to Ganoderma disease.

**SSO, Yamunanagar, Haryana:** Best progenies- 173, 175,178, 235 (UP), 274, 283, 289, 290 (Uttarakhand). Poor progeny – 242 (UP), rest progenies perform moderately. The best progeny 290 (Uttarakhand) found susceptible to Ganoderma disease.

**Scientific findings and contents**

The seed orchards of *D. sissooo* (CSO, Bithmera, Hissar, Haryana; CSO, Hoshiarpur, Punjab; SSO, Bithmera, Hissar, Haryanaand SSO, Yamunanagar, Haryana) were evaluated in respect of seed traits, seed vigour, storage potential, nursery performances and the best performed clones and progenies were screened for further multiplication.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Various seed orchards of *D. sissooo* have been evaluated in the project for further use by the stakeholders.

25. **Genetic improvement of khasipine (*Pinus kesiya)***

**Principal Investigator:** Dr. Ombir Singh, FRI, Dehradun

**Duration:** 2002- 2005

**Critical analysis of the research theme and summary of the study**

Seed Production Areas (SPA's) of *Pinus kesiya* have been established in the area of 5 & 10 ha at Khonghampat in the central forest division, Imphal and Riet Khawn in Shillong forest division in the state of Manipur and Meghalaya, respectively. Using International standards of selection procedure, a total of 33 plus trees have been selected in east and west khasihills of Meghalaya in this project. List of plus along with every details like background information, record form etc. gas also been prepared for further reference. Seedling Seed Orchard cum Progeny Trial was established at Umiam, Barapani over 2 ha area in Randomized Complete Design (RBD) with 16 progenies along with control in the state of Meghalaya.

**Scientific findings and contents**

Establishment of Seed Production Areas (SPA's), selection of plus trees and progeny trial of *Pinus kesiya* has been carried out in states of Manipur and Meghalaya in this project.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Establishment of Seed Production Areas (SPA's), selection of plus trees and progeny trial of *Pinus kesiya* has been laid in the project.

26. **Impact of *Mikania micrantha* Kunth. Ex H.B.K. on microenvironment of native species in Bherjan-Borjan-Padumoni wild life sanctuary, Dilli reserve forest and Abhoypur Reserve forest of Upper Assam**

**Principal Investigator:** Dr. Kuntala N. Barua, FRI, Dehradun

**Duration:** 2014- 2017

**Critical analysis of the research theme and summary of the study**

*Mikania micrantha* is one of the obnoxious invasive alien plant species of South American origin, affecting the forests of moist tropical region. The present study was an impact assessment of infestation by this weed in two Reserve forests (Abhoypur RF and Dilli RF) and one wildlife sanctuary (Bherjan-Borjan-Padumoni WLS) in upper Brahmaputra valley. The study revealed that the plant diversity is less in infested sites compared to uninfested areas. Damage to seedlings and saplings by smothering was observed adversely affecting the regeneration of trees, thus changing the species composition and forest structure in the long run. *Mikania* infestation was found to affect soil as well, increasing the soil temperature and pH and decreasing the moisture and nutrient level. Study on the butterfly population indicated that the specialists (Shade loving species) getting replaced by generalists, that prefer open habitats, having widespread distribution, and thus of lower conservation priority. The weed infestation was more in forest fringes and canopy openings, indicating the need for protecting the closed canopy, in order to prevent invasion by this weed.

**Scientific findings and contents**

Impact of *Mikania micrantha* on microenvironment of native species in Bherjan-Borjan-Padumoni Wild Life Sanctuary, Dilli Reserve Forest and Abhoypur Reserve Forest of Upper Assam was done in this project. The plant diversity was found less in infested sites compared to un-infested areas in the sanctuary.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Impact of *Mikania micrantha* on microenvironment of native species in Bherjan-Borjan-Padumoni Wild Life Sanctuary, Dilli Reserve Forest and Abhoypur Reserve Forest of Upper Assam was done in this project. Such type of studies should be carried out in national parks and sanctuaries at regular intervals for vegetation assessments.

27. **To study the timber markets of important agroforestry species in Eastern Uttar Pradesh**

**Principal Investigator:** Dr. Anubha Srivatava, CSFER, Allahabad

**Duration:** 2010- 2013

**Critical analysis of the research theme and summary of the study**

The study was carried out in six selected districts as Raebareli, Gorakhpur, Allahabad, Barabanki, Sonbhadra and Behraich. The information was collected about timber traders and tree growers of selected tree species viz. *Mangifera indica*, *Tectona grandis*, *Artocarpus heterophyllus, Acacia nilotica, Dalbergia sissoo, Azadirachta indica, Eucalypus sp., Poplar sp., Madhuca indica* and *Syzigium cumunii* in these districts. The following findings emerged as outcome of the project:

- It was found during study that preferred species of farmer of this region are – *Eucalyptus*, Teak, Shisham etc. on farm bunds and Mango, Mahua, Neem, Jamun, Kathal, Babool, etc. in form of orchards/woodlots, etc. The availability of Poplar is almost negligible in studied districts except Behraich.
- In Raebareli, farmers are planting *Eucalyptus* on tree buds of usar land. A total of 21 veneer/plywood industries are there. In these industries, only 60-65% raw material is available as per demand. The market value is Rs. 1500-1800 per tree for seven to eight year old tree of *Eucalyptus*.
- Less availability of industries in Alllahabad, Sonbhadra and Barabanki for consumption of raw material, causing the lowering of rates of timber in the region.
- In wood mandis, market is dominated by buyers as there is no provision of storage of wood for sellers and sellers are compelled to sale their products at the buyers rates.

**Scientific findings and contents**

Study on the Timber Markets of Important Agro forestry Species in Eastern Uttar Pradesh was carried out in six selected districts as Raebareli, Gorakhpur, Allahabad, Barabanki, Sonbhadra and Behraich. Less availability of industries in Alllahabad, Sonbhadra and Barabanki for consumption of raw materials caused the lowering of rates of timber in the region. In addition in wood mandis, market is dominated by buyers as there is no provision of storage of wood for sellers and sellers are compelled to sale their products at the buyers rates.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Study was carried out to assess the Timber Markets of Important Agro forestry Species in Eastern Uttar Pradesh was carried out in six selected districts.

28. **Variability studies in *Hardwickia binata* – A multipurpose tree species in Kanataka, Andhra Pradesh and Tamil Nadu**

**Principal Investigator:** Dr. A.N. Arun Kumar, IWST, Bengaluru.

**Duration:** 2008- 2013

**Critical analysis of the research theme and summary of the study**

Studies were carried out from natural populations and plantations in Karnataka, Tamil Nadu and Andhra Pradesh. Some of the basic parameters such as girth and height were recorded along with seed parameters and seedling growth. Core samples were also collected to obtain important information about wood traits. Efforts were also made to document the natural regeneration status in the study area. Finally, using RAPD markers, genetic diversity was also estimated.

Natural regeneration of *H. binata* was generally very low in all the locations wherever the work was carried out. Two reasons attributed for this condition was fire and browsing and both of them are equally important. Based on the preliminary studies on genetic diversity using RAPD markers indicated that the diversity is low and it may be attributed that the natural gene flow between populations of *H. binata* is limited.

**Scientific findings and contents**

The preliminary studies on genetic diversity in *Hardwickia binata* using RAPD markers indicated that the diversity is low and may be attributed that the limited natural gene flow between populations of *H. binata*.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Study was carried out to assess genetic variability in *Hardwickia binata*.

29. **Development of technologies for multiplication of economically important desert plant – *Capparis deciduas***

**Principal Investigator:** Dr. Sarita Arya, AFRI, Jodhpur.

**Duration:** 2010- 2016

**Critical analysis of the research theme and summary of the study**

The present investigation was undertaken to develop appropriate micropropagation technology as a non-conventional method for mass multiplication of economically and medicinally important trees through axillary bud induction and proliferation using *Capparis deciduas* as the plant material. The results showed that *Capparis decidua* could be successfully multiplied in vitro through axillary buds. Various physical and chemical conditions have been standardized for in vitro culture conditions using axillary buds (nodal segments) from mature (28-30 years) tree. The culture conditions were standardized for *in vitro* rooting of *in vitro* multiplied shoots. The findings can be used conservation, mass propagation and secondary metabolite production in the species.

**Scientific findings and contents**

The results showed that *Capparis decidua* could be successfully multiplied in vitro through axillary buds. Various physical and chemical conditions have been standardized for in vitro culture conditions using axillary buds (nodal segments) from mature (28-30 years) tree. The culture conditions were standardized for *in vitro* rooting of *in vitro* multiplied shoots.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Mass multiplication techniques through tissue culture have been developed for *Capparis decidua.*

30. **Documentation and distribution of Forest Invasive Species (FIS) of Jabalpur, Katni, Mandla and Seoni districts of Madhya Pradesh**

**Principal Investigator:** Dr. Sanjay Singh, TFRI, Jabalpur.

**Duration:** 2010- 2013

**Critical analysis of the research theme and summary of the study**

Invasiveness in tropical forest was determined by canopy opening, habitat heterogeneity and functional and species diversity of the ecosystem, propagule pressure differences of dominant species and invasive species and level of disturbance and degradation in the forest. 63 invasive plants were documented in forests of Mandla, Seoni, Katni and Jabalpur districts of Madhya Pradesh. *Lantana camara, Hyptis suaveolens* and *Ageratum conyzoides* were widespread causing significant losses to biodiversity and regeneration in these forests. Experiments for mechanical control of lantana showed that mechanical uprooting of *Lantana camara* for two consecutive years have the best results, but at the same time clearing lantana gave way to profuse growth of other invasive species.

**Scientific findings and contents**

63 invasive plants were documented in forests of Mandla, Seoni, Katni and Jabalpur districts of Madhya Pradesh. *Lantana camara, Hyptis suaveolens* and *Ageratum conyzoides* were widespread causing significant losses to biodiversity and regeneration in these forests.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Documentation of Forest Invasive Species (FIS) was done in the forests of Jabalpur, Katni, Mandla and Seoni Districts of Madhya Pradesh.

31. **Study on post flowering regeneration status of *Melocanna baccifera* in Tripura**

**Principal Investigator:** Dr. Dhruva Jyoti, RFRI, Jorhat

**Duration:** 2012- 2015

**Critical analysis of the research theme and summary of the study**

The regeneration status of Muli bamboo in Tripura, in general, may be termed as 'fair'. Regeneration status of Muli bamboo in altitude class 0-50 m was found as 'poor', whereas, altitude class 51-100 m, 101-150 m and 151-250 m comes under 'fair regeneration'. Remote sensing and GIS in combination with conventional method has proved to be a very useful tool in resource mapping of Muli bamboo in Tripura. Area estimated under regenerated Muli Bamboo was found 855.9 $km^2$ which is 8.16% of the total geographical area and 11.5% of the total forest/vegetation area. Total growing stock of Muli bamboo culm and whole bamboo in Tripura was estimated at 4520.8 and 5811.1 thousand tones, respectively. Site specific flowering trends time of Muli bamboo was mapped in the state which will be useful for planning of strategies before next flowering during 2040-50.

**Scientific findings and contents**

Regeneration status of Muli bamboo at lower altitude class was found as 'poor', whereas it was 'fair regeneration' at high altitude classes. Area estimated under regenerated Muli Bamboo was found 855.9 $km^2$ which is 8.16% of the total geographical area and 11.5% of the total forest/vegetation area. Total growing stock of Muli bamboo culm and whole bamboo in Tripura was estimated at 4520.8 and 5811.1 thousand tones, respectively.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Regeneration Status of *Melocanna Baccifera* in post flowering scenario was studied in the state of Tripura in the project.

32. **Studies on seed quality improvement in respect of various tree species of arid and semi – arid areas**

**Principal Investigator:** Dr. D. K. Mishra, AFRI, Jodhpur

**Duration:** 2002- 2007

**Critical analysis of the research theme and summary of the study**

The PI has tried to improve the seed quality of various tree species of arid and semi – arid areas without conclusive recommendations.

33. **Variability studies on seed quality parameters and seed mycoflora of *Bauhinia purpurea, Bauhinia retusa* and *Bauhinia variegata* for their ex-situ conservation'**

**Principal Investigator:** Dr. Manisha Thapliyal, FRI, Dehradun

**Duration:** 2009 – 2013

**Critical analysis of the research theme and summary of the study**

The variability in the seed quality parameters viz. size, weight, germinative capacity, vigour, *etc*. of *Bauhinia purpurea, Bauhinia retusa* and *Bauhinia variegata* collected from different sources has been studied and seed storage techniques for *ex situ* conservation of the species also been developed. The seed mycoflora of these species and its effect on seed quality has also been seen in the project.

**Scientific findings and contents**

- Significant variations were recorded in physical parameters of pods and seeds of the three Bauhinia species, these were not directly correlated to higher seed germination.
- FRI campus, Vikasnagar, Sahaspur, Mohkampur and Roorkee from Uttarakhand and Barla, Nagina, Dhampur, Devband, Muzaffarnagar, Rohana, Mussepur, Nazibabad and Kotwali in UP can be good sources for seeds of *B. purpurea* as all recorded high initial germinability (> 90%).
- The best seed sources of *Bauhinia variegata* were FRI campus, Dehradun, Vikasnagar, Uttarkashi, Haldwani in Uttarakhand and Kanpur, Gorakhpur in UP with mean germination above 95%.
- *B. retusa* collected from Jhadipani, Kainchidham, Retighat, Majhera and Koti had good quality and above 90% germination.
- $5^0$ and $-20^0$C were better than ambient room temperature for longer storability of seeds of *B. purpurea.* Seeds of *B. variegata* exhibited better storability than *B. purpurea* as seeds remained viable for 44 months at $15^0$C.
- Seeds of *B. retusa* had storability of less than 3 years till then seeds had lost viability completely and vigour of the seeds also reduced.
- Different species of *Bauhinia* showed higher fungal infection in stored condition. The important observation in the present investigation is the predominant occurrence of *Aspergillus* sp., *Penicillium* sp and *Mucor* sp. in the order of dominance.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

It is suggested that forest seeds must be regularly checked for their quality in storage conditions as fungal infection is one of the main reasons for deterioration of seeds and loss of viability & vigour in stored condition.

34. **Development of technological package for the production and quality evaluation of seeds of important medicinal plants**

**Principal Investigator:** Dr. VRR Singh, FRI, Dehradun

**Duration:** 2004- 2008

**Critical analysis of the research theme and summary of the study**

In this project first of all a survey was conducted in the state of Uttarakhand and a few places in UP to locate the populations of various medicinal plants and assess the correct time for their fruit and seed maturity for collection. Fruits of more than 100 species of medicinal plants were collected from different areas and seed was extracted from them. Seeds were cleaned and observations on their morphology, colour, weight, etc were noted. Then seeds were germinated after standardizing the temperature, media requirements for each species. Seed storage study was conducted on 10 species viz. *Abroma augusta. Andrographis paniculata, Datura innoxia, Emblica officinalis, Mallotus philippensis, Ocimum bascilicum Ocimum sanctum, Plantago ovata, Punica granatum, Withania somnifera.* Except the seeds of *Mallotus philippensis,* seeds of other 9 species were successfully stored for more than a year at 5 and $15^0$C.

**Scientific findings and contents**

The seeds were pretreated with growth regulators like $GA_3$, $KNO_3$, $H_2O_2$to promote germination and also overcome any dormancy, if present. The seed germination behaviour was studied every month for minimum one year to observe the effect of different seasons on the germination of seeds of *Abelmoschus moschatus, Abroma augusta, Abrus precatorius, Aegle marmelos, Albizia lebbeck, Anacyclus pyrethrum, Andrographis paniculata, Apium graveolens, Artemisia vulgaris, Asparagus racemosus, Asteracantha longifolia, Bauhinia variegata, Berberis asiatica, Bergenia ligulata, Carica papaya, Carum carvi, Cassia gluaca, Cassia javanica, Cassia laevigata, Cassia tora, Catharanthus roseus, Ceasalpinia bonduc, Celastrus panniculata, Centratherium anthelmenticum, Chicorium intybus, Coleus barbetus, Commiphora opabalsum, Coptis teeta, Cordia myxa, Coriaria nepalensis, Costus speciosus, Cuminum cyminum,, Cuscuta europea, Cymbopogon martinii, Datura innoxia, Datura metal, Digitalis pupurea, Diplocyclus palmatus, Emblica officinalis, Ficus glomerata, Ficus palmata, Ficus roxburghii, Gentiana kurroo, Gloriosa superba, Gynandropsis gynandra, Hedychium spicatum, Hericlium candicans, Hippophae salicifolia, Holoptelia integrifolia, Hyssopus officinalis, Jatropha curcus, Lawsonia inermis, Linum usitatissimum, Lipidium sativum, Mallotus phillipensis, Matricaria chammomile, Mimosa pudica, Mirabilis jalapa, Mucuna pruriens, Myrica nagi, Ocimum bascilicum, Ocimum kilmendeschericum, Ocimum gratissimum, Ocimum sanctum, Origanum vulgare, Oroxylum indicum, Peganum harmala, Piper cubeba, Piper longum, Plantago major, Plantago ovata, Potentilla rigida, Psoralia cordifolia, Punica granatum, Rauwolfia canesence, Rauwolfia serpentina, Rhus parviflora, Ricinus communis, Rosa moschata, Rubia cordifolia, Ruta graveolens, Saussurea lappa, Selinum veginatum, Sesamum orientale, Sida cordifolia, Silybum marianum, Sisymbrium irio, Solanum khasianum, Solanum nigrum,Spilanthus acemella, Strychnos nux – vomica, Terminalia bellirica, Terminalia chebula,*

*Thalictrum foliolosum, Verbascum thapsus, Withania somnifera, Woodfordia fruiticosa, Wrightia tomentosa, Zanthoxylum alatum, Zingiber chrysanthum.* However, for some species the seeds did not germinate inspite of giving various pretreatments to break their dormancy and promote germination.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Seed technology protocol of medicinal plants from the state of Uttarakhand has been developed in the project.

35. **Evaluation by volumetric assessment of the standing crop of *Eucalyptus* trees and coppice crop in captive plantation at Hempur in Udham Singh Nagar District**

**Principal Investigator:** Dr. N.S. Bisht, FRI, Dehradun

**Duration:** 2001- 2002

**Critical analysis of the research theme and summary of the study**

In this project, the evaluation of the standing crop of *Eucalyptus* trees and coppice crop in captive plantations (305 ha.) at Hempur in Udham Singh Nagar District was done using volumetric assessments. Assessments were done on volume of standard timber & small wood down to a limiting mean diameter of 5 cm over bark; debarked weight of the bole down to a limiting girth of 20 cm over bark and weight of the standard small wood with sampling intensity of 1.11%. In this height and DBH were regressed with dependent variables i.e. volume and weight of pole and firewood.

**Scientific findings and contents**

The evaluation of the standing crop of *Eucalyptus* trees and coppice crop in captive plantations (305 ha.) at Hempur in Udham Singh Nagar District suggests that:

- Total volume (Over Bark) = 17,410.855 cu m
- Total pole weight (Debarked) = 1,50,66,431.97 kg
- Total fire wood weight = 46,00,837.05 kg

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

In this project, the evaluation of the standing crop of *Eucalyptus* trees and coppice crop in captive plantations (305 ha.) at Hempur in Udham Singh Nagar District was done.

36. **Micropropagation of Chirpine (*Pinus roxburghii*) and Shisham (*Dalbergia sissooo*)**

**Principal Investigator:** Dr. Sarita Arya, FRI, Dehradun

**Duration:** 2002-2005

**Critical analysis of the research theme and summary of the study**

The micropropagation technology for in vitro multiplication of *Pinus roxburghii* through three regeneration pathways namely somatic embryogenesis, adventitious bud differentiation and axillary bud proliferation was developed in the project. The investigation concluded that *Pinus roxburghii* can be successfully multiplied in vitro through all the three regeneration pathways. Various physical and chemical conditions have been standardized for in vitro propagation through somatic embryos starting with immature zygotic embryos, through adventitious bud differentiation from mature zygotic embryos and through forced axillary branching using seedling shoots.

Plant regeneration via axillary bud culture has also been developed in *Dalbergia sissooo*. Micropropagation via axillary bud proliferation using nodal explants collected from selected clones will lead to production of genetically uniform and superior population. The *in-vitro* maintained shoots will provide a regular supply of shoots for rooting and field transfer without any demand for fresh explants material. This study can be utilized for mass multiplication of *Dalbergia sissooo* which are highly valued timber tree and is facing lots of problem due to high occurrence of crooked stem development. The protocol will provide tissue culture plants which will be free of crooked stem development.

**Scientific findings and contents**

The present investigation was undertaken to develop micropropagation technology for *in-vitro* multiplication of *Dalbergia sissooo* through axillary bud proliferation and somatic embryogenesis for superior clones available at FRI.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

In this project, the micropropagation protocol for *in-vitro* multiplication of *Dalbergia sissooo* through axillary bud proliferation and somatic embryogenesis was developed.

37. **Phytosociological and socio-economic impact of Joint Forest Management in Tamil Nadu**

**Principal Investigator:** Dr. D. Rajasugunasekar, IFGTB, Coimbatore.

**Duration:** 2001- 2003

**Critical analysis of the research theme and summary of the study**

In the project PI has tried to assessing the phyto-sociological status of JFM area in the state of Tamil Nadu. The species diversity has been studied for that Shanon-Weiner information index was used. The socio-economic impact of Joint Forest Management was also assessed for participating communities and percentage of contribution of Forest produce to the family income and mean annual income of villagers was also calculated.

**Scientific findings and contents**

In the project PI has tried to evolve a sustainable model of JFM for the local conditions of Tamil Nadu.

38. **Modeling the growth of *Eucalyptus* in Tamil Nadu**

**Principal Investigator:** Dr. Raman Nautiyal, ICFRE, Dehradun.

**Duration:** 2000- 2003

**Critical analysis of the research theme and summary of the study**

In the project the growth model for assessing growth of *Eucalyptus* was developed using secondary data from the existing trials at IFGTB Coimbatore. From the analysis of the data on the variables used to measure growth – Height (HT), Basal Diameter (BDM) and DBH (Diameter at Breast Height) for following inferences are drawn:

- The distribution, which characterized growth in a particular year, shows a marked change as the variables enter the third year.
- Gumbel and Gamma distributions are relatively robust in describing the growth in terms of Basal Diameter in all the three years of observations. These distributions are also robust when it comes describing Diameter at Breast height. Thus, both these variables – BDM and DBH – can become good predictors for height instead of predicting height from the distribution itself. It also brings froth the problem of predicting height to be used in modeling. Height varied considerable in the first three with height to be used in modeling. Height varied considerable in the first three years of growth, and this might be the reason that a particular distribution is not stabilizing is describing height. Thus, dependency on regressions with height as the criterion is more dependable to predict height as the criterion is more dependable to predict height.
- The combined use of regression and estimation with distributions can give better estimates for predictions, if used for local conditions only. Distributions may vary from place to place and more studies are required to infer this shift in distribution – i.e. with respect to space. This study limits to the temporal scale only. Spatial data from different locations are not included in the study. A combination of temporal and spatial data can give more insight into the growth dynamics.

**Scientific findings and contents**

In the project the growth model for assessing the growth of *Eucalyptus* has been developed using secondary data from the existing trials at IFGTB Coimbatore. More data, preferably at intervals of six months is required for more precise estimates. The data for this study is secondary in nature and therefore suffers the problem of time interval between collections of successive readings. The appropriate time of recording observations should also be standardized to increase the precision of the precision of the estimates.

39. **Standardization of nursery techniques for selected bamboo species of Northeast India**

**Principal Investigator:** Dr. S. Pattanaik, RFRI, Jorhat.

**Duration:** 1999-2003

**Critical analysis of the research theme and summary of the study**

Nursery techniques have been standardized for four target species viz., *Bambusa tulda, Bambusa nutans, Bambusa balcoa* and *Dendrocalamus hamiltonii.* The techniques include season, age of clum, size of cutting, treatment of cutting, multiplication media and macroproliferation. A limited amount of success was achieved in the fifth species i.e. *Bambusa pallida*. Vegetative propagation trails could not be taken up in the sixth species due to lack of availability of sufficient number of vegetative propagules. Instead, seeds were used to lay trials in macroproliferation.

**Scientific findings and contents**

Nursery techniques have been standardized for four species viz., *Bambusa tulda, Bambusa nutans, Bambusa balcoa* and *Dendrocalamus hamiltonii.*

40. **Development of elite planting material, establishment of model plantations & extension of nursery & plantation techniques of wild apricot to local communities in Himachal Pradesh**

**Principal Investigator:** Dr. Sandeep Sharma, HFRI, Shimla

**Duration:** 2004–2008

**Critical analysis of the research theme and summary of the study**

Nursery techniques have been standardized wild apricot and Model Nursery was established at Baragaon (Shimla). The Institute had raised 20,000 quality seedlings of Wild Apricot during 2004 to 2007. For carrying out plantation during first year under the 'NOVOD' project, two sites in Shimla district were selected viz. Baragaon are near Shimla town and Alampur area on Kufri – Chail road. The plantations were carried out in these two sites during last week of February, 2005. In addition plantations of Apricot were also established over 37.50 ha area in different forest divisions of Himachal Pradesh.

A total of six training programmes on “Wild Apricot – Nursery, Plantation, Oil Production and Its Uses” organized during the period from March 2005 to March 2007. Out of six training programme,

three training programmes were organized for the farmers of Shimla, Sirmour and Kullu districts of Himachal Pradesh.

**Scientific findings and contents**

Nursery techniques have been standardized for wild apricot with establishment of plantations in different forest divisions of Himachal Pradesh. Trainings on Apricaot were also provided to farmers in the project.

41. **Field performance of micro and macro propagated planting stock of selected five commercially important bamboo species**

**Principal Investigator:** Dr. T.S. Rathore, IWST, Bengaluru

**Duration:** 2004 – 2009

**Critical analysis of the research theme and summary of the study**

Field performance of micro and macro propagated planting stock of selected five commercially important bamboo species (*Bambusa bambos, B. balcooa, Dendrocalamus asper, D. strictus, D. stocksii* (*Pseudoxytenanthera stocksii*)) was evaluated in the project. The results are as:

- Established and evaluated field trials of selected five bamboo species in 16.0 ha area in Karnataka (13.0 ha) and Andhra Pradesh (3.0 ha).
- Established and maintained germplasm bank cum garden of 21 industrially important bamboo species in 0.5 ha area in Gottipura, Bengaluru during 2004-2007.
- Developed refined protocols for micro propagation of *Bambusa bambos, Dendrocalamus asper, D. strictus* and *D. stocksii.*
- Developed vegetative propagation process through clum cuttings of *D. stocksii.*

**Scientific findings and contents**

Field performance of micro and macro propagated planting stock of selected five commercially important bamboo species (*Bambusa bambos, B. balcooa, Dendrocalamus asper, D. strictus, D. stocksii* (*Pseudoxytenanthera stocksii*)) was evaluated in the project.

42. **Development of prediction models for resin production of *Pinus roxburghii***

**Principal Investigator:** Dr. S.S. Negi, FRI, Dehradun

**Duration:** 2005 – 2007

**Critical analysis of the research theme and summary of the study**

Models were developed for estimating resin production of *Pinus roxburghii* by measuring resin production in the forest division each in the state of J&K (Udhampur), Uttarakhand (Chakrata). and HP (Nahan). The study has been undertaken for establishing the relationship with various independent variables with independent variable i.e. resin yield. The other purpose was to develop models for prediction of resin yield. For this, multiple linear Regression analysis is used with all independent variables. The multiple Linear Regression model for predicting resin yield was evaluated for continuous variables diameter and height with the dichotomous variables such as aspect, altitude and site quality by assigning values 1 and 2 category wise. However, stepwise regression analysis was used to identify the important and significant contributors for the variation in resin yields.

**Scientific findings and contents**

The results of resin production indicated that:

- **At Udhampur:** 93 percent variability in resin yield was explained by the independent variable with model Resin Yield = 0.058 Aspect – 0.214 Altitude + 0.133 Site Quality + 0.030 Diameter + 0.029 Height, Adj $R^2$ = 0.934 SE = 0.3398; F= 681.70 (0.00).
- **At Nahan:** 99 percent variability in resin yield was explained by the independent variable with model Resin Yield = 0.687 Aspect – 0.078 Altitude + 0.432 Site Quality + 0.267 Diameter + 0.043 Height, Adj $R^2$ = 0.989 SE = 0.2961; F= 4271.66 (0.00).
- **At Tiunee:** 88 percent variability in resin yield was explained by the independent variable. However, height and site quality was negatively related with model Resin Yield = 1.365 Aspect – 0.098 Altitude - 0.121Site Quality + 0.609 Diameter - 0.034 Height, Adj $R^2$ = 0.0.885 SE = 1.1080; F= 370.63 (0.00).
- It is concluded that all the three sites have different models of resin tapping depending upon altitude, site quality, height, aspects, and diameter.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Models were developed for estimating resin production of *Pinus roxburghii.*

43. **Evaluation of australian seed sources and families of *Eucalyptus tereticornis* sm. for productivity and genetic improvement**

**Principal Investigator:** Dr. H.S. Ginwal, FRI, Dehradun

**Duration:** 2002 – 2006.

**Critical analysis of the research theme and summary of the study**

In the project, results of growth pattern and genetic analysis of families of *E. tereticornis* representing 13 sources of Australia and Papua New Guinea origin, established in the form of provenance cum progeny trail at three different locations of India; Forest Research Institute (FRI) campus, Dehradun, Uttaranchal (30°N Lat., 76°E Long, 610m altitude), Chiryanpur, Uttaranchal (29°N Lat., 78°E Long, 460m altitude) respectively and site II i.e. Midnapore, West Bengal (22°N Lat., 87°E Long, 23m altitude) in eastern India weremeasured and analyzed.

The results showed that the north Queensland provenances in particular Walsh River, QLD and Burdekin River, QLD are good and stable in their performance in different environmental conditions. North Queensland provenances of *E. tereticornis* have earlier been reported to perform better in two trials in India by CHATURVEDI *et al.* (1989). Though present results indicate early performance of the trial, nevertheless are very much informative as far the variability pattern in the test material with regard to growth performance of the provenances is concerned. The two sources can initially be used for large-scale seed production and can be recommended fro afforestation programmes. However the trails need to be evaluated further for selection of good phenotypes and analysis of stability of performance of the provenances.

**Scientific findings and contents**

Evaluation of Australian Seed Sources and Families of *Eucalyptus tereticornis* was done in the project for enhancement in Productivity and Genetic Improvement.

44. **Standardization of nursery techniques of *Strychnos nux-vomica* and *Strychnos potatorum***

**Principal Investigator:** Dr. S.D. Sonkar, TFRI, Jabalpur

**Duration:** 2005 – 2009

**Critical analysis of the research theme and summary of the study**

Seed germination studies of *Strychnos nux-vomica* and *Strychnos potatorum* under different physical and hormonal treatment were conducted. Seeds of *S. nux-vomica* and S. *potatorum* were sown in polythene bags to conduct fertilizer trail in order to accelerate the growth of seedlings. Data on germination, survival and growth of both the species under different experiments were recorded. On the basis of three year's observation it may be inferred that - 72 hrs soaking of seeds of *S. nux-vomica* and *S. potatorum* in cow dung slurry gave maximum 88% and 54% germination respectively. Maximum 80% and 56% germination of *S. nux-vomica* and *S. potatorum* under 100 ppm IBA was observed, respectively.

To accelerate the growth of *S. nux-vomica* and *S. potatorum* seedling a fertilizer trial consisting of four different level of N and P viz. 0, 50, 75 and 100 ppm was laid out with four application. Nitrogen and phosphorus separately or in combinations significantly boosted the growth of seedlings shoot height, root length, collar diameter. The highest value for the different components of the seedlings was observed to be under the treatment receiving 100 ppm nitrogen with 100 ppm phosphorus.

**Scientific findings and contents**

The nursery techniques of *Strychnos nux-vomica* and *Strychnos potatorum* was standardized in the project.

45. **Impact of pollutants on growth of plants**

**Principal Investigator:** Dr. Rupnarayan Sett, TFRI, Jabalpur

**Duration:** 2007 – 2009

**Critical analysis of the research theme and summary of the study**

Samples were collected for leaf, root and rhizospheric soil of *Cassia siamea*, *Dalbergia sissooo*, *pangamia pinnata, Peltaforum ferruginum, Azadiracta indica, Eucalyptus tereticornis, Tectona grandis* and *Alstonia scholaris* from least affected (control) as well as from highly affected sites ( Sponge Iron factory Raigarh, Chhattishgarh).Samples were carefully dried and packed for further analysis. Slug was used in pot culture experiments and Physico-chemical analysis of the samples was done in laboratory. To find out the *in vivo* effect of acid rain, a series of nursery experiments on the effect of simulated acid rain [SAR] on one year old seedlings of ten important tree species was done and results revealed that in comparison to the control set, the level of potassium increases significantly in the rhizospheric soil probably due to the effect of SAR which indicates loss of huge amount of potassium form the plant root system was there due to acid treatment.

**Scientific findings and contents**

Impact of pollutants on growth of *Cassia siamea*, *Dalbergia sissooo*, *pangamia pinnata, Peltaforum ferruginum, Azadiracta indica, Eucalyptus tereticornis, Tectona grandis* and *Alstonia scholaris* has been carried out in the project.

46. **Identification of mortality factors of *prosopis cineraria* and development of suitable management strategies**

**Principal Investigator:** Dr. S.I. Ahmed, AFRI, Jodhpur

**Critical analysis of the research theme and summary of the study**

For identification of mortality factors of *Prosopis cineraria* and making development of suitable management strategies, 138 localities were surveyed in 16 sites in for districts viz., Nagaur, Sikar, Churu and Jhunjhunu wherein approximately 1,37,097 khejri trees present. Randomly, a total of 3964 trees were examined for pest and disease infections. Maximum percentage of Khejri mortality in the four northwestern districts of Rajasthan viz., Nagaur, Sikar, Jhunjhunu and Churu has been recorded as being 36.30, 42.78, 41.00 and 37.69 respectively. The mortality percentage is being correlated with the other biotic (pests and diseases) and abiotic (soil and water quality, water table depletion, lopping intensity and interval use of ploughing implemnents and status of hardpan etc.) factors.

Amongst the other probable contributory factors: (i) Continuous depletion of water tables in Rajasthan. , (ii) Increasing number of tube wells or over exploitation of ground water; (iii) Effect of low rain fall and (iv) Change in soil properties and agricultural practices and (v) over maturity of trees are some of the suspected causes which may play an important role in large-scale drying of Khejri in north-western zone of Rajasthan. The data on the above aspects are being collected from the Khejri infested areas by conducting extensive surveys by the scientists of this institute.

**Scientific findings and contents**

Identification of mortality factors of *Prosopis cineraria* for making development of suitable management strategies by surveying 138 localities were surveyed in 16 sites in for districts viz., Nagaur, Sikar, Churu and Jhunjhunu in the state of Rajasthan has been carried out in the project.

47. **Fuel properties of important forest weeds**

**Principal Investigator:** Ritesh Kumar D. Ram, IWST, Bengaluru

**Duration:** 2007-2009

**Critical analysis of the research theme and summary of the study**

Study on calorific value, proximate analysis (ash content, volatile content and fixed carbon content) and elemental parameters (carbon, hydrogen, nitrogen and sulphur content) of two forest weeds i.e. *Lantana camara* and *Eupatorium spp* was carried out in the project. The aim was to evaluate the selected forest weeds as a raw material for energy production. Basic density of *Lantana camara* and *Eupatorium spp* was also determined. The calorific value of leaves and stem of *Lantana camara* was found to be 19.17 MJ/kg and 19.02 MJ/kg, respectively. The calorific value and other fuel properties of *Lantana camara* are comparable to *E. hybrid* and *C. equisetifolia*, prominent fuel wood species. The calorific value of *Eupatorium spp* was found 18.73 MJ/kg. The lower calorific value of *Eupatorium spp* may be due to their higher ash content 6.07% as compared to lantana (1.000%). The amount of ultimate carbon in *Eupatorium spp* and *Lantana camara*, ranges from 43 and 48%, respectively.

Thermogravimetric analysis under oxidizing atmosphere was carried out for understading the combustion characteristics of *Lantana camara* and *Eupatorium spp*. The results on physical, chemical and elemental properties will help in utilizing *Lantana camara* and *Eupatorium spp* as raw material/feed stock for energy production through thermochemical processes. The above fuel properties and study on burning profiles of these weeds under oxidizing atmosphere will also help in tailoring the gasifier's reaction processes specific to these biomasses.

**Scientific findings and contents**

The calorific value, proximate analysis (ash content, volatile content and fixed carbon content) and elemental parameters (carbon, hydrogen, nitrogen and sulphur content) of two forest weeds i.e. *Lantana camara* and *Eupatorium spp* has been carried out in the project.

48. **Processing and evaluation of plantation grown *Simarouba glauca* DC from Orissa**

**Principal Investigator:** Dr. S.K. Sharma, IWST, Bengaluru

**Duration:** 2006-2009

**Critical analysis of the research theme and summary of the study**

Wood processing studies on *Simarouba glauca* suggested that the timber is dimensionally stable due to low shrinkage values and may be utilized for different purposes where high dimensional stability against changes in moisture content is desirable. The timber dries very quickly without any seasoning defects. The timber is classified as moderately heavy, weak, not tough, soft and very steady. The timber has around 60-65% cellulose content and seed of the tree contain around 50-55% oil. The timber has been found suitable for making artifacts and meet the requirements. The timber was also found suitable for match sticks. The timber can be used for tool handles, light furniture and light packing cases. The species was found good for making 'BDR' grade plywood. Preliminary work indicated the potential of using wood for pencil making. Larger quantity of wood is required for commercial application.

**Scientific findings and contents**

Wood processing studies on *Simarouba glauca* has been carried out in the project.

49. **Trails on composting for specific afforestation needs and development of cost-effective packages in relevance to Chotanagpur plateau area and South West Bengal**

**Principal Investigator:** Dr. P.K. Das, IFP, Ranchi

**Duration:** 2002-2007

**Critical analysis of the research theme and summary of the study**

Procedure of Compost preparation from Rice straw (*Oryza sativa*), Rice husk, Putus (*Lantana camara*), Ghanto (*Schrebra swietenioides*), Chirchiri (*Achyranthus aspera*), Chakor (Cassia tora), Thethar (*Ipomea cornea*), vegetable waste and mixtures of different raw materials has been standardized in the project with the following recommendations:

- Compost has been prepared form organic matter within 50 to 160 days in the above ground chamber
- Chopping of raw material reduce the compost preparation time
- Addition of urea, SSP and cow dung accelerates the decomposition of raw material and thereby reduces the time requirement for compost production.
- Remixing and watering of raw material heap favours early production of compost
- Operational cost of compost production was found Rs. 5/kg, where material and labour cost is included.

**Scientific findings and contents**

Procedure of Compost preparation from Rice straw (*Oryza sativa*), Rice husk, Putus (*Lantana camara*), Ghanto (*Schrebra swietenioides*), Chirchiri (*Achyranthus aspera*), Chakor (Cassia tora), Thethar (*Ipomea cornea*), vegetable waste and mixtures of different raw materials has been standardized in the project.

50. **Standardization of nursery techniques and propagation method of *Buchanania lanzan*. spreng**

**Principal Investigator:** Dr. D.L. Nandeshwar, TFRI, Jabalpur

**Duration:** 2001-2006

**Critical analysis of the research theme and summary of the study**

Nursery and Propagation techniques of *Buchanania lanzan* has been standardized in the project.

The results indicated that the seed size and seed weight affects on germination and seedling growth. The medium size seeds ranged from 46.81mm to 50.40mm and seed weight 24.40gm/100 seeds perform better than small size seed and large size seeds; however large seeds produced higher seedling biomass and maximum seedling growth. The seed germination of *B. lanzan* is influenced by applying different pre sowing seed treatments. The mechanical breaking of seed endocarp and then soaking in cold water for 24 hours hastened the germination by 33% and also shortening the germination period. So mechanical breaking of seed endocarp is recommended to be applied as seed treatment before sowing the seeds in nursery beds. The seed sowing methods and various depth of seed sowing in beds affects the germination, hence the mechanical pressure of soil, soil temperature, soil moisture are largely responsible factors for controlling the seed germination. The line sowing methods in the depth of 1 to 2.5 cm perform better than the other methods of sowing and other soil depth. The different growth hormones like IAA, IBA and GA3 enhanced the seed germination and seedling development, But Indole Acetic Acid (IAA) at concentration of 200 ppm was found to be best as compare to the other concentration of growth hormones.

Management and control of the soil borne diseases in the seedling is paramount important. Fusarium wilt diseases once occur in the seedling it is very difficult to control. So incidence of the wilt can be avoided by soil drenching with Bavistine 0.2 percent at monthly intervals.

**Scientific findings and contents**

Nursery and Propagation techniques of *Buchanania lanzan* has been standardized in the project.

51. **Studies on plant diversity of Renuka and Simbalwara wildlife sanctuaries of Himachal Pradesh**

**Principal Investigator:** Dr. R.K. Verma, HFRI, Shimla

**Duration:** 2002-2006

**Critical analysis of the research theme and summary of the study**

Assessment of plant diversity of Renuka and Simbalwara Wildlife Sanctuaries of Himachal Pradesh has been carried out in the project. The following are the results:

**Renuka Wildlife Sanctuary:** A total of 109 herbaceous plant species, 43 plant species and 24 shrub species including regeneration of 15 trees and shrub species were recorded the sanctuary. Out of the total species, 73 species of medicinal value were also recorded from the area and 7 of them fall under the category of threatened plants. On the basis of importance value index, *Xanthium indicum* was the dominant species followed by *Oplimonus* sp., *Neuimbo nucifera* and *Phylla nudiflora*.

**Simbalwara Wild Life Sanctuary**: The forest is composed of 53 species of trees, 32 species of shrubs and 175 species of herbs. The plant communities identified at 400-525m and 525-650m elevation range was *Shorea robusta – Mallotus philippensis* and *Shorea robusta – Terminala alata* respectively. On this basis of importance value index, *Shorea robusta* was the dominant tree species at both the elevation ranges.

**Scientific findings and contents**

Assessment of plant diversity of Renuka and Simbalwara Wildlife Sanctuaries of Himachal Pradesh has been carried out in the project.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Such studies are required in other sanctuaries also.

52. **Studies on assessing growth performance and standardization of management practices for *Guadua angustifolia* kunth. in Karnataka**

**Principal Investigator:** Dr. Syam Viswanath, IWST, Bengaluru

**Duration:** 2005-2008

**Critical analysis of the research theme and summary of the study**

The growth performance of *Guadua angustifolia* in 6 locations of peninsular India indicated that the Columbian bamboo appears to better in adoptability and also its growth performance in semiarid rainfed condition like Bengaluru, Mysore, Hyderabad and Palakkad conditions. One of the important finding of this experiment is that the performance of this exotic species was found to be superior in Kodagu and Alwaye. The best performance in these two locations could be due to favourable locality factors and which falls under tropical humid conditions as compared to other locations, which fall under semiarid type of zones. Hence, the result showed significant interaction between location and species. The performance from the present findings clearly indicated that the species adopt will and performs better under tropical humid with excellent rainfall and soil factors. This species may be used for large scale plantation only in high rainfall tropical humid climatic zones with good deep loamy soils and with short dry spells. *Guadua angustifolia* also appears to have the capacity to tolerate periodic water logging better than other bamboo species and may be thought of afforestation along river banks and for stabilizing stream banks and soil erosion control.

**Scientific findings and contents**

The growth performance of *Guadua* angustifolia have been assessed in respect of viable bio-reserve, impact on soil etc in 6 locations of peninsular India with standardization of cultivation practices of the species.

53. **Studies on micro-propagation, field evaluation and conservation of *Pseudoxytenanthera stocksii* munro**

**Principal Investigator:** Dr. T.S. Rathore, IWST, Bengaluru

**Duration:** 2000-2005

**Critical analysis of the research theme and summary of the study**

Development of micro-propagation protocol, field evaluation and conservation of *Pseudoxytenanthera stocksii* has been carried out in this project. Based on the protocol developed, more than 4000 plants were produced during 2002-2005 through auxiliary shoot proliferation. Rooting percentage was about 100 percent (in vitro as well as ex vitro processes). This may be because of high level of rejuvenation and revigomation due to repeated in vitro shoot multiplication. Four week old rooted plantlet attained height of 8-10 cm with 4-6 roots in sand medium. Hardening in mist chamber for 4-5 weeks proved essential to promote new root growth, establishment of plants, shoot growth and high rate of survival. Keeping plants 3-4 weeks under shade before putting in open nursery favoured un-interrupted growth and high survival. From in vitro/ex vitro rooting stage clonal plantlets with minimum 4-5 tilllers, 20.53 cm in length with miniature rhizome can be developed within six months in 600 cc polybags/root trainer.

**Field trials:** Initial field trial conducted in the month of Sept. 2004 at Gottipura exhibited 100 percent survival despite the trial was laid during the off monsoon, plantlets maintained their growth phase, even after ten months of planting.

**Establishments of germplasm:** Offset cuttings of about 25 CPC were collected during 2002-2004 from germplasm Garden of *P. stocksii* from Sirsi Forestry College (UAS Dharwad). This collection was made with the objective of immediate use of superior genotype of *P. stocksii* for planting programme as well as for further improvement. Survival percentage of offset cutting was about 80 percent. Hardened plants raised by the offset cuttings in gunny bags were used for establishment of germplasm bank. At IWST nursery, plants raised through offset cuttings of CPC27, 28, 29 and 34 were planted in July 2003 and no mortality was observed. New sprouts from these plants were used for production studies. Apart from this, 16 CPC plants raised through offset cuttings were planted at Gottipura in Germplasm Bank of Bamboo in Sept. 2004. New culm developed was observed after six months. This germplasm bank of *P. stocksii* will be source of quality material for producing, evaluation and improvement.

**Scientific findings and contents**

Development of micro-propagation protocol, field evaluation and conservation of *Pseudoxytenanthera stocksii* has been carried out in this project.

54. **Studies on population status and berberine content in different provenances of *Berberis aristata* DC. in Himachal Pradesh and standardization of its propagation techniques**

**Principal Investigator:** Dr. A. Rajasekaran, HFRI, Shimla

**Duration:** 2005 – 2008

**Critical analysis of the research theme and summary of the study**

The population status and berberine content in different provenances of *Berberis aristata* in Himachal Pradesh has been carried out in the project with the standardization of its propagation techniques. The followings are the results:

- Seven provenances of *B. aristata* were identified in the statwe of Himachal Pradesh.
- Out of these, four provenance were identified in Shimla district (viz. Narkanda, Sarahan Chopal Kharapather) one each in Mandi (Jhanjeli), Kinnuar (Sangla) and Kullu (Sojha) districts.
- Out of seven provenances of *B. aristata*, only Kharapathar, Snagla, Sarahan and Narkanda have adequate populations. The population of *B. aristata* was very less in Sojha followed by Jinjheli and Chopal. Since the population of *B. aristata* is very limited, the traders mostly collect roots of *B. lyceum*, *B. chitria* and *B. asiatica* for preparation of various drugs.
- Most of the traders, forest department staffs and people often identify *B. chitria* which has reddish stem as *B. aristata.* Hence, there is confusion among the people about the identification of various *Berberis* species.
- The chemical analysis showed maximum berberine content of 2.81% in sample no. 30 collected from Kharapather area of Shimla district followed by 2.70% in sample no. 5 collected form Sangla Valley of Kinnaur district. The minimum berberine alkaloid content (0.29%) was recorded in sample no. 6 (Sarahan provenance of Shimla District) followed by sample no. 21 (0.32) of Shimla district (Chopal provenance).
- The stem cuttings of *Berberis aristata* took more than 60 days for the initiation of rooting.

**Scientific findings and contents**

The population status and berberine content in different provenances of *Berberis aristata* in Himachal Pradesh has been carried out in the project with the standardization of its propagation techniques.

55. **Ex-situ conservation of some critically endangered and rare plants of Uttaranchal**

**Principal Investigator:** Dr. Veena Chandra, FRI, Dehradun

**Duration:** 2005 – 2006

**Critical analysis of the research theme and summary of the study**

Conservation of 10 rare and endangered plant species from the state of Uttarakhand has been done at FRI in the project under Plant Conservation Programme sponsored by National Botanical Research Institute, Lucknow and Botanical Garden Conservation International (BGCI), UK.

During the period we were able to collect 9 species of RET plants from Uttarakhand. These were introduced in the Botanical Garden at FRI. Preparation of checklist of RET species of Uttarakhand has also been one of the objectives. A list of 165 species has been prepared based on published literatures such as Red Data Books, An Assessment of Threatened Plant Species in India. Various herbaria such as Dehradun Herbarium, Herbarium of the Botanical Survey of India, Dehradun, Herbarium of the Wildlife Institute of India, Dehradun, etc. were consulted for species distribution. Five species have been propagated/multiplied and reintroduced in their original areas of occurrence. Awareness training programmes were organized for school children of Kendriya Vidyalaya of Dehradun.

**Scientific findings and contents**

Conservation of 10 rare and endangered plant species from the state of Uttarakhand has been done at FRI in the project under Plant Conservation Programme sponsored by National Botanical Research Institute, Lucknow and Botanical Garden Conservation International (BGCI), UK.

56. **Studies on structural formation of vegetation for the conservation of biodiversity in the Gibbon wildlife Sanctuary, Assam**

**Principal Investigator:** Dr. P.K. Khatri, RFRI, Jorhat

**Duration:** 2004 – 2008

**Critical analysis of the research theme and summary of the study**

Structural formation of vegetation for the conservation of biodiversity in the Gibbon wildlife Sanctuary, Assam has been carried out in the project. The followings are the results:

- The Floristic composition in all sites was studied by general survey of the area.
- There were all together 286 species belonging to 212 genera and 97 family recorded in the present investigation. Out of 286 plant species, 98 represent tree species, 25 shrubs and 98 herbs, grasses, 48 climbers and 16 ferns.
- Studies on phenolgy of important plants with special reference to food preference of gibbons in the Sanctuary has revealed that the gibbons prefer different plants during different seasons and use leaves, fruits and flowers of trees and climbers. The occurrence of fruit trees preferred by gibbons was rare and scattered.

- Recommendations for conservation of Gibbon wildlife Sanctuary
- The present survey has clearly revealed that the biodiversity of this important sanctuary has fragmented over the past decade. It enabled not only the identification of areas of high ecological significance, which are critical for biodiversity, in different parts of the sanctuary. The following recommendations are made to facilitate future management of this important sanctuary.
- Upgrade the Gibbon wildlife Sanctuary to a higher conservation status.
- The Sanctuary, which is an area of high ecological significance, should be promoted to a higher protected area category, so that it could be afforded increased protection and management by the wildlife division Assam. Some adjoining areas of the tea gardens should also be incorporated into this proposed upgraded PA. A permanent range office of the GWLS should be established in a suitable location at Holongapara.

**Scientific findings and contents**

Structural formation of vegetation for the conservation of biodiversity in the Gibbon wildlife Sanctuary, Assam has been carried out in the project.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Such studies are required in other sanctuaries also.

57. **Influence of forest canopy cover on ground flora and micro-climate in Western Ghats (Maharashtra)**

**Principal Investigator:** Dr. Avinash Jain, TFRI, Jabalpur

**Duration:** 2010 – 2012

**Critical analysis of the research theme and summary of the study**

The study was carried to establish relationship among different parameters related to forests viz. canopy structure and density, ground flora, soil characteristics and meteorological parameters in Western Ghats. With the change in canopy structure in the forests of Raigad, Rantnagiri and Sindhudurg districts of Western Ghats of Maharashtra, composition of ground flora changed because ground flora depends mainly on trees, litter and its decomposition. With the increase in canopy density, number of tree species with their individuals increased but number of shrubs and herbs decreased. The status of regeneration was assessed as per method given by Shankar (2001) and Sen et al. (2008), which described the forests of Western Ghats of Maharashtra as 'Good', because density of seedlings > density of saplings > density of trees. pH and EC of soil samples collected from the selected forests decreased, while organic carbon, available nutrients and exchangeable cations increased with the increase in canopy density of the forests. Micro climatic parameters like temperature and light intensity decreased and humidity increased with increase in canopy density. The results of the study may serve as baseline data for further studies on vegetation and climate change and may also help in better silvicultural management of forests. The productivity of the forests of Western Ghats may be improved by managing canopy density through proper silvicultural operations.

**Scientific findings and contents**

The study was carried to establish relationship among different parameters related to forests viz. canopy structure and density, ground flora, soil characteristics and meteorological parameters in Western Ghats. The project concluded that the productivity of the forests of Western Ghats may be improved by managing canopy density through proper silvicultural operations.

58. **Evaluation of reproductive success in seed orchards of teak in India**

**Principal Investigator:** Dr. A. Nicodemus, IFGTB, Coimbatore

**Duration:** 2003 – 2007

**Critical analysis of the research theme and summary of the study**

Fertility variation was studied in two 30-year old Clonal Seed Orchards (CSO) of teak in four consecutive years (2003-2006). CSO I is located in Top slip (Tamil Nadu State) with 15 clones and CSO II in Walayar (Kerala State) with 20 clones. Thirteen clones are common to both the orchards.

Insects visiting teak inflorescence were studied in two clonal seed orchards of teak. Bees, flies and wasps were among the most frequently observed insects in teak Pollen load and a visitation rate of each species differed significantly. Honeybees were found to be the key pollinators of teak. Nectarivorous bids like sunbirds were also found to effect pollination in one of the orchards. X-radiography showed that 21 to 25% of fruits Walayar orchard and 21 to 44% in different SPAs had no fully developed seed and in the remaining the seed set was mostly 1 to 2. Fruit dimensions and weight correlated positively with seed filling. But germination and seed filling were not strongly correlated. Germination of Walayar orchard seeds was poor ranging from 4 to 22% in different years compared to two Nilambur SPAs which showed 56 to 63% germination. Seedling biomass was also higher in SPAs than XSO. These findings indicate that reproductive success in teak seed orchards is limited by several factors. Genetic and silvicultural interventions are essential to promote flowering and fruiting in teak orchards. Physiological manipulation of phenology and flower production will be viable option if cost is not prohibitive.

**Scientific findings and contents**

Evaluation of reproductive success in Seed Orchards of Teak located in Top slip (Tamil Nadu State) with 15 clones and CSO II in Walayar (Kerala State) with genetic and silvicultural interventions to enhance flowering has been done in the project.

59. **Documentation of indigenous knowledge on conservation and sustainable management in Darjeeling Himalaya**

**Principal Investigator:** Sunil Kumar Pal, IFP, Ranchi

**Duration:** 2004 – 2007

**Critical analysis of the research theme and summary of the study**

Indigenous traditional knowledge and customs of important communities of the Darjeeling Himalayas such as tamang, lepcha, limbu, Sherpa, kole and dhimal have been documented in the project.

Novel medicinal usage of plants by the above mentioned tribal communities for human and livestock diseases have been recorded along with the specific prescriptions for various ailments. Inherent conservational aspects being maintained through cultural and religious values by the tribal population in the region which is acting as a prime force for conservation of plant and animal species have been documented.

**Scientific findings and contents**

Indigenous traditional knowledge and customs of important communities of the Darjeeling Himalayas such as tamang, lepcha, limbu, Sherpa, kole and dhimal have been documented in the project.

60. **Cultivation of *Guadua angustifolia* kunth, and *Dendrocalamus asper* backer. in Kerala and Karnataka**

**Principal Investigator:** Dr. Syam Viswanath, IWST, Bengaluru

**Duration:** 2006 – 2009

**Critical analysis of the research theme and summary of the study**

Cultivation of *Guadua angustifolia* and *Dendrocalamus asper* in Kerala and Karnataka has been tried in this project. The followings are the results:
Established field demonstration plots of *D. asper* and *G. angustifolia*

- Generated basic data regarding the growth performances of these two species at three locations; TATA coffee Balamani estate at Thithimathi, (Kodagu district) in Karnataka and Chowara, Alwaye (Ernakulam district) and Thenkurissi (Palakkad district) of Kerala state.
- One of the important finding of this experiment is that the performance of two exotic bamboo species was found to be superior in Kodagu and Alwaye.
- These tow exotic species may be used for large scale plantation only in high rainfall tropical humid climatic zones with good deep loamy soils and with short dry spells.
- *Guadua angustifolia* also appears to have the capacity to tolerate periodic waterlogging better than *D. asper* and may be thought of for afforestation along river banks for stabilizing stream banks and soil erosion control as noticed in Aluva, Kerala.

**Scientific findings and contents**

Cultivation of *Guadua angustifolia* and *Dendrocalamus asper* in the states of Kerala and Karnataka has been tried in this project.

61. **Stand dynamics of some important tree species of Gujarat**

**Principal Investigator:** Dr. V.P. Tewari, AFRI, Jodhpur

**Duration:** 2002 – 2007

**Critical analysis of the research theme and summary of the study**

Stand Dynamics of *Eucalyptus* hybrid and *Acacia nilotica* has been carried out in six districts of the Gujarat State in India. The following are the results:

- Predictive ability of various log volume functions in estimating butt log volumes was assessed and tree volume functions and their validation was constructed for *Eucalyptus* hybrid and *Acacia nilotica*.
- Size class distribution using statistical distribution functions has been defined and site index equation has developed for assessing productive capacity of site.
- Growth and yield models for sustainable management of plantations for the species have developed.

**Scientific findings and contents**

Growth and yield models for sustainable management of plantations for the *Eucalyptus* hybrid and *Acacia nilotica* have been developed in Gujarat State in the project.

62. **Standardization of suitable potting media and root trainer size for improved planting stock production of some mandate species of Jharkhand and Southern West Bengal**

**Principal Investigator:** Dr. P.K. Das, IFP, Ranchi

**Duration:** 2002 – 2007

**Critical analysis of the research theme and summary of the study**

Present investigation was made find out suitable size of the container to obtain optimum growth of *Dalbergia sissooo*, *Gmelina arborea*, *Acacia mangium* and *Eucalyptus camaldunensis* in the nursery with general recommendations only.

**Scientific findings and contents**

Present investigation was made find out suitable size of the container to obtain optimum growth of *Dalbergia sissooo*, *Gmelina arborea*, *Acacia mangium* and *Eucalyptus camaldunensis* in the nursery with general recommendations only.

63. **Utilization of economic potential of *Parthenium***

**Principal Investigator:** Dr. Sanjay Naithani, FRI, Dehradun

**Duration:** 2003-2006

**Critical analysis of the research theme and summary of the study**

Economic Potential of *Parthenium* for use in plywood industry has been explored in this project. *Parthenium hysterophorus* is a suitable raw material for manufacture of particleboard. It is observed that suitable particle boards meeting all the requirements of Indian Standard Specification can be made using 14 percent phenol formaldehyde resin with 24.5 kg/cm$^2$ specific pressure for the pressing the board without any sizing agent but the water absorption can be reduced using 0.5 and 1 percent wax emulsion as sizing agent without lowering the values of other parameters below desired limit.

**Scientific findings and contents**

*Parthenium hysterophorus* is a suitable raw material for manufacture of fibreboard. It is observed that suitable fibreboards, grade II meeting all the requirement of Indian Standard Specification can be made using 14 percent phenol formaldehyde resin with 1 percent wax emulsion as sizing agent.

64. **Commercial cultivation of bamboo in Kodagu district: Raising of Quality Planting Meterial (QPM), establishment of demonstration plots and bamboo based value addition facilities**

**Principal Investigator:** Director, IWST, Bengaluru

**Duration:** 2006 – 2009

**Critical analysis of the research theme and summary of the study**

The project was funded by National Mission on Bamboo Application (NMBA), New Delhi. Kodagu Model Forest Trust (KMFT) implemented the project in Kodagu district in technical collaboration with Institute of Wood Science and Technology (IWST), Bengaluru and College of Forestry, Ponnampet. Demonstration plantations of *Dendrocalamus asper* has been established in the project. Multiplication facility for raising quality planting material of *Dendrocalamus brandisii* has also established with bamboo based value addition facilities at Kodangu.

**Scientific findings and contents**

Demonstration plantations of *Dendrocalamus asper* has been established in the project. Multiplication facility for raising quality planting material of *Dendrocalamus brandisii* has also established with bamboo based value addition facilities at Kodangu.

65. **Studies on the entomofaunal diversity and their interactions in selected provenances of sandal**

**Principal Investigator:** Dr. R. Sundarraj, IWST, Bengaluru

**Duration:** 2004 – 2007

**Critical analysis of the research theme and summary of the study**

Entomofaunal diversity and their interactions were studied in six sandal provenances (Bengaluru, Mandagadde and Thangali in Karnataka, Marayoor in Kerala and Chiteri and Javadis in Tamil Nadu) in the study. The following are the results:

- A total of 365 species representing 13 orders viz., Blattodea, Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Isopetera, Lepidoptera, Mantodea, Neuoptera, Odonata, Orthoptera and Thysanoptera were found breeding in the selected provenance of sandal.
- Bengaluru provenance recorded maximum number of insects being 300 species followed by Mandagadde and Javadis each recorded 160 species.

**Scientific findings and contents**

Entomofaunal diversity and their interactions were studied in six sandal provenances (Bengaluru, Mandagadde and Thangali in Karnataka, Marayoor in Kerala and Chiteri and Javadis in Tamil Nadu) in the study.

66. **Assessment of conservation status of hill bamboos (Nirgals), collection of germplasm from different eco-climatic zones in Satluj catchment area and establishment of germplasm bank**

**Principal Investigator:** Dr. K.S. Kapoor, HFRI, Shimla

**Duration:** 2000 – 2005

**Critical analysis of the research theme and summary of the study**

The study was undertaken with a view to understand the distribution pattern and extent of distribution of various hill bamboos species in the Sutlej catchment falling in Shimla district of Himachal Pradesh. Hill bamboo is a group of dwarf bamboos occupying montane regions in tropical areas of the world. The hitherto little studied group of plants is very significant from ecological point of view in addition to being of great local socio-economic value. It has also been endeavored through this study to highlight conservation concerns related to hill bamboos and strategies for their long term conservation have also been suggested.

As regard the use of this resource, major stress in the present study has been on its apparent use in the form of basketry. Efforts needs to be made to study the economic value and ecological impact on account of other uses of these species viz. removals for stakes for leguminous crops, walking sticks and fence re-inforcements, lopping for browse and commercial harvesting, etc.

**Scientific findings and contents**

Conservation Status of Hill Bamboos (Nirgals) was assessed in different Eco-climatic zones in Satluj Catchment Area and a Germplasm Bank was also established in the project.

67. **Litter dynamics and soil changes during stand development in plantation forest**

**Principal Investigator:** Dr. G. Singh, AFRI, Jodhpur

**Duration:** 2002 – 2006

**Critical analysis of the research theme and summary of the study**

Litter dynamics and soil changes during stand development in plantation forests of Rajasthan for the species of *E. camaldulensis, Acacia nilotica, Acacia tortilis*, *Dalbergia sissooo*, *Prosopis cineraria* and *Tecomella undulate* was studied in the project.

Litter production varied greatly among species and age classes as well. *E. camaldulensis* was found to produce high quantity of litter followed by *Acacia nilotica, Acacia tortilis*, *Dalbergia sissooo*, *Prosopis cineraria* and *Tecomella undulate*. Though leaf litter production was high in *D. sissooo* compared to *A. tortilis* and *A. nilotica*, total litter production was low. The data suggest that decomposition rate (weight loss) was rapid in case of *A. nilotica* litter where half decay was reached in 0.66 years. Litter in *E. camaldulensis* plantation showed a slow rate of decomposition. There was an increase in soil organic carbon (SOC), $NH_4$-N, $NO_3$-N and $PO_4$-P in the plantation area with increase in age.

**Scientific findings and contents**

Litter dynamics and soil changes during stand development in plantation forests of Rajasthan for the species of *E. camaldulensis, Acacia nilotica, Acacia tortilis*, *Dalbergia sissooo*, *Prosopis cineraria* and *Tecomella undulate* was studied in the project.

68. **Integrated nutrient management in shifting cultivation soil through green manuring and inorganic fertilizers**

**Principal Investigator:** Dr. Jasbir Singh, RFRI, Jorhat

**Duration:** 2003 – 2005

**Critical analysis of the research theme and summary of the study**

Integrated Nutrient Management in Shifting Cultivation Soil through Green Manuring and Inorganic Fertilizers was done Silonijan area, Karbi Anglong district of Assam in the project.

Improvement of the soil nutrient status and productivity of crop by green manure plants was found in following sequences: *Sesbania bispinosa* > *Dalbergia sissooo* > *Albizzia procera* > *Lantana camara* > *Chromolaena odorata* > Control > *Bauhinia purpurea* > *Trewa nudiflora* > *Gmelina arborea*.

**Scientific findings and contents**

Integrated Nutrient Management in Shifting Cultivation Soil through Green Manuring and Inorganic Fertilizers was done Silonijan area, Karbi Anglong district of Assam in the project.

69. **Standardization of protocol for viability testing and prolonging the viability and vigour of *Santalum album* L. seeds in storage**

**Principal Investigator:** Dr. Geeta Pandey, IWST, Bengaluru.

**Duration:** 2003 – 2005

**Critical analysis of the research theme and summary of the study**

The seeds collected from 20 clones of *Santalum album* (clonal germplasm bank, Gottipura Research Station, Hoskotewere) were studied for seed and seedling variability.

The study revealed that viability of *Santalum album* seeds in storage can be maintained at 5°C temperature and 9.2% moisture content. This would help in, long term storage of the species as an ex situ conservation measure and also providing seed material of superior genotypes on sustainable basis for plantation activities. The study has also resulted in the validation of Brunauer, Emmett and Teller (BET) theory for understanding relationship between seed and water content. This would form a base for better understanding the role of moisture content and temperature on seed viability.

**Scientific findings and contents**

The seeds collected from 20 clones of *Santalum album* (clonal germplasm bank, Gottipura Research Station, Hoskotewere) were studied for seed and seedling variability.

70. **Contribution of $N_2$ fixing plants on improvement of abandoned fallow in shifting cultivation**

**Principal Investigator:** Dr. Jasbir Singh, RFRI, Jorhat.

**Duration:** 2003 – 2006

**Critical analysis of the research theme and summary of the study**

An experiment was carried out in Karbi Anglong district of Assam to improve soil fertility and enhancement of agricultural productivity by using leguminous green manures. Three leguminous species *Crotalaria pallida, Sesbania bispinosa, Cajanus cajan* were selected as green manure and applied on rice, maize and mix crop (rice, maize and sesame). Out of these green manure trails *Crotalaria pallida* was found as the best green manure to improve soil constituents, increment of the crop productivity and nutrient uptake followed by *Sesbenia bispinosa*.

**Scientific findings and contents**

An experiment was carried out in Karbi Anglong district of Assam to improve soil fertility and enhancement of agricultural productivity by using leguminous green manures.

71. **Development of modern nursery techniques of important forestry species of goa *Bambus bambos, Dendrocalamus strictus, Terminalia tomentosa, Xylia xylocarpa* and *Myristica fragrans***

**Principal Investigator:** Dr. T.S. Rathore, IWST, Bengaluru.

**Duration:** 2000 – 2004

**Critical analysis of the research theme and summary of the study**

Modern root trainer based nursery technology was developed for the important species of Goa viz. *Bambus bambos, Dendrocalamus strictus Terminalia tomentosa, Xylia xylocarpa* and *Myristica fragrans* in the project. Nursery protocols were developed for mass production of quality seedlings of the species with optimization of potting media, container size, and biofertilisers to boost the seedling growth for better survival of the species.

**Scientific findings and contents**

Modern root trainer based nursery technology was developed for the important species of Goa viz. *Bambus bambos, Dendrocalamus strictus, Terminalia tomentosa, Xylia xylocarpa* and *Myristica fragrans* in the project.

72. **Planting stock improvement programme in *Cedrus deodara***

**Principal Investigator:** Dr. Rajesh Sharma, HFRI, Shimla.

**Duration:** 2003 – 2010

**Critical analysis of the research theme and summary of the study**

Through sample plots studies, 50 ha seed stand of *Cedrus deodara* was selected for their conversion into Seed Production Area (SPAs) under the project. Complete enumeration of the finally selected seed stands was done with trees marked for retention and culling after assessing each individual tree both for its qualitative and quantitative traits. Marking lists were prepared and submitted to SFD to obtain culling permission from the competent authority. These plus trees were marked with yellow band and numbered and each Forest Division was informed about their location, number and site details to protect these trees. A progeny trail with 52 progenies was raised in the nursery using Randomized Block Design during January 2007. These progenies were maintained in the nursery with one pricking up done during August 2007. Progenies were planted nin the field using Randomized Block Design during August 2009 at Cheog to study genetic variation in the progenies for growth traits.

**Scientific findings and contents**

Through sample plots studies, 50 ha seed stand of *Cedrus deodara* was selected for their conversion into Seed Production Area (SPAs) and established in the state of HP in this project.

73. **Management of *Bambus nutans* for enhancing the productivity of marketable culm through silvicultural practices**

**Principal Investigator:** Satyam Bordoloi, RFRI, Jorhat.

**Duration:** 2005 – 2008

**Critical analysis of the research theme and summary of the study**

*Bambus nutans* is one of the 13 most important species of bamboos enlisted by National Bamboo Mission. The present investigation was carried out to study the effect of some important factors necessary for scientific management of bamboo plantation in order to obtain higher economic yield. The following are the results:

- Initially a market survey was carried out to determine the minimum length and collar diameter of this bamboo species which is marketed. The factors and effects of which were studies under this project; were thinning, soil mounding and fertilizer (DAP) applications. This study helped to set a standard for growth parameters to define a marketable culm.
- Market survey reveals that the demand for *B. nutans* in these markets is just after *Bambusa balcooa* and *Bambusa tulda*. It was also observed that minimum marketable length of *B. nutans* is 7m and minimum basal diameter of marketable culm is 4 cm.
- Minimum 40% thinning and 20 cm of soil mounding gave the best result in regards the growth parameter during the first year. After one and half year of the experiment, best performance was found in 60% thinning and 30 cm soil mounding. No significant thinning and mounding effect was observed after twenty four months of the study.
- Therefore we may conclude that minimum 20% thinning and 20 cm soil mounding in the bamboo clumps to sustain the productivity.
- It was observed that application of fertilizer increased the emergence of new shoots in the treated clumps. Average height and average diameter of shoots were also found to be increased in the fertilizer treated clumps. Treatment F3 (1.5kg DAP/Clump) produced maximum number of shoots/clump with maximum average height (43 cm) and maximum diameter (8.0).

**Scientific findings and contents**

The scientific management of bamboo plantations has been developed in the state of Assam in order to obtain higher economic yield in this project.

74. **Standardization of sustainable harvesting practices of Arjuna (*Terminalia* Arjuna) bark**

**Principal Investigator:** Dr. A.K. Pandey, TFRI, Jabalpur.

**Duration:** 2010 – 2012

**Critical analysis of the research theme and summary of the study**

Arjuna bark can be obtained on a sustainable basis after every 24 months by extracting opposite quarters of the trunk bark rather than girdling the trees. The present method was developed during five years study conducted in Chhattisgarh and Madhya Pradesh, India. In this method, 25% trunk bark should be removed by putting longitudinal strip of ¼ quarter of the trunk diameter. Only outer and middle bark should be removed leaving the inner bark (cambium layer) for regeneration (sharpened tool should be used for harvest of bark). Bank recovery of trees after harvest varied significantly with girth of the tree. Properly harvested trees with the technique developed by us generally recovered well. The study indicates that distinct girth classes regenerated at different speeds. Application of Bordeaux mixture, IAA (Indole Acetic Acid) and Neem extract didn't have any effect on the regeneration (regrowth) of bark.

The concentration of chemical constituents varied among the girth class and location. It increased with the increase in girth class. The concentration also varied in original and regenerated bark and was higher in original bark. The concentration of chemical constituents in regenerated bark was observed to increase each year.

The non-destructive harvest of Arjuna bark could be the most important ways to get quality raw material on sustainable basis without destroying resources. This study could be helpful in making better policy and management of *T.* Arjuna for sustainable harvest and dependable rural livelihoods.

**Scientific findings and contents**

Sustainable harvesting practices of Arjuna (*Terminalia* Arjuna) bark have been developed in this project.

75. **Development of nursery practices for production of quality planting stock of bamboos in N.E.**

**Principal Investigator:** D.K. Banerjee, RFRI, Jorhat.

**Duration:** 2005 – 2008

**Critical analysis of the research theme and summary of the study**

The objective of the project was to standardize the media combination for quantity planting stock production but only generalized concepts were recommended in the project.

76. **Standardization of non-destructive harvesting practices of Arjuna (*Terminalia* Arjuna), maida (*Litsea chinensis*) bark.**

**Principal Investigator:** Dr. A.K. Pandey, TFRI, Jabalpur.

**Duration:** 2005 – 2008

**Critical analysis of the research theme and summary of the study**

Non-destructive harvesting practices of Arjuna (*Terminalia* Arjuna), Maida (*Litsea chinensis*) bark have been developed in this project with the following results.

**Arjuna (*Terminalia* Arjuna)**

- Arjuna bark can be obtained on sustainable basis if the bark is harvested through non-destructive harvesting techniques in proper season and sufficient time is allowed between two successive harvests for the plant to regenerate new bark.
- Arjuna bark should be harvested in February-March (ideal time) to get quality produce. Harvesting of bark should not be done or avoided during rainy season as it attracts insect and fungal infestation.
- Bark should be harvested longitudinally, not all over the circumference of trunk/branches.
- In younger trees having CBH less than 60 cm bark should be removed by strip harvesting. Bark should be removed by putting 15 cm wide strips on the main trunk of the tree.
- For sustainable harvest, only ¼ or $^{1}/_{3}$ of the mature bark of the tree trunk (girth) should be extracted. Remove only outer and middle bark leaving the inner bark for regeneration.
- Sustainable bark harvesting can be done after every two years by extracting opposing quarter of the trunk bark rather than girdling the trees.

**Maida (*Litsea chinensis*)**

- Maida bark can be obtained on sustainable basis it the bark harvested through non-destructive harvesting techniques in proper season and sufficient time is allowed between two successive harvests for the plant to regenerate new bark.
- Maida bark should not be harvested before 8-10 years of growth or (60 cm GBH) to get quality produce.
- Maida bark should be harvested in December-March (ideal time) to get quality produce. Harvesting of bark should not be done or avoided during rainy season as it attracts insect and fungal infestation.
- Bark should be harvested longitudinally (stripping), not all over the circumference of trunk/branches.
- For sustainable harvest, only ¼ or $^{1}/_{3}$ strip of the mature bark of the tree trunk (girth) should be extracted. Remove only outer and middle bark leaving the inner bark for regeneration.
- Sustainable bark harvesting can be done after every one year by extracting opposing quarter of the trunk bark rather than girdling the trees.

**Scientific findings and contents**

Non-destructive harvesting practices of Arjuna (*Terminalia* Arjuna), Maida (*Litsea chinensis*) bark have been developed in this project.

77. **Comprehensive tree improvement program for *Gmelina arbora* in Karnataka Phase-I progeny trail.**

**Principal Investigator:** Dr. Ashutosh Srivastava, IWST, Bengaluru

**Duration:** 2006 – 2009

**Critical analysis of the research theme and summary of the study**

A Tree improvement program (Progeny Trial) for *Gmelina arbora* was established and assessed in the state of Karnataka. The following are the results:

- The selection of the plus trees is often based on the phenotype of the mother trees. This approach may be misleading as the superior phenotype of the plus tree may be due to edapho-cilmatic factors favorable for the growth of the tree and local competition from the adjoining trees. Progeny trial is a tool to evaluate the worth of plus tree on the basis of performance of their progenies.
- This study indicated that the progenies of phenotypically superior plus trees from Karnataka SGA-1, SGA-2, SGA-4, SGA-11, SGA-16and SGa-17 did not produce the progenies of superior nature under Bengaluru conditions. The best performing family was SGA-9 which should be used extensively for *Gmelina arborea* plantations in Bengaluru and surrounding areas.
- Similarly, plus trees from Andhra Pradesh had excellent phenotypic characters but failed in Bengaluru due to die-back problem. Hence, use of seeds from these plus trees is not recommended for afforestation programme in Bengaluru.
- SGA-9 and SGA-11 are the two plus trees whose seeds should be used in establishing multi-locational trails in Karnataka to further validate the results of the present study.

**Scientific findings and contents**

A Tree improvement program (Progeny Trial) for *Gmelina arbora* was established and assessed in the state of Karnataka.

78. **Standardization of flower induction schedule in CSO of *Tectona grandis* and its impact on fruit set**

**Principal Investigator:** Dr. Ashutosh Srivastava, IWST, Bengaluru

**Duration:** 2009 – 2012

**Critical analysis of the research theme and summary of the study**

Methods of flower induction schedule in CSO of *Tectona grandis* and its impact on fruit set has been studied in the project.

- Low fruit production in clonal seed orchards has been an important limitation in teak improvement programmes in India and worldwide. Lack of flowering and asynchrony in flowering among the constituent clones are major constraints teak breeders are presently facing.
- The chemicals like CCC @ 250 ppm, ALAR @ 250 ppm, Paclobutrazol @ 3g/tree, Salicylic acid @ 200 ppm, Potassium nitrate @ 2% and PEG @ 10% were induced the flowering in both the study sites. It would be worthwhile to study combination effects of the above chemicals for further enhancement of flowering in the next experiment.
- In light of the above, the experiment laid out during the year 2010-2011 comprising of 12 treatments with 3 replicates each. In this experiment ALAR @250 ppm stem injection with girdling of lower 3 branches is considered as a control and it is the basal treatment for all the treatments. The chemicals like Paclobutrazol, Potassium nitrate, Salicylic acid and PEG in different combinations were applied along with the basal treatment. The observations on flower induction and fruit set have been taken at both the test orchards.

**Scientific findings and contents**

Methods of flower induction schedule in Clonal Seed Orchard - CSO of *Tectona grandis* and its impact on fruit set has been studied in the project.

79. **Studies on seed borne mycoflora of arid zone tree species and their management**

**Principal Investigator:** Dr. K.K. Srivastava, AFRI, Jodhpur

**Duration:** 1993 – 2001

**Critical analysis of the research theme and summary of the study**

- Pods and seed infection due to *Botryodiplodia theobromae*, *Fusarium solani* and *Alternaria tenuis* on *Tecomela. undulate* plantations and *B. theobromae,* and *Collectotrichum sp.* in *Acacia nilotica* on canal side plantation of IGNP area of Rajasthan have been found.
- The non-pathogenic mycoflora viz., *Asperfillus niger*, *A. flavus, Penicillium citrimum. P. chrysogenum* and *Mucor* sp. were found on all the tree species.
- Pods and seed of *A. lebbeck* were found attacked by *Fusarium* sp. and *Coniella* sp.
- On *A. indica* seeds seven pathogenic mycoflora belonging to six species of Fungi-imperfecti, viz., *Curvularia lunata, Helminthosporium* sp., *Phytophthora, Alternaria* sp. *Aspergillus flavus, Chaetomium* sp. and *Xylaria* sp. were isolated and identified.
- Fungicidal treatment with Captof (0.2%) or Foltaf (0.2%) was found very effective against seed borne mycoflora. These fungicides were found very effective when seeds were treated with aqueous solution of these fungicides for 5 minutes.
- The bio-efficacy of various plant products i.e. Neem Seed Kernel Powder (NSKP); Karanj Seed Kerenel Powder (KSKP); Neem Leaf Powder (NLP) and Neem Seed Oil (NSO) were tested against neem seed mycoflora of neem. Neem seed oil and Neem Leaf Powder (NLP) wet performed better than other treatments.
- Plant extracts of *Capparis deciduas, Jatropha curcus, Pongamiz pinnata, Calotropis procera* and *Eucalyptus* oil were tested in different concentration against neem seed mycoflora. It was found that higher concentration i.e. 10% showed better results as compare to others.
- In brief, pathogenic and non-pathogeneic mycoflora were indentified on neem, babul, siris, rohida and Khejri in the state of Rajasthan.

**Scientific findings and contents**

Seed borne mycoflora of arid zone tree species and their management in the state of Rajasthan have been studied in the project.

80. **Field performance of micro and macro propagated planting stock of bamboo selected five commercially important species**

**Principal Investigator:** Dr. R. Yasodha, IFGTB, Coimbatore

**Duration:** 2004 – 2009

**Critical analysis of the research theme and summary of the study**

Field performance of micro and macro propagated planting stock of bamboo species (*B. bambos*, *D. strictus, P. stocksii* and *Ochlandra travancoica)* have been evaluated in multilocational trials in the project.

- Twenty five hectares field plantations were established to study the performance of micro-propagated plants of three species of bamboos, *B. bambos*, *D. strictus* and *P. stocksii*.
- Among the three species tested, *B. bambos* showed better growth than *P. stocksii* and *D. strictus*, however the utility value of the culms vary among the species.
- Micro-propagated, seed raised and cuttings propagated plants show similar growth in the field conditions. Initially, cuttings raised plants showed lesser mean number of shoots, however, no significant variation was noticed after 3 years of planting. It may be due to the number of rhizomes developed during the initial phase of establishment.
- Bamboo propagules over 8 months old at the time of field planting were escaped from rabbit damage; hence to avoid the damage of the shoots by rabbits it is essential to plant 8-12 months old plants. If the newly produced culm is thick, vulnerability to rabbit damage is less.
- Bamboos prefer well drained loamy soil and growth and production of new culms was highly affected in poor soils like gravel and rocky types.
- In irrigated conditions, the mean height of the tallest culm of micropropagated *B. bambos* at the age of 1.5 years was 4.2m, whereas under unirrigated conditions, 4.5 year old plants showed 3.1m height.
- On un-irrigated but good soil type (Bharathiar University campus), miropropagated *D. strictus* was growing well than *B. bambos* and *P. stocksii.*

**Scientific findings and contents**

Field performance of micro and macro propagated planting stock of bamboo species (*B. bambos*, *D. strictus, P. stocksii* and *Ochlandra travancoica)* have been evaluated in multilocational trials in the project.

81. **Improvement of degraded shifting cultivation lands through introduction of *Thysanolaena maxima* (Broom grass) along with *Cajanas cajan* as $N_2$ fixing plant**

**Principal Investigator:** Dr. I.P. Bora, RFRI, Jorhat

**Duration:** 2006 – 2009

**Critical analysis of the research theme and summary of the study**

- Broom grass growing areas of Assam were surveyed and rhizomes were collected based on selected criteria. Collected rhizomes were multiplied and altogether 800 seedlings of both selected and local individuals were planted n the experimental site at different spacing regime.
- Study showed that during the harvesting stage of both the year plant growth was significantly less in 1m spacing that the other two spacing trial. Better production Brooms were noticed from the rhizomes collected from quality individuals. Comparatively more number of panicle was recorded in 2.5 m spacing while panicle length was observed more or less same in 2m and 2.5m spacing. This indicates that 2.5 m spacing is sufficient for profuse growth of *T. maxima*.
- Productivity of *T. maxima* mainly depends upon the site condition, quality of planting materials used and maintenance of plantations. The Broom yield is observed higher in 2$^{nd}$ year cultivation due to increment of productive clums per tussock. Maximum yields were observed in 2m spacing in *C. canjan* applied plot. Though there is no significant difference recorded in terms of growth between the two spacing trial but the maximum yield were found in 2m spacing due to presence of higher number of tussock. This spacing facilitated proportionate increase in rhizome and root biomass resulted in development in higher number of sprouting culms.
- *T. maxima* can be a profitable enterprise when it was cultivated alongwith *C. cajan* as green manure in degraded jhum fallow. The profit can be increased further if the Brooms are processed by the grower themselves. Recently jhumias has turned to cultivate cash crops to uplift their economic conditions in addition to shifting cultivation. Depletion of soil fertility and invasion of fast growing exotic weeds resulting low productivity to target crops in fallow land. Implementation of technology for plantation of *T. maxima* with *C. cajan* in fallow land can enhance the productivity and increase fertility status of soil.

**Scientific findings and contents**

Improvement of degraded shifting cultivation lands through introduction of *Thysanolaena maxima* (Broom grass) along with *Cajanas cajan* as $N_2$ fixing plant in the state of Assam have been studied in the project.

82. **Development of post harvest techniques for seed production in *Jatropha curcas***

**Principal Investigator:** R. Anandalakshmi, IFGTB, Coimbatore.

**Duration:** 2005 – 2009

**Critical analysis of the research theme and summary of the study**

- Reproductive efficiency of *Jatropha curcas* is good, but the ratio of female flowers is very poor compared to the male flowers thereby affecting seed production. Fruits need to be harvested at yellow or black pulpy stage and it is safe to avoid collecting dry fruits.
- Oil content and quality in the second fruiting season October – December was superior to the first season i.e. July-September but the quantity of seed produced in the second season was lower than the first.
- Oven drying at 40°C for one or shade drying at ambient temperature (30 ± 1°C; RH 65%) for 10 days are suitable methods for drying *Jatropha* seeds.
- Normal aerated storage environment is sufficient enough to store *Jatropha* seeds both for oil and planting purpose.
- It is essential to separate the shell or seed coat from *Jatropha* seed to improve oil recovery & quality.
- *Jatropha* seeds can be efficiently processed using the 'Seed decoater'. Kernel and seed coat in the ratio of 80:20 obtained from the machine enabled better oil recovery with superior physico-chemical characteristics compared to whole seed oil.
- Seed production was observed to be poor in *Jatropha curcas* despite its high reproductive efficiency. The ratio of female to male flowers was very low and research inputs to improve female flower production would give a large scope for successful *Jatropha* cultivation. Efforts to establish small scale *Jatropha* seed processing and oil extraction unit at village level through self-help groups need be taken up so that the grass root level community shall be benefited.

**Scientific findings and contents**

Post Harvest Techniques for Seed Production in *Jatropha curcas* have been developed in the project.

83. **Survey and evaluation of selected species for energy plantation in North East region of India**

**Principal Investigator:** N.N. Zhasa, RFRI, Jorhat

**Duration:** 1999 – 2002

**Critical analysis of the research theme and summary of the study**

- A total of 35 species of trees and shrub are being as a fuelwood in the Jorhat district of Assam. But it is not that all 35 species are used in all the blocks. Some of the species, which have significant contribution in one block, is not at all used in other block. Like, *Anthocephalus chinensis*, it is a prominent species for fuelwood, its role as fuelwood is every prominent in the entire district expect in Majuli block. As a whole *Melia azedarach* is a highly sought species with the 11.12% of the total consumption of fuelwood, followed by *Anthocephalus chinenesis* (8.5%), *Albizia lucida* (6.19%), *Mesua ferra* (5.85%), *Mangifera indica* (5.83%), etc. The least percentage of use of the species was *Shorea robusta* (0.25%). In the bottom of the list is the *Emblica officinalis*, although it is very much preferred species as far as its medicinal value is concerned, but its use as fuelwood is very less, it contributes only 0.38% of the total consumption.
- Block wise picture reveals that contribution of different species not alike in all the blocks. Some interesting information is coming up. In the Titabor block, 28 species are being used for fuelwood. *Melia* azedarach is top in list (12.29%), followed by *Lagerstroemia speciosa* (8.96), *Albizia lucida* (8.68), *Tectona grandis* (8.28), *Castanopsis hystrix* (7.96), *Anthocephalus chinensis* (7.88), etc. One of the important fuelwood species *D*ysoxylum procerum is not in use in this block.
- In the North West Jorhat block, only 26 species of the fuelwood are in use. Here, top position is occupied by Dysoxylum procerum (12.51%) where same species is not at all preferred in other block like Titabor, Jorhat and Jorhat East and its contribution is very meager in Jorhat Central (0.04%). Other species in this block are in the order of *Albizia procera* (11.61%), *Litsea sebifera* (10.62%), *Bombax ceiba* (7.14%), *Anthocephalus chinensis* (6.89%), etc.
- Besides this, 3 bamboo species are also consumed for firewood. These are Jati (*Bambusa tulda*), Bhaluka (*Bambusa balcoa*), and Mokal, (*Bambusa nutans*). Among these, the percent use of Bholuka, Jati and Mokal are 48%, 47% and 5% respectively of total bamboo consumption.

**Scientific findings and contents**

Survey, listing and evaluation of species for Energy Plantation in North East Region of India has been done in this project.

84. **Development of yield assessment methods for *Eucalyptus* spp. and *Anacardium occidentale* using image analyzer**

**Principal Investigator:** Dr. V. Sivakumar, IFGTB, Coimbatore

**Duration:** 2006 – 2007

**Critical analysis of the research theme and summary of the study**

Stand volume can be measured indirectly in a variety of ways. Image analyzer is largely used in biology to measure pollen, leaf, seed and root characters for accurate results. The new method proposed is for estimation of basal area using image analyzer which will replace existing method of wedge prism. The steps involved in the proposed method are; Mean diameter estimation using image analyzer, Estimation of number of trees per hectare, Estimation of basal area per hectare from mean diameter, Prediction of height from girth at breast height and Application of form factor to estimate volumes.

Methods have been developed for single tree height and diameter estimation using pictures taken with a reference scale at breast height. The pictures can be taken from 10 meters distance to 30 meters distance. Correction tables are given to find out actual height of the trees from the height of the trees observed in the image. The correction factors were worked out to estimate diameter at different heights and volume at every 5 meter ground distance. Simple multiplication of respective correction factor will give us the actual diameter. In case of single tree volume, the surface area and the height of the tree found out after image analysis must be calculated based on the proposed formula before multiplication of correction factor. The said height and diameter can be estimated in high precision and accuracy with an error of ±1.0%. Pictures for height and diameter estimation can be taken in day time.

The single tree volume estimation method showed a mean error of 3.02 ± 3.9%. The pictures taken after sun set results in better accuracy. This procedure can be applied for clones of *Eucalyptus*. The error will considerably be reduced when images are taken from specific distance.

Pictures for crop volume estimation need to be taken after sun set. The error estimated (<5.7%) in this method is limited to few samples without considering the clonal variation. The clone specific and location specific prediction model will improve the efficiency of estimation and can bring down the error to acceptable limits (2-3%). Validation of the developed methods and field evaluation studies will enlighten superiority of the developed method over the existing yield assessment methods.

In case of *Anacardium occidentale*, the fruit yield estimation is possible in clones with red colour fruit. Method have been proposed for counting the number of fruits on the surface of the crown and thereafter projecting to the total crown area and conversion of number of fruit to nut weight.

**Scientific findings and contents**

A new method of yield assessment for *Eucalyptus* spp. and *Anacardium occidentale* using image analyzer has been developed in this project.

85. **Screening and evaluation of wild varieties of *Emblica officinalis* fruit in various agro-climatic zones of Western Ghats**

**Principal Investigator:** R. Ezhumalai, IWST, Bengaluru

**Duration:** 2005 – 2008

**Critical analysis of the research theme and summary of the study**

Screening of high yielder of wild plant of *Emblica officinalis* from ten selected Agro-climatic zone of Western Ghats, based on Ascorbic acid content and fruit yield has been in the project. Results shows that two places of Western Ghats namely Thenmalai (1020mg/100g) and BRT hills (1010mg/100gm) show highest ascorbic acid content but while comparing fruit yield, trees from BR hills (285gm) gave higher yield than tree from Thenmalai (184gm). Based this observation, we can conclude that trees from BR hills can be selected for further mass multiplication or crossing with other local hybrid varieties.

Results also indicate that dry deciduous forests and thorn forest show higher active principles content. It was about 30-40% more than recorded yield.

Environmental factors not only influence growth, development and distribution of plants but also influence the quantity and quality (chemical constitute) of herbal biomass. Secondary metabolites in *Emblica officinalis* are also affected by these site factor as in the case of Rauvolfia serpentine (Sarin, 1986) Datura metel (Sarin, 1976). It is also noted that drier the climatic condition higher vitamin-C content.

**Scientific findings and contents**

Screening of high yielder of wild plant of *Emblica officinalis* from ten selected Agro-climatic zone of Western Ghats, based on Ascorbic acid content and fruit yield has been studied in the project.

86. **Comparative studies on natural resistance of bamboos to biodegradation in Assam**

**Principal Investigator:** D. Gurung, RFRI, Jorhat

**Duration:** 2005-2009

**Critical analysis of the research theme and summary of the study**

The three bamboo species viz. *B. tulda, B. bambos, B. balcoa* show considerable degree of resistance to bio-degradation, however their utilization and durability depends on the species of bamboo, its maturity and moisture content. Comparative natural resistance of selected bamboo species to biodegradation from three regions of Assam viz. Burnihat, District-Kamrup; , Salna in Nagaon district of Assam and RFRI Campus in Jorhat district of Assam. The following are the results:

**Burnihat, Kamrup:** The study has found that *B. pallida* is naturally resistant to biodegradation in the biotic and abiotic conditions of Burnihat, Kamrup followed by *B. bambos* (Kotoha bah) and *B. balcoa* (Bholuka bah).

**Salna, Nagaon:** The study found that naturally most resistant bamboo species was *Bambusa tulda* (Jati bah) followed by *D. giganteus* (Bor Kako bah) and *D. hamiltonii* (Kako bah)

**RFRI, Jorhat:** The naturally most resistant bamboos to biodegradation in Jorhat were *B. bambos* and *B. tulda*. The least resistant bamboos from Jorhat test yards were *M. baccifera* and *B. polymorpha*.

**Scientific findings and contents**

Comparative natural resistance of three bamboo species viz. *B. tulda, B. bambos, B. balcoa* to biodegradation from three regions of Assam has been studied in the project.

87. **Studies on seed source, determination of age of the tree and establishment of germplasm bank in sandal**

**Principal Investigator:** Dr. A.N. Arunkumar, IWST, Bengaluru

**Duration:** 2005 – 2008

**Critical analysis of the research theme and summary of the study**

Studies on seed & seedling variation in different populations of sandal in the state of Karnataka, Tamil Nadu and Kerala, determination of age of the tree and establishment of germplasm bank were carried out in this project. The following are the results:

- During the survey in the state of Karnataka, Tamil Nadu and Kerala, it was found that tree of girth 30 cm and above is nearly absent in the natural conditions. There are few trees of considerable girth in and around the office of state Forest Departments, because of the protection. However, these trees are also few. A systematic study to estimate the population size by establishing sample plots was not carried out because even for normal visualization, trees above 30 cms girth is nearly absent.
- It was also found during this study that regeneration in sandal in not an issue as there is sizeable population of trees less than 10 to 15 cm girth where ever a minimum protection is provided.
- Variability in seed and seedling parameters were observed in different populations of sandal.
- Variability was observed for heartwood and oil content among the three locations. The mean heartwood percentage was 73.60, 83.63 and 82.07, for Iruttipallam, Marayoor and Bengaluru, respectively.
- The mean oil percentage recorded were 2.02% (Iruttipallam), 2.30% (Marayoor) and 2.18% (Bengaluru), respectively.
- Considerable difference in number of rings for a given girth class in case of all the three locations.
- A seedling based ex situ germplasm bank has been established at Gottipura Field Research Station, Hoskote, Bengaluru. Seedlings representing twenty seed sources were planted at a spacing of 4x4 meters.

**Scientific findings and contents**

Studies on seed & seedling variation in different populations of sandal in the state of Karnataka, Tamil Nadu and Kerala, determination of age of the tree and establishment of germplasm bank were carried out in this project.

88. **Development of advanced generation seed orchard of *Acacia mangium* based on biomass and wood density**

**Principal Investigator:** Dr. Maheshwar Hegde. IFGTB, Coimbatore

**Duration:** 2009 – 2014

**Critical analysis of the research theme and summary of the study**

The project "Development of Advanced Generation Seed Orchard of *Acacia Mangium* Based on Biomass and Wood Density" was under taken to develop advanced generation seed orchards of *Acacia mangium*, supply of improved seeds to user agencies and improvement of productivity.

Initially, existing IFGTB breeding populations of *Acacia mangium* at Karunya in Tamil Nadu and Nilambur in Kerala in the form of seedling seed orchards (SSOs) were evaluated for growth as well as wood density. The survival, growth and tree form were better at Nilambur which is a relatively high rainfall area compared to Karunya. Evaluation of families and seed sources revealed that among the seed sources, SSO (Karunda PNG SE) QLD, and Bitruri PNG performed better for total tree height though they were not significantly different from many other seedlots. SSO (Karunda PNG SE) and Queensland (QLD, Komavel PNG (SSO selections) performed better for clearbole height. Wood density was highest in *A. auriculiformis* (0.6008) and it was highest among *A. mangium* seedlots in Indonesian bulk seedlot (0.5365) and also MPM seedlot (0.536). Tully mission beach QLD performed poor among *A. mangium* seed sources. Hertibilities ($h^2$) for total height (0.435), stem straightness (0.362) and girth at breast height (0.334) were relatively high. Heritabilities for clear bole height (0.294), and wood density (0.29) were moderate. For number of primary braches $h^2$ was low at the age of 12 years. 125 Superior trees were selected based on total height, stem form, crown and girth in Nilambur SSO (66) Karunya SSO (31), Panampally (4), KFRI campus (6), Pachamala plantations (6) and Peringamala plantation (12). Half-sib nursery of these superior trees was raised. 126 half-sib families of *A. mangium* were planted in a progeny trial at Palode in Kerala during July 2011 with four replications and 4 tree in a plot in Latinized row-column design. The trial was evaluated for various growth and form characteristics at one and two years of age. During the second year of evaluation all the characters found to vary significantly. The wood density ranged from 0.270 to 0.479 g/cm$^3$ with mean wood density was 0.396 g/cm$^3$ (among 33 families sampled) at 2½ year of age.

The resistograph was used as an instrument to estimate wood density indirectly. Three was high positive correlation between wood density and Resistograph readings (r=0.814) indicating that the instrument can be used for rapid, indirect and non destructive estimation of wood density in breeding population. It can be used in selection of families as well as individuals for high and low wood density at early age. The trial was thinned during March 2014 by removing 50% trees and it can be used as advanced generation seed orchard. The plantations raised from second generation seed orchards expected to have better stem from which in turn will enhance the timber utility. Some very good trees in the top raking families in the progeny trial can be cloned and used in future clonal trails.

**Scientific findings and contents**

The project "Development of Advanced Generation Seed Orchard of *Acacia Mangium* Based on Biomass and Wood Density" was under taken to develop advanced generation seed orchards of *Acacia mangium*, supply of improved seeds to user agencies and improvement of productivity.

89. **Biomass, net primary productivity and shoot productivity of seven industrially important bamboo species in semi arid and humid tropics of Peninsular India**

**Principal Investigator:** Dr. Syam Viswanath. IWST, Bengaluru

**Duration:** 2014 – 2016

**Critical analysis of the research theme and summary of the study**

Evaluation of comparative growth performance, biomass productivity as well as assessment of edible shoot production including its nutrient value, besides standardizing management schedule in six bamboo species in humid tropics and semi-arid zones of peninsular India, viz. *Bambusa balcooa, B. bambos, Dendrocalamus asper, D. stocksii, D. strictus,* and *Guadua angustifolia* under two contrasting agroclimatic condition in tropical humid zone in Koppa, Chickmaglur and in a semiarid zone Hoskote (Bengaluru) has been in the project.

The project has came out important information on matching species with site like the potential productivity of *Dendrocalamus stocksii* in semiarid areas and the nutritive value of its shoots for the first time. The project has provided estimates of total above ground biomass of these six species in humid and semiarid areas besides information related to scientific management of bamboo plantations, harvesting, processing of shoots, nutrient composition etc. which may be of practical significance to Forest managers and cultivators planning for commercial bamboo cultivation.

**Scientific findings and contents**

Evaluation of comparative growth performance, biomass productivity as well as assessment of edible shoot production including its nutrient value, besides standardizing management schedule in six bamboo species in humid tropics and semi-arid zones of peninsular India has been in the project.

90. **Introduction of selected genotypes of karanj, kusum and bamboo as tree components in agroforestry models in lateritic belt of Eastern India**

**Principal Investigator:** Dr. Animesh Sinha. IFP, Ranchi

**Duration:** 2011 – 2015

**Critical analysis of the research theme and summary of the study**

Agro-forestry model consisting of three tree components viz., kusum (*Schleichera oleosa*), karanj (*Millettia pinnata*) both bio-diesel plants and bamboo (*Dendrocalamus asper*) has been studied in the project. The following are the results:

- In general, yield of crops decreased when cultivated under trees in comparison to monoculture of crops but the higher yield reduction was observed under bamboo based agroforestry models, where crops yield hardly ranged from 37-72% of monoculture.
- Growth of tree components, particularly kusum and karanj saplings intercropped with crops were significantly higher than growth in monoculture of trees. Whereas, the average annual production of bamboo shoot was less in bamboo based agroforestry models (0.69-1.1 t/ha) than in monoculture (1.33 t/ha).

- The Land Equivalent Ratio (LER) was 1.6 in bamboo + higher followed by 1.4 in the bamboo + turmeric models. The net return was maximum from kusum + colocasia model (Rs. 0.45 lac/ha), karanj + turmeric model (Rs. 0.65 lac/ha) and bamboo + ginger model (Rs. 1.27 lac/ha) in a year among corresponding tree based agroforestry models.
- As the young kusum saplings were not suitable for lac cultivation and karanj saplings were not in the stage of seed production, no income from these trees was realized. In due course of time, developed agroforestry model(s) may be followed in community land for livelihood improvement of farmers.

**Scientific findings and contents**

Agro-forestry model consisting of three tree components viz., kusum (*Schleichera oleosa*), karanj (*Millettia pinnata*) both bio-diesel plants and bamboo (*Dendrocalamus asper*) has been studied in the project.

91. **Studies on pollarding and propagation in kusum (*Schleichera oleos*a) for lac cultivation**

**Principal Investigator:** Dr. Animesh Sinha. IFP, Ranchi

**Duration:** 2011 – 2015

**Critical analysis of the research theme and summary of the study**

Kusum plantations established by vegetative propagation (stem cuttings/grafting) can be considerably more profitable than those using conventional seed propagation techniques. The profitability of cuttings in terms of economic gains can be raised further if the cuttings/ scions are obtained from an elite genotype due to its inherent positive characteristics.

The rooting ability of Kusum linked to its genotype and other contributing factors. Among the treatments, 2000 ppm IBA added with 5% sucrose initiated rooting in ten CPTs out of fifteen CPTs and showed the highest rooting (25.6%) in IFP-SO-33. Overall, for all the CPTs the rooting success was poor in the present study. One of the reasons for poor rooting is the age factor of the trees. The highest grafting success was also observed I IFP-SO-33 (30%). The success in clone production was found more in air-layering than grafting or rooted stem cuttings. Treatment of combination of auxins (IBA (1000 ppm) + IAA (500 ppm + NAA (500 ppm) + 5% sucrose) showed highest (50%) success in air – layering.

The feasibility of lac cultivation on early stage of Kusum trees with pollarding was also studied. It was feasible to go for lac cultivation on pollarded trees after 1.5 years of pollarding. The yield harvested was 1.76 and 2.24 times of brood lac applied on trees pollarded at 1 m and 1.5 m, respectively whereas, the lac yield was 3.51 times of brood lac applied in the case of non-pollarded trees. Through the yield of pollarded trees was less in comparison to non-pollarded trees, it is expected that the farmers will be motivated in future for lac farming by planting Kusum plants and applying pollarding techniques on them due to easy management of lac crop.

**Scientific findings and contents**

Pollarding and propagation feasibility in kusum (*Schleichera oleos*a) for lac farming has been studied in the project.

92. **Evaluation and identification of optimal parameters for flowering and fruit set in different tamarind orchards (*Tamarindus indica* L.)**

**Principal Investigator:** A. Mayavel. IFGTB, Coimbatore

**Duration:** 2010 – 2014

**Critical analysis of the research theme and summary of the study**

To address the flowering and fruiting of unproductive tamarind orchards, evaluation of seedling and clonal tamarind orchards at Thoppur and Mullangaddu for vegetative and reproductive traits has been done in the project. Soil analysis and physiological traits of tamarind orchards and found that very low level of K, Phenol, carbohydrate and protein limits flowering of tamarind orchards in both location. Tamarind orchards were imposed with 20 different cultural, physical, manuring, chemical and growth regulator treatments for enhancing flowering and fruiting. The higher percentage of tree flowered, length of inflorescence, number of flower per inflorescence and number of fruit per inflorescence were recorded in spraying of 2% $KNO_3$ and soil drenching of Cultar 3000ppm. The higher fruit productivity was recorded in soil drenching of 2% $KNO_3$. Among different treatment imposed to tamarind orchards soil drenching of Cultar 3000ppm and spraying of 2% $KNO_3$ found to be effective for regulation of flowering fruiting of unproductive tamarind orchards. This study will have immense value and address the livelihood support in rural areas through improving productivity of unproductive tamarind plantation.

**Scientific findings and contents**

To address the flowering and fruiting of unproductive tamarind orchards, evaluation of seedling and clonal tamarind orchards at Thoppur and Mullangaddu for vegetative and reproductive traits has been done in the project.

93. **Multilocational trails of *E. camaldulensis* and *D. sissooo* clones**

**Principal Investigator:** Dr. U.K. Tomar. AFRI, Jodhpur

**Duration:** 2002 – 2014

**Critical analysis of the research theme and summary of the study**

Screening of the clones of *E. camaldulensis* and *D. sissooo* for Gujarat region on the basis of adaptability, productivity, and other desired qualitative characters has been done in this project. The results are as:

***E. camaldulensis*:**

Studies revealed that Gandhinagar site was best for plantation of *E. camaldulensis,* followed by Kheralu and Deesa, respectively. Thirty six clones were evaluated at four experimental stations of Gujarat Forest Departments over a period of ten years. Clones no. 159 was best in Deesa, 83 at Gandhinagar, 158 at Kheralu and 100 number clone at Rajpipala site. These selected superior clones can enhance the productivity two to three times than inferior planting stock.

***D. sissooo (Sisham):***

Thirty clones were evaluated at four experimental stations of Gujarat Forest Departments over a period of ten years. In *D. sissooo*, the differences between clones were not as prominent as observed in case of *E. camaldulensis*. Site wise selected best four clones were 5, 89, 103 and 107 at Dessa and 5,36, 48 and G5 were more suitable at Rajpipala site. Interestingly, clone number 5 and G5 performed better three sites, 37 and G2 at two sites and rest 4, 36, 48, 89, 103 and 107 only at single site.

**Scientific findings and contents**

Screening of the clones of *E. camaldulensis* and *D. sissooo* for Gujarat region on the basis of adaptability, productivity, and other desired qualitative characters has been done in this project.

94. **Effect of flowering on culm quality of *Dendrocalamus brandisii* and to explore its potential for making bamboo composite products**

**Principal Investigator:** Dr. Anil Kumar Sethy. IWST, Bengaluru

**Duration:** 2012 – 2014

**Critical analysis of the research theme and summary of the study**

Evaluation of effect of flowering on the culm quality of *Dendrocalamus bradisii* and exploration of suitability of flowered bamboo of *D. brandisii* and *Bambus bambos* for composite products has been done in this project. The results are as:

- Histo-chemical and biochemical studies on bamboo culms confirm that the starch content of *D. brandisii* culms depletes after flowering and no significant variation in starch content was observed along the culm height. Starch content was observed to be one of the predisposing factor for susceptibility of bamboo to borer attack (powder post beetles) as flowered bamboo, with depleted starch, was found unaffected by borers. This suggests that flowered clums can be stored and used for longer period as compared to non-flowered bamboo.
- Except bending stiffness, all physical and mechanical properties tested such as density, volumetric shrinkage, bending and compressive strengths were significantly lower in after flowered culms while the values for non-flowered and during flowering culms were comparable. Bending stiffness was comparable for all the three stages of bamboo. Although, the bending and compressive strength of flowered culms of *D. brandisii* were lower than the non-flowered and during flowered culms, still the properties are comparable to the corresponding strength properties reported for standard teak.
- The mechanical properties of particle boards made from non flowered culms were comparatively higher than the particle boards made from during-flowering and after-flowering culms in both the species. Except thickness swelling, all other physical and mechanical properties of particle boards made from different stages of bamboo surpassed the required values specified in the Indian standard IS: 3087 – 2005. Similarly, the mechanical properties of bamboo plastic composite made from after flowered culms were either comparable or even significantly better than the mechanical properties of bamboo plastic composite made from non-

flowered and flowering culms. Hence, the findings suggest that flowering does not affect the suitability of bamboo for manufacturing particle boards and bamboo plastic composites.

**Scientific findings and contents**

Evaluation of effect of flowering on the culm quality of *Dendrocalamus bradisii* and exploration of suitability of flowered bamboo of *D. brandisii* and *Bambus bambos* for composite products has been done in this project.

95. **Studies on suitability of *Eucalyptus camaldulensis* dehnh. and *E. tereticornis* sm. clones for various agro-climatic zones of Southern India**

**Principal Investigator:** Dr. Vijayaraghavan. IFGTB, Coimbatore

**Duration:** 2008 – 2014

**Critical analysis of the research theme and summary of the study**

The project evaluated the already short listed (33 clones by IFGTB) & high productive clones of *Eucalyptus tereticornis* and *Euclayptus camaldulensis* under different agro climatic zones of South India and identified the best performing stable clones to a particular site for use by farmers, industries and other user groups.

Accordingly extensive multi location clonal trails has been laid in twelve locations covering four different states of southern India and identified the stable clones across the location and site specific clone in each location. The average per hectare productivity of seven stable clones viz., 9,10,14,17,186,191,196 and 27, 98, 21.07, 18.73, 21.99, 18.47, 32.86 and 22.15 tonnes/ha and it is higher than the commercially available clones and on par and above with the released clones at the age of three years. This will help the State Forest Departments, forest corporations, wood based industries and farmers to improve the productivity. Through this project seven high productive clones have been identified for clonal release.

**Scientific findings and contents**

The project evaluated the already short listed (33 clones by IFGTB) & high productive clones of *Eucalyptus tereticornis* and *Euclayptus camaldulensis* under different agro climatic zones of South India and identified the best performing stable clones to a particular site for use by farmers, industries and other user groups.

96. **Assessment of optimum harvest limits of *Picrorhiza kurrooa* and *Valeriana jatamansi* in Himachal Pradesh**

**Principal Investigator:** Dr. A. Rajasekaran, HFRI, Shimla

**Duration:** 2009 – 2014

**Critical analysis of the research theme and summary of the study**

Optimum harvesting limits and harvest cycle of *Picrorhiza kurrooa* and *Valeriana jatamansi* has been developed without hampering the population status in the state of Himachal Pradesh.

Improper post harvest management of the medicinal and aromatic plants adversely affects their quality, chemical constituents (percentage), composition and content due to microbial growth and biochemical changes. The study revealed that both the species have inherent capacity to positively respond to harvesting. In the present study, it was observed that extraction of *Picrorhiza* is unselective and unmanaged. It has been reported by the harvesters that the regeneration of the plant is less as compared to the past due to over exploitation. At 25% and 50% level of harvest both the species could return to their initial level of density after three years of harvest which indicate that these species can be sustainably utilized from an area with at least 3 to 5 years harvest cycle with proper regulation. Areas subjected to over-exploitation needs to be closed for further extraction for a period of minimum five years which may give the capacity to rejuvenates itself.

**Scientific findings and contents**

Optimum harvesting limits and harvest cycle of *Picrorhiza kurrooa* and *Valeriana jatamansi* has been developed without hampering the population status in the state of Himachal Pradesh.

97. **Progeny testing of selected clones for establishment of clonal and seedling seed orchard in *Eucalyptus***

**Principal Investigator:** Dr. V. Sivakumar. IFGTB, Coimbatore

**Duration:** 2008 – 2014

**Critical analysis of the research theme and summary of the study**

Progeny trails for selected clones of *Eucalyptus camaldulensis* were conducted in Chennai, Pulvayal, Karaikudi, Thiyagadurgam, Marakkanam, Coimbatore, Hyderabad and Nellore and best performing families were identified in the project. The results are as:

- Quality of the seeds produced from two different CSOs present in Coimbatore and Sathyavedu were tested. Seeds collected from Sathyavedu seed orchards were found to be about 5% superior in GBH and height. The genetic gain estimates also showed that a maximum of 15% improvement was observed in certain progeny trials over clonal control populations.
- Progeny trails for selected clones of *Eucalyptus camaldulensis* were conducted in Chennai, Pulvayal, Karaikudi, Thiyagadurgam, Marakkanam, Coimbatore, Hyderabad and Nellore during 2009 and 2010. Four years growth assessment showed that families, 24, 32, 113, 21, 121,

118, 30 and 18 showed superiority based on the individual trial analysis and families 42, 64, 98, 114, 88, 58, 69, 77, 81 and 124 showed superiority based on combined trail analysis.

- Study conducted in seeds collected from CSOs at Coimbatore with 100 clones and Sathyavedu with 80 clones to understand the effect of presence of number of clones in CSOs on the growth superiority of the progenies showed that progenies of Sathyavedu CSO with 80 clones has given better progenies than Coimbatore CSO with 100 clones. The average superiority is 5.3 and 5.1% respectively for GBH and height.
- CSOs were established in Nellore and Salem with tested clones in an area of 9 ha for collection of quality seeds.

**Scientific findings and contents**

Progeny trails for selected clones of *Eucalyptus camaldulensis* were conducted in Chennai, Pulvayal, Karaikudi, Thiyagadurgam, Marakkanam, Coimbatore, Hyderabad and Nellore and best performing families were identified in the project.

98. **Integrated strategy for evaluation of indigenous fast growing multipurpose trees of Eastern India for plantation forestry**

**Principal Investigator:** Dr. Sanjay Singh. IFP, Ranchi

**Duration:** 2008 – 2013

**Critical analysis of the research theme and summary of the study**

Improved nursery technology of *Anthocephalus chinensis* and *Bombax ceiba* for quality seedling production has been developed in Eastern India in this project. The results are as:

- Extensive survey was carried out to identify superior seed sources and candidate plus trees have been identified in Bihar, West Bengal and Jharkhand. In all 31 CPTs of *Anthocephalus chinensis* and 50 CPTs of *Bombax ceiba* were selected. The root trainer cell size of 150cc or 300 cc (seeding density 225$m^{-2}$ to 144 $m^{-2}$) was found to be best for production of based on morphological, biomass and seedling quality characteristics. Growing media consisting of (80% compost with either sand or soil 20% soil) appeared superior was production of good quality planting stock in case of both the species.
- Experiments revealed that the treatment of 1000 ppm IBA for 1 hour recorded significantly superior root induction (77.2%) in *A. chinensis* while 1000ppm IAA gave the best rooting (47.2%) in *B. ceiba*. These treatments may be employed for mass clonal multiplication of the species. Hedging schedule in the hedge gardens of both the species were standardized. Hedging the stockplants twice a year (Feb-Mar and Sep-Oct) proved optimal for desirable shoot production and rooting of cuttings. Regular tending and maintenance was carried out of vegetative multiplication gardens established under the project. Remarkable success (100%) plantlet production was achieved in case of *A. chinensis* while the technique was less successful with 34% plantlet production was there in *B. ceiba* emphasizing differential ability of the tree species to different clonal procedures. The air layer process developed for cloning elite genotypes of Kadamb has insurance of higher survival rates and faster rooting appeared to be a

viable option for clonal propagation of desired elite material of *Anthocephalus chinensis*. The process is simple, economical and space saving as no separate cloning area, controlled environmental conditions and intermittent misting are required.

**Scientific findings and contents**

Improved nursery technology of *Anthocephalus chinensis* and *Bombax ceiba* for quality seedling production has been developed in Eastern India in this project.

99. **Improvement of clonal propagation techniques of bamboo and enhancement in field survival**

**Principal Investigator:** Dr. S. Nath. IFP, Ranchi

**Duration:** 2007 – 2011

**Critical analysis of the research theme and summary of the study**

Improved clonal propagation techniques for bamboos (*D. asper, D. strictus, B. nutans)* has been developed in the project for use in eastern parts of India.

Vegetative propagation with up to 90% rhizome genesis is possible without rooting hormone for culm segments of 8 to 21 months of age. Basal and mid culm parts facilitate higher rate of propagation during February to May under Chhotanagpur climatic condition, though propagation is possible throughout the year for most species of Jharkhand. Pre and post monsoon planted tissue culture plantlets of *D. asper* hardened for 150 and 250 days exhibit up to 93% in field survival. The hardening under agro-net shed preceded by mist-chamber hardening is not obligatory. Among the species tried, *D. strictus* is the hardiest and can withstand moisture stress for longer period while *B. nutans* plantlets require weekly and *D. asper* bi-weekly irrigation during hardening in nursery. The propagated plants from culm segments need at least 6 month of nursery gestation period for 100% survival under rainfed condition. Soil media treated with bulky organic matter in poly bags during hardening in nursery facilitates rhizome number and quality of planting materials.

Jharkhand with more than 25% fallow and 7.1% barren land may provide tremendous scope for extending the bamboo area from its present status of 14.5% natural bamboo forest area and 1.5% in non-forest area. Appropriate planning and transfer of technology as derived from the present project up to the grassroot level may generate not only employment opportunity but also huge bamboo resources in the state.

**Scientific findings and contents**

Improved clonal propagation techniques for bamboos (*D. asper, D. strictus, B. nutans)* has been developed in the project for use in eastern parts of India.

100. **Selection and evaluation of potential seed sources of *Gmelina arborea* from Jharkhand and adjoining states**

**Principal Investigator:** Dr. M.V. Durai, IFP, Ranchi

**Duration:** 2009 – 2013

**Critical analysis of the research theme and summary of the study**

CPT selection of *Gmelina arborea* from Jharkhand, West Bengal and Orissa and their evaluation has been done in this project.

A total of 53 CPTs (9CPTs in West Bengal, 31 in Jharkhand and 13 in Odisha) were selected after extensive survey for evaluating their worth. As the fruiting happen at same in all states and fallen seeds were eaten by grazing animals, seeds were collected from 25 CPTs and its progenies were evaluated for 19 morpho-metric traits. The JHG23 family attended maximum mean height, while minimum in JHG39. Maximum mortality was observed in family ODG29. There was significant genetic variability among and within the progenies of families, which could be effectively exploited for higher timber production of *Gmelina arborea*.

**Scientific findings and contents**

CPT selection of *Gmelina arborea* from Jharkhand and Orissa and their evaluation has been done in this project.

101. **Identification of distinct traits for DUS for conifers**

**Principal Investigator:** Dr. Rajesh Sharma, HFRI, Shimla.

**Duration:** 2009 – 2013

**Critical analysis of the research theme and summary of the study**

Identification of distinct traits for DUS for *Pinus roxburghii* and *Cedrus deodara* in respect of needle length and colour, bark, branching pattern, cone size and shape and crown form has been carried out in the project.

In order to define distinct traits in chir-pine and deodar selective surveys of the populations was carried out in the state of Himachal Pradesh. For *Pinus roxburghii* ten populations namely Dibkan, Obta and Garha, Banethi, Chhabal, Platu, Kopra, Bindraban, Malan, Nihari and Surkhigala were surveyed. For *Cedrus deodara* twelve populations namely, Cheog, Rohanda, Chail, Kufri, Labrang, Jungi, Kalpa, Thharoch, Udaipur, Kanyali, Chhichar and Surkhigala were surveyed. The needle length and colour, bark, branching pattern, cone size and shape and crown form of the populations was measured and distinct traits were marked for each conifer species.

**Scientific findings and contents**

Identification of distinct traits for DUS for *Pinus roxburghii* and *Cedrus deodara* in respect of needle length and colour, bark, branching pattern, cone size and shape and crown form has been carried out in the project.

102. **Assessment of phytodiversity dynamics for conservation in Jeypore reserve forest**

**Principal Investigator:** Dr. Ranjeet Kumar, RFRI, Jorhat

**Duration:** 2009 – 2012

**Critical analysis of the research theme and summary of the study**

Status of phyto-diversity in Jeypore Reserve Forest was assessed for conservation purpose in the project. The results are as:

30 families, 63 genus and 97 species are recorded for tree. 20 no of family, 30 genus and 42 species are observed for shrubs and 27 families, 48 genus and 53 species are recorded for herbs. Additional 86 species of trees, 41 species of shrubs and 54 species of herbs were observed in Jeypore Reserve Forests. *Dipterocarpus retusus* is dominant species, *Dedroclamus hamiltonii* is dominant species. Maximum density of natural regeneration is observed for *Schizostachyum polymorphum* at site no. 01 and 03. Density is observed maximum for *Vatica lanceafolia* at rest of sites. Maximum density of sapling is observed for *Vatica lanceafolia, Shorea assamica* and *Mesua ferra* at site no. 1, Density of sapling of *Mesua ferrea* is observed maximum at site 3. *Vatica lancefolia* show maximum sapling density for rest of sites. Soil is sandy clay loam. Bulk density and soil moisture increases with depth and soil is acidic and pH decreases with depth, whereas, soil organic carbon, available N, available P and available K decrease with depth.

**Scientific findings and contents**

Status of phyto-diversity in Jeypore Reserve Forest was assessed for conservation purpose in the project.

103. **Raising of model nursery under the project of A.P. medicinal and aromatic plants board with species such as myrobalans (*Terminalia spp*.), sandal wood, red sanders, etc**

**Principal Investigator:** Dr. Ravi Shankar Reddy, IFB, Hyderabad.

**Duration:** 2012 – 2013

**Critical analysis of the research theme and summary of the study**

Two lakhs seedlings of Myrobalans (*Terminalia spp*.), Sandal wood, Red sanders were produced using modern nursery techniques. Seeds of *Santalum album, Pterocarpus santalinus, Terminalia bellirica* and *Terminalia chebula* were sown on beds and seedlings were transplanted to polybags. All together seedlings of *Santalum album, Pterocarpus santalinus, Terminalia bellirica* and *Terminalia chebula, Aloe vera* and other medicinal species like *Ocimum sanctum, Andrographis paniculata, Asparagus racemosus*, ect. were raised. A SSO of Myrobalans were established over four hectare area.

104. **Studies on plant diversity in cold deserts of district Kinnaur, Himachal Pradesh**

**Principal Investigator:** Dr. R. K. Verma, HFRI, Shimla.

**Duration:** 2004 – 2009

**Critical analysis of the research theme and summary of the study**

Plant diversity was assessed in cold desert areas in district Kinnaur of Himachal Pradesh in this project. The results are as:

Plant diversity along an altitudinal gradient varying from 3000m-5000m in Labrang area, showed that the total number of plant species was 191 belonging to 47 families and 127 genera. While carrying out studies in Lippa – Asrang area having elevations varying from 2750m to 5000m above msl revealed that the total number of plant species was 191 belonging to 49 families and 134 genera. *Artemisia brevifolia, Heracleum candicans, Thymus linearis, Bergenia stracheyi* and *Bistorta affinis* were the dominant herbs dotting different elevational ranges. The composition of vegetative along an altitudinal gradients varying from 2700-4200m in Pooch area revealed that 192 plant species belonged to 55 families and 136 genera. The composition of vegetation along an altitudinal gradients varyi8ng from 3000-5000m in Ropa-Giavung area showed that the total number of plant species was 160 belonging to 51 families and 119 genera. The dominant families were Asteraceae, Polygonaceae, Rosaceae and Ranunculaceae. Plant diversity study conducted at an altitudinal gradient varying from 3000-5000m above msl in Namgia area revealed a total number of 142 plant species belonged to 49 families and 105 genera. The plant status along an altitudinal gradient with elevation varying from 3000-5000m above msl in Hango area showed that the total number of plant species was 130 belonging to 41 families and 101 genera.

The distribution pattern of plant species was mostly contiguous in all the altitudes ranges in all areas. The Index of similarity for shrub and herb species between different altitudes was low indicates remarkable degree of dissimilarity in plant species between different altitudes. The dominant families were Asteraceae, Rosaceae, Ranunculaceae, Lamiaceae and Polygonaceae, Apiaceae and Umbelliferae. The fertility status of soil of cold desert areas was low to medium in range. Three species of Junipers viz., *Juniperus polycarpus*, *J. Communis* and *J. indica* were recorded from the cold desert area. The regeneration of *Cedrus deodara, Pinus wallichiana, Juniperus polycarpos, Populus cilatta, Salix alba* and *Pinus gerardiana* were observed. Labrang, Pooh, Lippa-Asrang and Ropa-giavung were diversity rich areas. Out of 114 medicinal plant species recorded from the cold desert areas, 24 species fall in the category of threatened plants.

**Scientific findings and contents**

Plant diversity was assessed in cold desert areas in district Kinnaur of Himachal Pradesh in this project.

105. **Phenotypic selection, reproduction and propagation in *Ailanthus excelsa*: Perspectives for safety matches industry and farmers in Tamil Nadu**

**Principal Investigator:** D. Rajasugunasekar, IFGTB, Coimbatore

**Duration:** 2005 – 2009

**Critical analysis of the research theme and summary of the study**

Phenotypic selection, reproduction and propagation in *Ailanthus excelsa* and its possibility to use in Safety Matches Industry and Farmers in Tamil Nadu was studied in this project. The results are as:

For germ-plasm assemblage, 220 phenotypically superior trees of *Ailanthus excelsa* have been selected by surveying different Agroclimatic zones of Tamil Nadu. Due to the polygamodiocious nature of the species, finally seeds have been collected from 92 individual tree (TN) and bulk seeds from different states like Andhra Pradesh, Uttarakhand, Madhya Pradesh and Rajasthan. Seed parameters have been studied for the seeds collected from different sources seedlings have been raised in the nursery of IFGTB and the growth data of *Ailanthus excelsa* seedlings has been collected and analysed.

Three Germplasm bank have been established, One in Tirupati, Andhra Pradesh, Two trials in Tamil Nadu (TNFD lands) namely Salem and Kanchipuram districts. In the Andhra Pradesh trial Periodical data from the germplasm has been collected and analysed. The analysis of 80 seed lots (TN, MP, Rajasthan, Uttarakhand and AP) showed that the early growth performance of Cauvery delta zone (TN) was found to be good compared to other seed sources. Based on the one and half year biometric data 40 individuals of *Ailanthus* have been marked for the future clonal propagation. The top ten best performing seedlots were 65, 70, 74, 38(CDZ), 69(NWZ), 88(CDZ), 1(WZ),7 and 8(NWZ). Attempts have been made to standardize the vegetative propagation by collecting the cutting periodically.

**Scientific findings and contents**

Phenotypic selection, reproduction and propagation in *Ailanthus excelsa* and its possibility to use in Safety Matches Industry and Farmers in Tamil Nadu was studied in this project.

106. **Investigations on the resistance of commercially available bamboo in Karnataka to borers, termites and fungi**

**Principal Investigator:** Raja Muthukrishnan, IWST, Bengaluru

**Duration:** 2004 – 2008

**Critical analysis of the research theme and summary of the study**

Investigations were carried on the resistance of commercially available bamboo in the state of Karnataka against borers, termites and fungi in this project. The results are as:

- Surveys to different bamboo depots revealed that mainly 2 species of bamboos viz. *Bambusa bambos* and *Dendrocalamus strictus* are of commercial importance. Dealers were ignorant of low cost bamboo preservation techniques and its advantages. These commercial bamboos are sold untreated.
- The major borer identified to cause damage to commercial bamboo was *Dinoderus minutus* Fabricius followed by *Lyctus afticanus* Lesne and *Heterobostrychus aequalis* Waterhouse. The annual loss of revenue caused by insect borers in bamboo depots is around 25% to 40%.
- The bottom portion of the culm was found on an average to be more durable against borers and fungal attack.
- Five morpho species of parasites could be collected from *Dinoderus minutus* and only one species could be identified as *Heydenia indica* belonging to the Family: Pteromalidae. The others species belonged to families Bracondiae, Ichneumonidae and Eurytomidae.
- Bamboo from wet zone and dry zine were evaluated separately against termites and fungi. *Bambusa bambos* procured from wet zone were more durable than those procured from dry zone. *Dendrocalamus strictus* from dry zone were more durable compared to those form wet zone. Commercially available bamboo *D. stirctus* was found to be more durable against termites and fungi compared to *B. bambos*.
- Decay tests showed that *D. strictus,* culms of wet zone were more durable when compared to clums of dry zone. In *Bambusa bamboo*, a reverse trend was observed i.e. dry zone culms are more durable than wet zone.
- The comparatative efficacy of 12 different pesticides, including 2 plant based products an paints were tested for protection of commercial bamboo against termites. Neem seed kernel extract (NSKE) and Nimbedicine proved to be less effective against termites. Chemicals such as organophosphates, Imidaclorpid and synthetic pyrethroids showed good protection of bamboo against termites for more than a year. One and two coats of Cashew nut liquid (CSNL) based paints and varnished showed poor protection of bamboo against termites over period of 12 months.
- Dip treatment of Bamboos for 48 hours with Ammonical copper arsenite did not give good protection against termites over period of 24 months.
- Comparative treatments of split bamboo with CCA 4% by Pressure treatment, Hot and cold treatment and Shock wave treatment showed good protection against termites over a period of 36 months.

**Scientific findings and contents**

Investigations were carried on the resistance of commercially available bamboo in the state of Karnataka against borers, termites and fungi in this project.

107. **Clonal screening of *Dalbergia sissooo* in relation to nitrogen utilization and biomass production**

**Principal Investigator:** Dr. S.P. Chaukiyal, FRI, Dehradun

**Duration:** 2008 – 2013

**Critical analysis of the research theme and summary of the study**

Screening of clones of *Dalbergia sissooo* in relation to nitrogen utilization and biomass production has been done in this project. The results are as:

In the present study nitrogen uptake, assimilation and nodulation behavior in twenty four (9 + 5 = 14) different clones of *Dalbergia sissooo* were studied. First set (09 clones) of the clone was disease resistant, collected and tested by Pathology Division from the Uttar Pradesh whereas, second set (15 clones) were not resistant and collected by Genetics and Tree Propagation Division Forest Research Institute Dehradun. The details of these clones have already been given in the materials and methods chapter. The study was carried out with respect to critical characters viz. morphological traits, biomass, nodulation, nitrogen fixation and assimilation studies in individual clones of *Dalbergia sissooo*.

Considering all the parameters studied, clones no. 002 (Bijnor, Uttar Pradesh); 009 (Haridwar, Uttarakhand); 013 (Haridwar, Uttarakhand) and 057 (Ambala, Haryana) performed better in growth, biomass, nodulation, nitrogen fixation and assimilation activity as compared to other.

**Scientific findings and contents**

Screening of clones of *Dalbergia sissooo* in relation to nitrogen utilization and biomass production has been done in this project.

108. **Standardization of nursery technology for mass propagation of selected medicinal plant species**

**Principal Investigator:** Dr. Sandeep Sharma, HFRI, Shimla

**Duration:** 2000 – 2007

**Critical analysis of the research theme and summary of the study**

Nursery techniques of medicinal plants of Himachal Pradesh have been standardized for mass propagation in this project. The results are as:

33 species of medicinal plants of temperate Himalayas at Brundhar nursery (Manali), 30 species at Shilly nursery, Solan, 10 species at Shillaru Nursery (Shimla) and 15 species at Model Nursery (Shimla) were maintained during the project period for research, training and demonstration purposes. Nursery trials were conducted for improving the agro-techniques of economically important medicinal plant species e.g. *Picrorhiza kurrooa* (Kutki), *Valeriana jatamansi* (Mushkbala), *Aconitum heterophyllum* (Atish), *Angelica glauca* (Chora), *Polygonatum verticellatum* (Salam Mishri) etc. Nursery techniques were improved for the mass production of

nursery stock of four species viz. *Picrorhiza kurroa*, *Valeriana jatamansi*, *Aconitum heterophyllum* and *Angelica glauca*. Macro-proliferation techniques have been developed for the multiplication of mature plants of *Picrorhiza kurrooa* and *Valeriana jatamansi* in the nursery. A nursery implement namely 'Multiple Nursery Planting Bar' was designed fabricated and commissioned for maintaining desired spacing of *Valerina jatamansi* during planting in the field.

It is low cost simple technique based on Bamboo macro-proliferation technique developed by FRI-Dehradun. This method ensures that each propagule possess some part of shoot along with rhizome parts & some roots at the time of separation from mature healthy plant.

**Scientific findings and contents**

Nursery techniques of medicinal plants of Himachal Pradesh have been standardized for mass propagation in this project.

### 109. Molecular characterization of *Mimosa diplotricha* C. wright seed polysaccharide

**Principal Investigator:** Dr. Vikas Rana, RFRI, Jorhat

**Duration:** 2011 – 2014

**Critical analysis of the research theme and summary of the study**

Molecular characterization of *Mimosa diplotricha*, one of the worst weeds affecting forest ecosystems, agricultural lands and pastures in Assam, has been done under this project. It is adversely affecting the regenerations of tree species in Kaziranga National Park. Utilization of weeds as a bioresource is an emerging field, for economic utilization of the same as well as weed control. The results are as:

- The composition and structure of a neutral galactomannan from the seeds of *Mimosa* diplotricha has been studied. The structure of the water soluble polysaccharide in *Mimosa diplotricha* seed has been elucidated for the first time, and is new information to science.
- The outcome of this research can serve to develop novel sources of hydrocolloids and galactomannan based industrial products. The use of *Mimosa diplotricha* seeds for this purpose would help in control and elimination of the weed also.
- The chemical and physic-chemical analysis of polysaccharide extracted from the seeds of M. diplotricha indicated that it is rich in galactomannan. The molecular characterization showed that biopolymer is composed of D-galatose and D-mannose in a ratio of 1:1.37 with a main chain of (1→4) linked β-D-mannopyranosyl unit. α-D-Galactopyranosyl units are attached as single unit side chains on the manopuranose units through (1→6) linkage. The homogeneity and low degree of contaminants such as proteins revealed a polysaccharide with potential for industrial uses.

**Scientific findings and contents**

Nursery techniques of medicinal plants of Himachal Pradesh have been standardized for mass propagation in this project.

110. **Establishment of multilocational trails of superior accessions of *Jatropha curcas* under the network programme of DBT**

**Principal Investigator:** Dr. A.K. Pandey, TFRI, Jabalpur

**Duration:** 2008 – 2011

**Critical analysis of the research theme and summary of the study**

Multi-locational trails of superior accessions of *Jatropha curcas* were established in the state of MP and their growth performance, seed characteristics and oil content was assessed under tropical climatic condition of Jabalpur in this project. The results are as:

- Multilocational and half sib progeny trails have been established at Tropical Forest Research Institute, Jabalpur campus.
- The study revealed variation in growth parameters and seed characteristics of different selected superior accessions of *J. curcas*. The differences in growth performance, seed characteristics and yield potential is could be due to environmental factors that are playing vital role in growth and development of different accessions in tropical climatic conditions of Madhya Pradesh. The selected accessions represented few best performing accession of a particular locality, soil and climatic condition. These accessions possessed genotypic characters according to their locality, but when grown in Jabalpur (Madhya Pradesh), they were adjusted by local climatic conditions and this adjustment affected their performance.
- In case of Multilocational trial comprising of 7 accessions, two accessions from HNB Garhwal (HAP GUA and HAP GUC) and two from NBRI Lucknow (JA-9 and JA-126) performed best whereas accession from Biotech-Park Lucknow (BTP-U) proved poorest. Seed yield in two years (i.e. 2010 and 2011) were very low, but showed a great variation. Therefore, long-term determinations are necessary to estimate the exact yield potential.
- In case of Half sib progeny trial comprising of 19 accessions, three accessions from MSSRF Chennai (MSSRF-16, MSSRF-154, and MSSRF-118); one from HNB Garhwal (HAP-44) and three from NBRI Lucknow (JA-18, JA-2 and JA-139) performed better among other accessions. However, it is very early to say that above accessions are best as the half sib progeny plantation is two years old only.

**Scientific findings and contents**

Multi-locational trails of superior accessions of *Jatropha curcas* were established in the state of MP and their growth performance, seed characteristics and oil content was assessed under tropical climatic condition of Jabalpur in this project.

111. **Field efficacy of chemical control measures for the management of khejri mortality in north-western districts of Rajasthan**

**Principal Investigator:** Dr. S.I. Ahmed, AFRI, Jodhpur

**Duration:** 2007 – 2010

**Critical analysis of the research theme and summary of the study**

Field efficacy of chemical control measures for the management of khejri mortality in north-western districts of Rajasthan has been in this project. The results are as:

Selection of sites: Two sites had been selected for study, Triloki (Siker) and Jhareli (Nagpur).

Best treatment: Root treatment using Bavistin 50% WP + Chloropyriphos 20% EC + Agromin) with shoot treatment with AFRI paste + 2/3$^{rd}$ tree lopped was found to be best in Jhareli district of Nagpur. After one year the disease infections reduced from 37% to 12% whereas pest infestation reduced from 38% to 11%. The average long production increased from 11.08 to 13.32 kg per tree after treatment on dry weight basis.

Avenue trees of Khejri at Sikar-Jaipur road were found severely attacked by heart rot disease.

The austere and indiscriminate lopping of khejri trees by the farmers seems to be the primary cause of pest/disease infestation. Gap in looping can help to overcome this problem.

**Scientific findings and contents**

Field efficacy of chemical control measures for the management of khejri mortality in north-western districts of Rajasthan has been in this project.

112. **Variation in photosynthesis in clones of sandal and *Eucalyptus***

**Principal Investigator:** Dr. Arun Kumar A.N., IWST, Bengaluru

**Duration:** 2005 – 2013

**Critical analysis of the research theme and summary of the study**

Assessment of variation in photosynthesis in the clones of sandal and *Eucalyptus* has been carried out in this project. The results are as:

This study was carried out on 38 clones of sandal and 25 clones of *Eucalyptus*. The plant material used for this study in case of sandal was six-month-old grafted plant. The scion material was collected from the clonally propagated plants and was cleft grafted on one and half year old sandal seedling, which was used as the stock. In case of *Eucalyptus*, *in situ* observations were recorded at the field Significant differences are observed in stomatal conductance, intercellular $CO_2$ concentration, transpiration rate, photosynthetic rate in different clones in both the species.

**Scientific findings and contents**

Assessment of variation in photosynthesis in the clones of sandal and *Eucalyptus* has been carried out in this project.

113. **Demonstration trial of male and female *Ailanthus excelsa* plants raised through grafting**

**Principal Investigator:** Dr. U.K. Tomar, AFRI, Jodhpur

**Duration:** 2007 – 2014

**Critical analysis of the research theme and summary of the study**

Grafting technique of *Ailanthus excelsa* has been developed in this project. The results are as:

- Grafting technique of *Ailanthus excelsa* is developed which holds 50% success rate. Female plans in case of *Ailanthus excesla* were found to be more vigorous than the male plants in all growth parameters of above ground, which can be useful for Agroforestry planning and also help in the improvement of the economy for the farmers. $I_2$ Irrigation treatment was best fitted for both types of trees and the differences between female and male trees were also maximum on all growth parameters.
- The observations show that female trees are superior to male trees in all the characteristics except length of primary root. Length of primary root of male trees was found to be longer than that of female trees.
- Through grafting we get 25% increment in the stem height which can yield a good amount of wood per tree to the farmer. This can also increase the total profit of the farmer after compensating the total cost of plantation through granfting.
- The trail shows an increment of around 60% through grafting female plants over male plants in leaf fodder yield at five year age.

**Scientific findings and contents**

Grafting technique of *Ailanthus excelsa* has been developed in this project.

114. **Vegetative propagation and silvicultural practices for selected tropical timber species for plywood and panelwood industries**

**Principal Investigator:** Dr. Geeta Joshi, IWST, Bengaluru

**Duration:** 2011 – 2017

**Critical analysis of the research theme and summary of the study**

Mass propagation techniques of *Melia dubia, Anthociphalus cadamba, Grevillea robusta* and *Ailanthus excelsa* have been standardized to raise large scale plantations with quality planting material in this project. For propagating difficult to germinate species and clonal material vegetative propagation by rooting of stem cuttings is often being used. Stem cuttings are inexpensive and easier to practice than other vegetative propagation methods, such as tissue culture. The results are as:

In this study treating stem cuttings of *Melia dubia, Anthociphalus cadamba* and *Ailanthus excelsa* with 1500, 2500 and 1000ppm IBA respectively has been found to enhance rooting. Semi hard

wood cuttings performed best in *M. dubia* and *A. cadamba.* While in *A. excelsa* more rooting more rooting was observed in soft wood cuttings. Best season for rooting was February, September and October and March for *M. dubia, A. cadamba* and *A. excelsa* respectively. For all the species polytunnel conditions were best for rooting. *Grevillea robusta* did not respond to any treatment for rooting. Increased anthropogenic activates has resulted in higher atmospheric concentrations of $CO_2$ which has resulted in global warming and is also affecting growth of plants. It has been reported that little increase in growth rate during the initial stage by elevated $CO_2$ can have a greater impact on growth of the trees at later stages. It was observed different species responded differently to elevated $CO_2$ In general 600ppm was optimum for growth of seedlings of all the species. *M. dubia* responded positively even at 900ppm. Shoot and root length and fresh and dry weight increased in *M. dubia* and *A. cadamba* under elevated $CO_2$ levels. In *A. excelsa* and *G. robusta* there was no significant change in shoot and root length as compared to ambient conditions. There was no change in total carbohydrates and sugars in response to elevated $CO_2$ levels in all the four species while the free amino acid was found to increase in all four species and protein content increased in *M. dubia, A. cadamba* and *G. robusta*.

The cultivation and management practices play a very significant role in the growth and productivity of plantations. In all the four species the combination of organic and inorganic fertilizers was found to be best for growth. Larger spacing of 20X20ft. and 25X25ft were found to be best for *M. dubia,* and *A. cadamba.* While *G. robusta* performed better at smaller spacing of 1.5X 1.5ft.

**Scientific findings and contents**

Mass propagation techniques of *Melia dubia, Anthociphalus cadamba, Grevillea robusta* and *Ailanthus excelsa* have been standardized to raise large scale plantations with quality planting material in this project.

115. **Effect of *Populus deltoides* on medicinal plants**

**Principal Investigator:** Dr. Charan Singh, FRI, Dehradun

**Duration:** 2005 – 2011

**Critical analysis of the research theme and summary of the study**

The growth of medicinal plants viz. Satavar (*Asparagus recemosus*), Chitark (*Plumbago zeylanica*), Tulsi (*Ocimum sanctum*), Ashwagandha (*Withania somnifera*) under *Populus deltoids* was observed in farmer field at Village Kuhedi in district Haridwar and in Demo plot, Premnagar in district Dehradun. Effect of shade on the medicinal plants was studied and observed that the Satavar and Chitark having suitable combination with *P. deltoides* spacing 4x5 m and planted at 60x60 cm as under-storey crop. The understory crop of these medicinal plants showed some less bushiness in comparison to open area due reduction in light intensity up to 44.00% in summer and 52.40% in winter. Production of *A. recemosus* (dry roots), *O. sanctum* (whole plant), *P. zeylanica* (whole plant except seeds) and *W. somnifera* (roots) was 15.00, 7.50, 3.75, 5.00 and 2.50 quintal respectively with proper irrigation.

Through cost-benefit analysis it was found that Satavar and Chitark are suitable medicinal crops

with *P. deltoides*. A net gain of Rs. 1712026.00 and Rs. 1873834.00/ha can be observed from Poplar – Chitrak and Poplar – Satavar respectively, if two crops of each medicinal plant are grown as under storey crop of poplar. Tulsi and Ashwangandha are not found suitable combinations with poplar as their market value is not sound. The production of Tulsi in one ha was 22.50 quintal while the production of Ashwagandha roots was only 5.00 quintal/ha in two crops. The sale value of this production was only Rs. 18000.00 and Rs. 27500.00, which shows no economic viability in comparison of Satavar and Chitrak.

**Scientific findings and contents**

The growth of medicinal plants viz. Satavar (*Asparagus recemosus*), Chitark (*Plumbago zeylanica*), Tulsi (*Ocimum sanctum*), Ashwagandha (*Withania somnifera*) under *Populus deltoids* was observed in this project with cost- benefit ration in farmer field at Village Kuhedi in district Haridwar and in Demo plot, Premnagar in district Dehradun .

116. **Mortality of kikkar (*Acacia nilotica*) in Haryana and Punjab ant its management**

**Principal Investigator:** Suresh Chandra, FRI, Dehradun

**Duration:** 2007 – 2010

**Critical analysis of the research theme and summary of the study**

During last decades a large scale mortality of kikar was recorded in almost all age classes in Punjab and Haryana. Causes and preventive measures of mortality of kikkar (*Acacia nilotica*) in the states of Haryana and Punjab were studied in this project. The results are as:

The study is an attempt to know the effect of biotic stresses, climatic change and physio-chemical attributes of soil. For this purpose four agro-climatic zones each in Punjab and Haryana were selected. The role of decay fungi in mortality of kikar was also studied which developed as a result of development activities such as road widening, tarring and expansion of cable network. These activities result in suffocation of roots, root exposure (fig-18) and cause injuries to the stem and branches. Not a single cause was found responsible for the mortality but many factors were found responsible.

*Acacia nilotica* must be planted in mixed stands. Since the *Ganoderma* root rot infection spreads through root-to-root contact resistant tree species such as *Boxbax ceiba* and *Ailanthus excelsa* should be planted in between two kikar plants which will work as a barrier between roots of adjacent kikar plants. This practice can check the spread of *Ganoderma lucidum* root rot, a common cause of kikar mortality.

Common practice to number the trees by blazing of the bark should be stopped. This will discourage the entry of *Celosterna scabrator* (Borer) and other parasites.

Garbage should not be duped and burnt near the base of trees which it will check the bark bursting and injuries due to fire. The injured trees are attacked by pathogens, saprobes and insect pests.

In nut shell, injuries on the butt region and roots due to development activities, fire, cattle, etc. exposes the Kikar trees to the attack of diseases and insect pests and should be avoided to raise healthy plants.

**Scientific findings and contents**

Causes and preventive measures of mortality of kikkar (*Acacia nilotica*) in the states of Haryana and Punjab were studied in this project.

117. **Impact of major forest invasive plants on the biodiversity of Chakrata forest division**

**Principal Investigator:** S.R. Joshi, FRI, Dehradun

**Duration:** 2007 – 2010

**Critical analysis of the research theme and summary of the study**

Impact of *Eupatorium odoratum* and *Sarcococca saligna* on regeneration of banj (*Quercus leucotricophora*) deodar (*Cedrus deodara*) in Chakrata Forest Division has been studied in this project. The results are as:

- It is observed that the lesser Himalayan species of banj (*Quercus leucotricophora*) is being invaded by *Eupatorium odoratum* an exotic species. Large tract of banj forest has been found covered by the *Eupatorium* species.
- It is observed in the deodar forest of Kanasar range, Chakrata division that regeneration is badly affected by the invasion of *Sarcococca saligna* which is an endemic invasive species. It seems that there is an acute nutrient competition between *Sarcococca saligna* and *Cedrus deodara* seedlings.
- The sal forest of north and central India has found to be badly infected by *Lantana camara*. The lantana not only reducing the regeneration capacity of *Shorea robusta* but also eliminated important associates of sal.

**Scientific findings and contents**

Impact of *Eupatorium odoratum* and *Sarcococca saligna* on regeneration of banj (*Quercus leucotricophora*) deodar (*Cedrus deodara*) in Chakrata Forest Division has been studied in this project.

118. **Assessment of suitable age of seedlings of forestry species for plantation in Uttar Pradesh**

**Principal Investigator:** Arvind Kumar Pandey, CSFER, Allahabad.

**Duration:** 2007 – 2010

**Critical analysis of the research theme and summary of the study**

Assessment of suitable age of seedlings of forestry species for plantation in the state of Uttar Pradesh has been in the project. The findings are as:

The findings of the project reveal the suitable age of the seedlings of fast growing and slow growing species when they are to be transplanted in the field. Some species as Semal, Shisham, Imli, Karanj and Kathal performed well for 1 yr old seedlings in plantation. Other species like *Eucalyptus*, Jungle Jalebi, Kathsagaun and Australian Babool perforemed well for one as well as two year old seedlings in the trails. Hence one year old seedlings of Semal, Shisham, Imli, Kathal and Karanj can be planted for the superior performance of species. For species like *Eucalyptus*, Jungle Jalebi, Kathsagaun and Australian Babool, one as well as two year old seedlings can be planted for similar growth performance. Thus all the fast growing species are not behaving in the same way. The behavior of Semal and Shisham is different from *Eucalyptus*, Jungle Jalebi, Kathsagaun and Australian Babool. The species like Imli, Karanj, and Kathal have strongly favored early planting for their best performance, late transplanting harms their survival and growth. In general, to avoid the extra nursery and transportation costs for two year old seedlings, all the mentioned species may be suitably planted in one year of nursery age. In block as well avenue plantation, suitable are criterion of seedlings should be taken care of irrespective of their height depending upon the site and its microclimate.

**Scientific findings and contents**

Assessment of suitable age of seedlings of forestry species for plantation in the state of Uttar Pradesh has been in the project.

119. **Refinement of modern nursery practices for raising quality seedlings of selected important forest tree species of arid and semi arid areas**

**Principal Investigator:** Dr. N.K. Bohra, AFRI, Jodhpur.

**Duration:** 2011 – 2016

**Critical analysis of the research theme and summary of the study**

Modern nursery practices have been developed in the project for raising quality seedlings of selected important forest tree species of arid and semi arid areas. The findings are as:

- On the basis of various growth parameter of different experimental species, it is concluded that using best manure, container size and potting mixture quality seedlings can be prepared. Further use of Biofertilizers can enhance its growth rate.
- Various container size, Potting mixtures and different types of manures were tested for *Prosopis cineraria* Druce Mimosoideae, *Azadirachta indica* A. Juss *Melia*ceae and *Tecomella undulata* (Smith) Bignoniaceae seedlings. The best treatment of all three species in relation to 2 month, 4 month and 6 month old seedlings were found out for raising quality seedlings.

**Scientific findings and contents**

Modern nursery practices have been developed in the project for raising quality seedlings of selected important forest tree species of arid and semi arid areas.

120. **Nursery techniques of *Stereospermum suaveolens* DC**

**Principal Investigator:** Dr. Anita Tomar, CSFER, Allahabad.

**Duration:** 2011 – 2013

**Critical analysis of the research theme and summary of the study**

*Stereospermum suaveolens* is commonly known as "Patla". The species yields a good quality timber and is useful medicinal plant. Best seed sources and nursery techniques of *Stereospermum suaveolens* have been developed in this project. The findings are as:

- A complete survey in Uttar Pradesh was undertaken where natural population of the species occurred. Five districts (Faizabad, Chitrakoot, Allahabad, Mirzapur and Lakhimpur Kheri) were surveyed and from each district seed sources were identified. In Uttarakhand, Dehradun seed sources were identified. Total 5 seed sources of U.P. and one seed sources from Uttarakhand where naturally available tree were found and genetic resources was carried out to elucidate the genetic variation and relationship of capsule and seed traits on germination percentage to select the best planting material for higher productivity.
- Under this study, two provenances, viz. Uttar Pradesh and Uttarakhand where *S. suaveolens* is naturally available were screened for genetic variation to establish relationship of capsule and seed traits with germination percentage leading into the selection of the best planting material for higher productivity. Eight traits were studied viz. capsule length, capsule width, 100-capsule

weight, seed width, 1000 seed weight, seed per capsules and maximum seed length with wings and without wings.

- The study revealed that seed source of Shankargarh (Allahabad) is superior to test of the seed sources on the basis of capsules and seeds characteristic but seed source of Faizabad and Dudhwa National Park gave best germination percentage so these can be probably recommended for large scale plant production of the species for future afforestation programme.
- Nursery sowing season is April to May before sowing seeds to be overnight soaked in cold water. In nursery germination period is 15-30 days. Germination starts after 15 days and continues for another 15 days. Seventy to eighty per cent of germination can be expected. Five cm height seedlings can be transplanted to the containers and one-year-old seedlings can be planted in the field. The leaves of young seedlings are very much susceptible to Coccinelidae larvae attack. Seedlings also need protection during winters from frost. The viability of seeds is one year.
- *Stereospermum suaveolens* is not amenable to air layering nor to vegetative propagation as it is a very hard to root species.

**Scientific findings and contents**

Best seed sources and nursery techniques of *Stereospermum suaveolens* have been developed in this project.

121. **Survey selection performance trial and estimation of yield potential of *Jatropha curcas* in Rajasthan and Gujarat**

**Principal Investigator:** Dr. D.K. Mishra, AFRI, Jodhpur

**Duration:** 2007 – 2012

**Critical analysis of the research theme and summary of the study**

Collection of morphological superior clones of *Jatropha curcas* and testing them under similar conditions was done in this project in the states of Rajasthan and Gujarat. Area was surveyed for the selection of CPPs in *Jatropha* growing area of Udaipur and Banswara. A total of 30 CPPs were selected and tested for oil estimation. SFD, Gujarat was approached to provide seeds of selected CPPs. Seeds were received from 56 CPPs and based on oil estimation, 11 CPPs were selected for further studies. Thus a total of 30 CPPs were selected 919 from Rajasthan and 11 from Gujarat) for progeny trial.

Two progeny trails one with 5 replications having single plant per replication at FRI, Jodhpur and another with 15 replications in RBD at Haldughati, Udaipur was established in July 2008 with 30 CPPs and were evaluated after 44-months of planting in the field.

The maximum oil percent was in seeds collected from Ghatole-Bans-Raj-07 (35.20%) and minimum in Baruch-GUJ-399 (27.60%).

**Scientific findings and contents**

Collection of morphological superior clones of *Jatropha curcas* and testing them under similar conditions was done in this project in the states of Rajasthan and Gujarat.

## 122. Vegetative propagation of some difficult to toot commercially important tree species

**Principal Investigator:** Dr. Dinesh Kumar, FRI, Dehradun

**Duration:** 2010 – 2013

### Critical analysis of the research theme and summary of the study

Studies on vegetative propagation of some difficult to toot commercially important tree species (*Diploknema butyracea, Anogeissus latifolia, Lagerstroemia parviflora* and *Adina cordifolia*) has been carried out in this project. The results are as:

- Branch cuttings of two-years old hedge of *Diploknema butyracea* treated with 4000 ppm IBA during Feb resulted in 92.2 per cent rooting and 88.9 plant percent. In *Anogeissus latifolia,* apical cuttings of ten years old plants treated with 4000 ppm IBA during April led to 2.2 per cent rooting. Rooting did not take place in cuttings of *Lagerstroemia parviflora* but 15.6 per cent callus formation took place upon treatment with 5000 ppm IAA during April. In *Adina cordifolia,* epicormic shoot cuttings taken from mature trees resulted in 77.8 per cent root induction and 75.6 plant per cent using 4000 ppm IBA.
- In *Diploknema butyracea,* air layering led to 71.1 per cent rooting and 63.3 plant percent with use of Rooter Strand Grade 1 in juveline cuttings (one to two years age) during April. Mature shoots of *Diploknema butyracea, Anogeissus latifolia, Lagerstroemia parviflora,* and *Adina cordifolia* did not give success during air layering.
- Grafting and budding success were 33.3 and 46.7 per cent for *Diploknema butyracea,* 23.3 and 30.0 per cent for *Anogeissus latifolia,* 13.3 and 16.7 per cent for *Lagerstroemia parviflora* and 26.7 and 36.7 per cent for *Adina cordifolia* when one-year-old scions were grafted or budded on one-year-old rootstocks of respective species.

### Scientific findings and contents

Studies on vegetative propagation of some difficult to toot commercially important tree species (*Diploknema butyracea, Anogeissus latifolia, Lagerstroemia parviflora* and *Adina cordifolia*) has been carried out in this project.

123. **Studies on scale up of protocols for in vitro propagation, hardening, production of cloned plants and establishment of field trials of sandalwood (*Santalum album* L.)**

**Principal Investigator:** Dr. Geeta Joshi, IWST, Bengaluru

**Duration:** 2008 – 2012

**Critical analysis of the research theme and summary of the study**

Studies were carried out to develop complete protocol for *in vitro* propagation of sandal through axillary and somatic embryogenesis and to carry out field trail to assess the performance of *in vitro* raised plants in field. The results are as:

**Micropropagation through axillary shoot proliferation:** Nodal shoot segment as explants had 91.67% bud break within 4-5 weeks on MS medium with additives + NAA 0.1 mg/1. + BAP 2.5 mg/1. *In vitro* differentiated shoots were further multiplied on fresh medium consisting of additives and NAA 0.1 mg/1 + BAP 1.0 mg/1 and were subcultured for 8 to 10 cycles at an interval of 4-6 weeks. For high frequency rooting the in vitro raised shoots were pulse treated with IAA 2500 ppm + IBA 2500ppm (pH-7.0) for 30 min and the inoculated in MS basal medium consisting of Glucose 3% and Agar 0.58%.

**Micropropagation through Somatic embryogenesis:** Embryogenic callus was induced from leaves, internodes and nodal explants on MS + vitamins + Sucrose 3% + Additives + 2. 4-D 2.0mg/1 + Agar 0.6%. Induced callus were multiplied in the callus multiplication medium consists of MS + vitamins + Sucrose 3% + Additives + 2. 4-D 2.0mg/1 + Agar 0.6%. 92.67% synchronized embryo was induced on WP medium with sucrose 3% + Additives + IAA 1.0mg/1 + BAP 1.0mg/1 + Agar 0.58%. Induced embryos were subcultued in liquid maturation medium consisting WP medium along with ABA 1.0mg/1 + PEG 3.75% + Mannitol 1.0% + Sorbitol 1.0%. 88.12% embryo germination was obtained when matured embryos were inoculated on WP medium fortified with Sucrose 3% + IAA 1.0mg/1 $GA_3$ 1.5mg/1 Glutamine 100mg/1 + Agar 0.58% and incubated under dark condition at 22°C.

**Hardening:** Hardening was carried out in two steps, primary hardening was carried out in sand for 35 days under polytunnel (RH was initially >90% and gradually reduced to mist chamber humidity of 70±5%) followed by secondary hardening in potting medium consisting of compost: soil: sand (30:10:60v/v) with *Mimosa pudica* as host and supplemented with biofertilizer in mist chamber conditions (28±3°C and 70±5% RH). After primary hardening, secondary hardened plants were maintained in mist chamber for 15 days before shifting to nursery conditions. After primary and secondary hardening plants produced through axillary shoot proliferation had 57.37% of survival and had high variability in growth. While the plants produced through somatic embryogenesis had 75.48% survival and uniform growth.

**Field trail:** Field trail of *in vitro* raised plants of sandalwood was successful, after six months survival on *in vitro* raised plants of sandalwood in field was 73.68%.

**Scientific findings and contents**

Studies were carried out to develop complete protocol for *in vitro* propagation of sandal through axillary and somatic embryogenesis and to carry out field trail to assess the performance of *in vitro* raised plants in field in this project.

124. **Durability and Treatability of *Melia Composita***

**Principal Investigator:** D. Venmalar, IWST, Bengaluru

**Duration:** 2009 – 2010

**Critical analysis of the research theme and summary of the study**

Durability and treatability of *Melia Composita* timber against fungi and termite with oils of Cashew Nut Shell Liquid (CNSL), Neem seed oil and *Pongamia pinnata* seed oil (eco-friendly wood preservatives) has been done in this project. The results are as:

- It is easy to treat *Melia composita* wood with these preservatives for the required absorption both by dipping and pressure methods. Following are the treatment schedules:
  - ✓ Pressure treatment – 15'/3kgcm$^{-2}$/60'/5', initial vacuum of 50 cm Hg for 15 minutes, an air pressure of 3 kg/cm$^2$ for 60 minutes and a final vacuum of 50 cm Hg for 5 minutes.
  - ✓ Dipping treatment – 48 hours of dipping period.
- Against fungus CNSL preservative show 'Resistant class II and Pongamia and Neem seed oil show 'Moderately resistant class III.
- All the three oils can be used as eco-friendly wood preservatives to protect *Melia composita* wood.
- The efficacy of the three oils, eco-friendly preservatives can be rated as CNSL > Pongamia > Neem.

**Scientific findings and contents**

Durability and treatability of *Melia Composita* timber against fungi and termite with oils of Cashew Nut Shell Liquid (CNSL), Neem seed oil and *Pongamia pinnata* seed oil (eco-friendly wood preservatives) has been done in this project.

125. **Selection and vegetative propagation of *Neolamarckia cadamba* (roxb.) miq – An alternative species for pencil, match wood and ply wood industries**

**Principal Investigator:** Dr. A. Vijayaraghavan, IFGTB, Coimbatore

**Duration:** 2010 – 2015

**Critical analysis of the research theme and summary of the study**

Selection of CPT's, progeny performance assessment and standardization of germination & vegetative propagation technology of *Neolamarckia cadamba* has been done in this project. The results are as:

- The wood based industries, farmers; Forest Development Corporations and Forest Department of various states in India are looking for some better species for pencil/match wood/ply wood production which can be achieved by the most preferred species like *Neolamarckia cadamba* which fetches more income to the farmers and also to the industries.
- Accordingly, selection of CPT's has been done in plantations of Tamil Nadu and Andaman and in natural forests of Kerala Assam and Andaman & Nicobar Islands. Fruits were collected from the identified CPT's and raised seedlings.
- Seedlings were raised with established the progeny trial at three locations viz., Neyveli, Nagercoil (Tamil Nadu) and Panampally (Kerala). Growth data were recorded and analysed. The analysis showed that progenies 54, 112, 57 and 61 has recorded maximum mean height growth and progenies 54, 57, 123, 129 and 61 has recorded maximum girth at breat height in Panampally. Whereas in Nayveli progenies 216, 133 and 112 has recorded maximum mean height growth and progenies 54, 57, 123, 129 and 61 has recorded maximum girth at breat height. Based on the one year growth data individuals of *N. cadamba* from the good performing progenies 54, 122, 61, 123, 112, 123 can be marked for the future clonal propagation which will pave the way for improvement in terms of productivity.
- The sieved seeds need no pre-sowing treatment but need special care during watering, due to minute nature of seeds. Seeds of about 0.1g (about 2500 seeds) can be sown in galvanized or wooden trays filled with fine river sand and soil and treated with fungicide. The seeds are better mixed with sterilized sand before sowing. Sowing in February month gives better result. Winter sowing is not successful. The germination of *N. cadamba* seeds in open beds is generally difficult and is prolonged over a period of eight weeks. Therefore, plants are invariably raised in shaded beds to minimize insolation and splashing effects of rain water.
- To standardize the vegetative propagation technique by means of using cost effective polytunnel technique, to tap immediate gains of tree improvement programme we found that among the treatments viz., 500, 600, 700, 800, 900 and 1000 and NAA viz., 500, 600, 700, 800, 900 and 1000 IBA and NAA at 500 ppm is giving good results than all other treatments. It is recommended that coppice shoots of N. cadamba can be treated with IBA 500 ppm to get more rooting percentage.

**Scientific findings and contents**

Selection of CPT's, progeny performance assessment and standardization of germination & vegetative propagation technology of *Neolamarckia cadamba* has been done in this project.

126. **Study on reproductive biology and breeding systems in *Ailanthus excelsa* and *Ailanthus triphysa***

**Principal Investigator:** D. Rajasugunasekar, IFGTB, Coimbatore

**Duration:** 2010 – 2013

**Critical analysis of the research theme and summary of the study**

Studies were made in this project to understand of floral structure, phenology, pollination biology and breeding systems of *Ailanthus excelsa* and *A. triphysa*, which is prerequisite for the reproduction as well as hybrid production. Accordingly in *Ailanthus triphysa*, Kartotyping work has been done with root tips and FAA fixed pollens. Pollen viability and male & female structural variation *Ailanthus triphysa* have been studied. Pollen storage is being standardized. Kay pollinator (*Apis cerena indic*) Indian Honey bee and Dammar bee (*Trigona iridipennis*) have been indentified fruits are dispersed by wind and short-lived up to 3-6 months. *Ailanthus excelsa* is polygamodioecious with low male female ratio (1:5) male flowers were shortlived when compared to the female flowers. In *A. triphysa* Male flowers are bigger than female flowers. Number of flowers per female inflorescence varies between 150 to 600. Male flowers have 5 petals, 10 stamens and a sterile carpellode while female flowers have 5 petals, sterile stamens called staminodes and a trilocular ovary with three ridged, large and showy. Stigma is directly attached to the ovary. The sterile stamens in female flowers are half the size of those fertile in the male. Stigma in the female flower is big compared to the size of the flower and it is positioned in such a way so as to easily receive pollen grains from outside. Both male and female flowers have nectariferous disc. Anthers dehisce longitudinally with very little sticky pollen. Pollen grains are having a diameter of about 22/um and are highly fertile with only 2.5 to 5 percent sterility. Flower opening and anthesis occur at night in between 12 and 5 am. Flowers have a mild sweet smell. Very small insects are visiting the flower. Flowers are very small and hence there is no chance for bird pollination. Since the pollen is sticky and very small in quantity, the possibility of wind pollination also can be ruled out. Investigation of floral biology and plant pollinator interaction also been studied *Ailanthus excelsa* seeds collected from Maharashtra has been raised in IFGTB Nursery and added to the germplasm assemblage. Intra specific control crossing of *Ailanthus triphysa* has been attempted. Two acres of *Ailanthus triphysa* Germplasm has also been established at Panampalli research station and Nilambur Division of Kerala.

**Scientific findings and contents**

Studies were made in this project to understand of floral structure, phenology, pollination biology and breeding systems of *Ailanthus excelsa* and *A. triphysa*, which is prerequisite for the reproduction as well as hybrid production.

127. **Growth variability in *Melia dubia* plantations and seed germination studies**

**Principal Investigator:** Dr. Arun Kumar A.N., IWST, Bengaluru

**Duration:** 2011 – 2016

**Critical analysis of the research theme and summary of the study**

Variability in seed germination and growth in various plantations of *Melia dubia* has been studied in this project. The findings are as:

- 21 plantations were selected from different *M. dubia* growing areas in southern parts of Karnataka. The plantations were selected with wide range of spacing (2mx2m to 10mx10m), age 1 to 9 years) and management practices (unmanaged, partially managed and intensively managed). For seed germination studies, eighteen different pre treatments were provided. To develop growth models, five model equations were considered and a multiple linear equation was developed on the basis of age, spacing, growth rate and management practices. Growth variability was recorded for girth and height traits.
- The study demonstrated that there was a drastic reduction in the girth increment in narrow spaced and unmanaged plantations. In case of a intensively managed and closely spaced plantation of 2mx2m, the first year average girth was 2.043 cm while the increment in average girth reduced to 3.11 cm at the end of third year. In case of a well managed large spaced plantation (10mx10m), the average annual girth increment was 21.20cm, 21.24cm and 20.33cm, at the end of 3$^{rd}$, 4$^{th}$ and 5$^{th}$ year respectively. Out of the five models studied for predicting the time required for achieving 200cm girth, all the model equations described the girth data with exceptionally high coefficient of determination. Among various seed pre treatment measures tried to enhance the germination, using the previous year's stone collected from the field showed better germination and is also an ideal method to obtain better germination. The study provides passport data on growth aspects in *M. dubia* plantations.

**Scientific findings and contents**

Variability in seed germination and growth in various plantations of *Melia dubia* has been studied in this project.

128. **Development of nursery technique of fiber yielding Himalayan nettle**

**Principal Investigator:** S.R. Baloch, FRI, Dehradun

**Duration:** 2010 – 2012

**Critical analysis of the research theme and summary of the study**

Nursery techniques of Himalayan nettle (*Girardina diversifolia*) have been developed. The results are as:

- The seed of Himalayan nettle mature during the month of November and December.
- Seed of nettle is brownish to black in color. A single seed weight is 0.0044 gram having a diameter of 2.5mm and 1 gram seed contains 229 seeds.
- Mean germination percent is higher in the month between April and July in both the sites. The best time for sowing seeds is from March onwards.
- Germination of seeds is best when sown and cared in plastic trays at natural sites. Potting mixtures containing sand: garden soil: and vermicompost (2:1:1) is best.
- Germination of Himalayan nettle seed is best at 5mm depth.
- Stem cuttings found not suitable for propagation of *G. diversifolia* even treating with rooting hormone do not induce rooting.

**Scientific findings and contents**

Nursery techniques of Himalayan nettle (*Girardina diversifolia*) have been developed.

129. **Development of viable technique for efficient charcoal production from different bamboo species of NE India**

**Principal Investigator:** Dhruba Gurung, RFRI, Jorhat

**Duration:** 2010 – 2012

**Critical analysis of the research theme and summary of the study**

- The people of the region still follow the age old practice of pit kilns to produce wood charcoal.
- The bamboo charcoal produced using brick kiln was better giving the total yield of an average of 30.26% charcoal on the basis of weight of the bamboo raw material used. The yield varied from 26-38.96% of the raw material used.
- The metallic drum kiln gave the best charcoal yield and also bamboo vinegar along with usable bio-gas/bamboo gas/ flu gas or syn gas. About 66kg of dry bamboo with an average moisture content of 18.67% produced nearly 32.51% of bamboo charcoal; 3 liters of bamboo vinegar and gas which was burnt for nearly 4 hours. Through literature survey it came to be known that the flue gas mainly contains methane, carbon monoxide and hydrogen.
- This syn gas could be stored and compressed, using suitable tools to be used in conjunction with LPG Gas; LNG gas for the purpose of household cooking or as a fuel for vehicles.
- Bamboo like *Bambus tulda, Bambusa balcooa, Bambusa nutans* and *Bambusa bambos*, with a

moisture content ranging from 17 to 25% produce an average 30.26% of charcoal, which includes both the properly carbonized (76%) and partially carbonized (24%) and powder charcoals on total charcoal produced basis. On proper carbonization, the quantum of partially carbonized charcoal may range from zero to 24% and properly carbonized averages 76% on the basis of total charcoal produced.

- The actual difference on charcoal yield due to bamboo species varied between 21% in *Bambusa nutans* and 39% in *Bambusa balcooa*. This difference in production may be due to air inlet control and opening of the kiln besides the moisture content in bamboo charcoal at the time of weighing and the attentiveness of the worker.
- The duration of pyrolysis depended on the bamboo will thickness, split or round and moisture content in it. In case of *Melocanna baccifera* half and quarter split bamboo needed 3 hours to complete carbonization whereas round and unsplit *Melocanna baccifera* needed 6½ hours.
- Besides given a good yield of bamboo charcoal brick kiln was also used to derive bamboo vinegar @ 2-5 liters per cycle and also preservative treatment of bamboo to enhance its durability. Bamboo vinegar was produced as a by-product from bamboo carbonization in the brick and drum kilns. Depending upon the moisture content of the bamboo used for pyrolysis, the vinegar collected was about 2-5 liters per operation. These vinegars are composed of 80-90% water and more than 200 types of organic compounds consisting of variety of acids, phenols and alcohols.

**Scientific findings and contents**

Techniques for efficient charcoal production from different bamboo species has been developed of NE region of India.

130. **Ecological dynamics of vegetation structure and assessment of morphological adaptive variation to create base line data in selected species in Dalma wildlife sanctuary**

**Principal Investigator:** H.C. Sindhu Veerendra, IFP, Ranchi

**Duration:** 2009 – 2012

**Critical analysis of the research theme and summary of the study**

Vegetation structure in Elephant Dalma Wildlife Sanctuary in the state of Jharkhand has been assessed in this project. The results are as:

- Dalma wildlife sanctuary is an important Elephant habitat in the Indo-Malayan region. It is classified as critical and endangered by WWF and IUCN.
- There are 183 species from 68 genera from 58 families.
- Top canopy reaches to a maximum of 36 m while middle canopy was found at 10-15m. Undergrowth was found up to a maximum of 3 m and was rich with plants of medicinal values.
- Inventorization of elephant foor species has been carried out. The main species are: *Hemidesmus indica, Kydia calycina, Mallotus philippensis, Aegle marmelos, Boswelia serrata, Bauhinia variegate, Bauhinia purpurea, Ficus bengalensis, Ficus virens, Gmelina arborea, Shorea robusta, Syzigium cumini, Terminalia belerica*.

- Of the three Major invasive spcies, *Lantana camara* (Verbinaceae) has been found only in buffer zones. Similarly, *Parthenium* has been found inouter fringes. Both are represented by few numbers indicating nonacclimatization of those species in the plant communities. Other species *Eupatorium odoratum* (Asteraceae) is distributed widely in the sanctuary.
- To sum up, the sanctuary is rich in plant species. The age of the forest is also young suggesting that it will support a large number of animal species Although few villages with significant cattle are present inside the sanctuary, damage to forest vegetation is at sustainable level.

**Scientific findings and contents**

Vegetation structure in Elephant Dalma Wildlife Sanctuary in the state of Jharkhand has been assessed in this project.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Assessement of vegetation structure and changes has been done in other sanctuaries also.

## 131. Characterization of *Eucalyptus* clones for physiological and nutritional parameters

**Principal Investigator:** Dr. S. Saravanan, IFGTB, Coimbatore

**Duration:** 2008 – 2013

**Critical analysis of the research theme and summary of the study**

Characterization of *Eucalyptus* clones for physiological and nutritional parameters has been done in this project. The results are as:

- Established *Eucalyptus* clonal trails at four locations (Coimbatore, Pudukottai, Sivagangai and Tirunelveli) with 29 short listed clones from IFGTB ITC, TNPL and TAFCORN and one seedling for comparison purpose for assessing the water use and nutrient use efficiency of various clones. Morphological parameters like leaf area, leaf length and width, specific leaf area and leaf area index have been worked out for the short listed clones. Physiological parameters like $CO_2$assimilation, net photosynthetic rate, stomatal conductance, transpiration rate, etc. were recorded from the four trial plots. The ratio of the net photosynthetic rate to transpiration is termed as Instantaneous water use efficiency (μ mol $mmol^{-1}$). Higher the value, better the efficiency of plant to divert water for photosynthesis.
- Based on the above study, C-14, C-19, C-188, C10, C-123 and C-186 showed higher productivity and better water use efficiency and these clones can be multiplied in a large scale for distribution.
- Under this project, data on growth parameters, physiological parameters, water and nutrient use efficiency of various clones has been generated for further future tree breeding programmes.

**Scientific findings and contents**

Characterization of *Eucalyptus* clones for physiological and nutritional parameters has been done in this project in the state of Tamil Nadu.

## 132. Diagnostic survey of indigenous and institutional Participatory Forest Management in Himachal Pradesh

**Principal Investigator:** Shri K. D. Sharma, IFS, DCF, HFRI, Shimla

**Duration:** 2005-2009

**Critical analysis of the research theme & summary of the study**

The study was a survey based study for evaluation on demanded species, role of women, attitude of people towards forest management, constraints in propagation and management of forests in people participation and find out the suitable approach. An exclusive survey was conducted in the different areas of Himachal Pradesh and finally 33 VFDC/JFMC/HPFSRP Panchayats in 8 forest circles namely; Dharmshala (5), Kullu (5), Rampur (4), Nahan (4), Mandi (5), Bilaspur (5), Chamba (2) and Shimla (3) were selected for study and members of the committees and local other people were interviewed to collect the desired information. Frontline staff of the State Forest Department was also interviewed to know management criteria of forests and their attitude towards local people and vice-versa. During interview, trends of forest management, participation level of people, preferred species for a particular area were focused. Overall the study was based on Participatory Rural Appraisal in which status of Join Forest Management with number of different committees involved in the forest management and total area under such management is explored. As per quantification, 1749 committees were operational with involvement of 4110 villages and population people in 305868 ha area under JFM of the State.

**Scientific findings and contents**

The scientific contents in the study comprise of management set-up of forests, choice of site specific forestry origin species by people for plantation in forest area and outside forests as well. People of Shivalik region below 914msl showed their preference for *Grewia optiva, Bauhinia variegata, Morus alba, Bambusa spp., Acacia nilotica, Albizia chinensis, Dalbergia sissoo. Ficus palmata, Malotus philipinensis, Eucaluptus spp., Grevilea robusta, Aegale marmelos* , etc. for fuel, food, fodder and timber. People residing Mid-Himalayan demanded almost same species with addition of *Bombax cieba, Teminalia balarica and Saraca indica.* In Hi-Hill Region, people showed their preference for *Quercus leucotrichophora. Q. semicarpifolia, Q. dilatata, Pinus roxburghii, P. wallichiana, Picea smithiana, Abies pindrow* and *Celtis australis,* etc. In Cold Dry Zone, *Salix alba, Populus spp., Robinia pseudoacacia, Pinus gerardiana* were preferred species by local people. Some constraints as told by people and visualized during the study were shortage of fund, lack in proper aftercare of plantation, specially, after over the scheme. Lack of sustainable income generation from afforestation scheme was also a constraint as told by people.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The study is a survey to find out the involvement of people in in-situ and ex-situ forest management and sustainable development. The managed forests and plantation may be taken as prototypes and demos for people and capacity building may be developed through trainings and other awareness programmes. Some volunteers should be appointed as village level workers (VLOs) to address the issues to subject experts and planners so that effective policies for forest management with people participation may be framed. Further, long term schemes for afforestation may be launched with adequate funding and proper monitoring.

# Hydrology

1. **Comparison of hydrological regime of a micro-watershed having dense oak forest with a degraded micro-watershed**

**Principal Investigator:** Dr. R.K. Tiwari, DCF, FRI, Dehradun
**Co Principal Investigator:** 1. Shri S.P.S. Rawat, Scientist-F, FRI, Dehradun and
2. Shri Ganga Singh

**Duration:** 2007-2012

**Critical analysis of the research theme & summary of the study**

The forested areas in lower western Himalayan ranges in India which constitute the head water catchments for many hilly streams have seen a large degradation in forest cover due to grazing, deforestation and other human activities over the years. The change in forest cover is likely to alter the soil moisture regime and consequently, the flow regime in the streams. In the present study undertaken by Forest Research Institute, Dehradun two micro-watersheds namely Arnigad with dense Oak forests and Bansigad degraded Oak forests located on Mussoorie Himalayas were selected to continuously monitor for the period of three years (2008-2011) to understand and quantify the influence of forest cover on soil moisture regime, rainfall-runoff relationship and soil erosion.

The recording of the relevant data was successfully done for a period of three years. During the study, hydrological data (stream discharge, sediment load and soil moisture) and meteorological data (rainfall, temperature, relative humidity, evaporation and wind speed) were taken continuously to monitor and assess the impact of forests on hydrological behavior of watershed. A continuous recording of stream discharge was done with the help of digital water stage recorder installed at the weir constructed across both the streams. The data was analyzed to quantify the impact of forests comprising primarily of Banj Oak on hydrology of watershed. The findings are of enormous importance for scientific management of micro-watersheds in lesser Himalayas. Further, the applicability of SWAT model in estimating discharge and sediment yield using experimental data from two forested watersheds was assessed.

**Scientific finding and contents**

The study has come out with a detail analysis on impact of forest cover on soil erosion, soil moisture regime, soil moisture storage, rainfall- runoff relationship and infiltration. As per finding of the project, annual Suspended Sediment Load was 61% less in dense forested micro-watershed than degraded one indicates that forest controls excess suspended sediment load and water quality of stream discharge under dense forest cover is better. Annual bed load was 83% less in dense forested micro-watershed than degraded one whereas the annual total load was 44% less in dense forested micro-watershed than degraded one. The average annual total sediment load was approximately two times lesser in dense forested micro-watershed than degraded micro-watershed indicated role of forest in erosion regulation.

The soil moisture values in both the watersheds show an annual cycle with highs and lows during periods of high rainfall and high evapotranspiration respectively. Soil moisture was found 3% more in dense forested micro-watershed as compared to degraded micro-watershed. Soil moisture under dense forest cover was higher than the degraded forest during all the seasons. The values during

monsoon, winter and summer seasons were obtained as 40.33, 29.29 and 25.95% respectively under dense forest and 39.34, 25.50 and 22.58% respectively under degraded forest. The present analysis of soil moisture regime gives us understanding of how soil moisture storage varies within and between the micro-watersheds. The analysis revealed large variations in soil moisture storage at different location and depths and also during different seasons in the watersheds. A high positive correlation was found between tree density and soil moisture content. The mean soil moisture content over the entire period of study was found higher in dense forest than the degraded forest.

A detail study on infiltration rate in two microwatersheds revealed that average steady state infiltration rate under dense Oak forests and degraded Oak forests conditions in both the microwatershed was 31.30 cm/hr and 10.4 cm/hr respectively indicating that dense Oak forests allow higher infiltration rate supporting higher base flow during the lean period.

Finding of continuous rainfall and stream discharge data of the two micro-watersheds for the three years period revealed that annual runoff is inversely proportion to the forest cover. The average runoff coefficient for the three years under dense forest conditions was o.56 in comparison to 0.64 under degraded forest conditions. Under dense forest conditions, runoff during the monsoon period (June to September) accounted for 57% of the total annual runoff and rest 43% was available during the lean period (October to May), whereas under degraded forests, runoff during the monsoon period (June to September) accounted for 76% of the total annual runoff and only 24% was available during the lean period (October to May). The higher interception losses and higher evapotranspiration is also responsible for lower annual water yield under dense forest cover. The results also indicate that base flow under dense forest conditions are higher supporting stream flow during the lean period.

The mean annual water and sediment yield simulated by SWAT model were close to the observed values in both the watersheds. The simulated water yield over the entire study period was 59.4% in Arnigad watershed and 63.7% in Bansigad watershed of the mean annual rainfall. The simulated mean annual sediment load of both the watersheds were 8.45 and 21.97 t $ha^{-1}$ respectively. The results indicated that SWAT is capable of estimating discharge and sediment load from Himalayan forested watersheds, the estimates of which are often required for operation and management of irrigation and hydropower projects in the region.

Findings of the study are summarized as under;

a) Higher forest cover provides better quality stream flow, better soil moisture regime in the watershed, higher base flow during lean period and flood protection due to lower and delayed flood peaks.
b) The annual water yield under higher forest cover is lower.
c) The hydrological parameters like soil moisture, soil erosion, sediment load, infiltration rate, runoff etc for the two microwatersheds under different forest covers have been quantified.
d) SWAT model can be used for prediction of annual runoff and sediment yield for the lower Himalayan ranges.

**Suggestions regarding follow up, patenting possibility, utilization aspects and prototype**

The study provides current hydrological responses of watersheds at micro scale in Mussoorie, lesser Himalayas. Valuation of environmental services provided by forested catchment, hydro-ecological linkages in watersheds and impact on the management of watersheds on the population living downstream need long term research. The present study is a short term study, which has been carried

out for the two micro-watersheds primarily under Oak forests, which may be used as a reference study. Further research priorities in forest hydrology should focus on following issues;

a. Hydrological studies are required to done under different forest types of the country. To understand the response of change in forest cover on the quantitative and qualitative water yield, long term hydrological studies are required. Impact of forest management through various silvicultural practices, plantations, logging operations or impact of forest degradation due to forest fire, insect attacks etc on the hydrological response of the watersheds, long term and continuous studies are required under different forest types of the country.

b. Secondly, studies are required to understand the evapotranspiration requirement of various species under different climatic conditions. The impact of different species on soil moisture regime of a catchment is different and it is a function of cumulative impact of transpiration requirements of species and its impact on infiltration. A protocol needs to be developed for major species covering major forest types of the country and also for major plantation species to give an option to the policy makers on the choice of species to maximize the water yield from a watershed.

2. **Assessment of impact of constructed water harvesting structure on soil moisture/vegetation in Bundelkhand using remote sensing & GIS techniques.**

**Principal Investigator:** Shri Dheeraj Kumar Gupta, Scientist-C, TFRI, Jabalpur.

**Duration:** 2018

**Critical analysis of the research theme and summary of the study**

The Bundelkhand region of Madhya Pradesh has been facing acute shortage of rainfall in the past few years. The average rainfall is 990.9 mm with a range of 767.8 to 1086.7 mm. About 90% of the rainfall is from July to September in about 30-35 spells. Delayed onset of rains, early withdrawal combined with long dry spells lead to drought like situation. The project entitled "Assessment of impact of constructed water harvesting structure on soil moisture/vegetation in Bundelkhand using Remote Sensing and GIS techniques" was undertaken to assess the impact of the implementation of this Bundelkhand Special Package which primarily aims to quantify the role of soil moisture conservation (SMC) structures for augmenting water conservation, improving ground water and surface water availability during the post-monsoon period in the years 2011-16. The objectives of the project were;

a. To identify the location/extents of water harvesting structures.
b. To identify the changes in vegetation status in the vicinity/ downstream of soil moisture conservation (SMC) structures.
c. To identify the changes in surface soil moisture in the vicinity/ downstream of SMC structures.
d. To quantify ground water level using CGWB data.

In this project, field visit based identified structures' data were collected from monitoring and evaluation reports of forest divisions for both phases. Extents of new water bodies (new permanent and new seasonal) was derived using water transition layer. Land use and land cover (LULC) data was used for vegetation (double/triple crop) area identification in the vicinity/downstream of the structures. Soil moisture data was collected from Terra Climate: Monthly Climate and Climatic

Water Balance for Global Terrestrial Surfaces, University of Idaho through Google earth engine. Ground water level collected from Central Ground Water Board (CGWB), Bhopal was used to assess changes in ground water level within 1 km buffer in the vicinity and downstream of the structures. The period 2005-10 carried out as pre-scenario whereas the period 2011-16 as post-scenario. Further, paired two samples for means statistics (t-test) at 5% level of significance was used as evaluation criteria.

On the whole, the study noticed changes in water bodies' extent, vegetation (double/triple crop), soil moisture and water level rise. These significant improved realizations are the results of the soil and water conservation structures constructed through the implementation of Bundelkhand Special Package during the years 2011-16.

**Scientific finding and contents**

This is primarily a monitoring and evaluation type of project in which remote sensing techniques have been used to evaluate the impact of soil and moisture conservation structures on the downstream area. There is no knowledge creation or scientific findings in the project. However, results of the study are as under;

As per assessment of monitoring and evaluation reports, total number of soil and water conservation structures can be projected to be 4420 in the six districts of Madhya Pradesh which were identified as contour bund, anicut stop dam, boulder check dam, contour dyke, contour trench, ponds, tanks, earthen check dam, gali plugging, percolation pit, percolation tank, retention tank, retaining wall, scattered counter trenches, stop dam, storage tank, water storage tank and waste weir.

Increase in surface water bodies' extent was observed to be 1301 ha wherein new permanent (conversion of land into permanent water) and new seasonal (conversion of land into seasonal water) were 5 ha and 1296 ha respectively. These structures (percolation tank, storage tank and talab) were less than 2 ha surface area in size.

An increase in double/triple crop area(from 78.5 to 136.7 $km^2$ between before (year 2010) and after the implementation of Bundelkhand special package (after the year 2010)) was observed within one km downstream of the recorded structures which showed significant changes at 5% level of significance.

More than 91.7 % (1215 out of 1324) recorded structures showed significant changes in the soil moisture in 1 km vicinity and downstream between the implementation of the scenarios.

Ground water level analysis using spatial mean of water level for post-monsoon period (November month) shows significant change (mean increase of 1.13 m, i.e. from 9.13m to 8.0 m depth) in rise at 5% level in post-scenario.

# Protection (Pathology)

1. **Screening of eucalyptus germplasm for disease resistance against *cylindrocladium* leaf and seedling blight**

**Principal Investigator:** Dr. Amit Pandey, Scientist –F, FRI and
**Co Principal Investigator:** Dr. N.S.K. Harsh and
Dr H.S. Ginwal

**Critical analysis of the research theme and summary of the study**

This project was undertaken with the objectives to collect C. *quinqueseptatum* isolates from Uttar Pradesh and identify pathogen population lines by DNA fingerprinting and artificially inoculate different eucalypt germplasm with highly virulent isolates for testing disease resistance. For screening disease resistance against *Cylindrocladium* leaf blight (CLB), the commonly used Eucalyptus germplasm by industries and state forest departments were artificially inoculated and infection index was recorded. Accordingly, virulence of pathogen and disease resistance of host was worked out.

**Scientific findings and contents**

Out of 28 pathogen isolates from different locations, 3 most virulent isolates were used for screening different eucalyptus germplasm for disease resistance screening. After disease rating two germplasm viz. Cittor and *Corymbia* hybrid were identified as moderately resistant. Germplasm PB 417 was found to be moderately susceptible. Germplasm 3020 and PB 4 I 4 were categorized as susceptible. All the other germplasm tested found to be highly susceptible to CLB. The DNA fingerprinting of all the Eucalyptus germplasm was done by RAPD-PCR. Mosseler primers segregated susceptible germplasm. Operon series primers segregated moderately susceptible germplasm.

Identification of highly virulent isolates has equipped Forest Pathology Division of FRI for testing disease resistance in different new eucalypt clones, being produced by various agency, against highly damaging *Cylindrocladium* leaf and seedling blight in north Indian states.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Moderately resistant germplasm of Cittor and *Corymbia* clones may be tried for plantation at multi location and incidences of *Cylindrocladium* leaf and seedling blight may further be observed for confirming the disease resistance in the clones.

2. **Influence of beneficial microbes in conferring salt tolerance to casuarinas clones**

**Principal Investigator:** Dr. V. Mohan, Scientist - F, IFGTB and
**Co Principal Investigator:** Shri R. C. S. Jayaraj, IFS

**Duration:** 2010-2013

**Critical analysis of the research theme and summary of the study**

Alleviating plant salt stress and remediating saline soils are of great economic interest. Beneficial microbes such as *Mycorrhizal* fungi, *Frankia* and PGPRs are associated with many plants including trees. In this project, the status of beneficial micro flora from the samples of salt affected areas is investigated and efficacy of beneficial microbes on the growth improvement in selected *Casuarina equisetifolia* clones have been tested in nursery.

A total of 51 Plant Growth Promoting Rhizobacterial (PGPR) isolates (18 isolates of Phosphate Solubilizing Bacteria (PSB), 16 isolates of Azotobacter and 17 isolates of *Azospirillum*, 25 different AM fungi isolates and 3 *Frankia* isolates were made from the saline samples. Salt tolerance ability of these microbes were tested.

**Scientific findings and contents**

Result of nursery experiment indicated that 16 different clones of *C. equisetifolia* perform better in saline soil when inoculated with beneficial microbes. Among different beneficial microbes, *Frankia* and AM fungi were found highly significant in enhancing growth and survival of the plant in field.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The technique developed for liquid based bio-fertilizer production of PGPR and mass production of AM and ECM fungi in the laboratory could be easily transferred to user groups and may facilitate the Private Entrepreneurs and other user groups to exploit them commercially. The potential bio-inoculants can be supplied to required quantities to user groups for nursery and field applications.

3. **Screening for Blister bark disease resistance in *Casuarina equisetifolia* clones**

**Principal Investigator:** Dr. A. Karthikeyan, Scientist - E, IFGTB and
**Co Principal Investigator:** Dr. R. Anandalakhmi, Scientist – D, IFGTB, Coimbatore

**Duration:** 2009-2014

**Critical analysis of the research theme and summary of the study**

This project was taken to identify the blister bark disease resistant clones of *Casuarina equisetifolia* caused by a fungal pathogen *Subramanionopora vesiculosa (Trichosporium vesiculosum)*. Under this project 250 clones of *C. equisetifolia* from different places have been examined while 3 isolates of the pathogen were used for testing of resistance through disease severity score under nursery condition.

**Scientific findings and contents**

Screening test for resistance identified 36 clones of *Casuarina equisetifolia* as resistant to the blister bark disease in nursery and field while 55 as moderately resistant. Higher Phenol content in clones has been identified as one of the reason for resistance in clones against the disease.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Method of inoculation of *T. vesiculosum* and evaluation of disease resistant clones of *C. equisetifolia are new attempts,* which may open avenue for carrying out research on similar disease problem of other forest species. Identified disease resistant clones of *C. equisetifolia* may be considered for plantation.

4. **Development of botanical pesticidal formulation and demonstration of application in forest nurseries and plantations**

**Principal Investigator:** Dr. O. K. Remadevi, Scientist – G and
**Co Principal Investigator:** Dr. R. Sundararaj, Scientist – G, IWST, Bengaluru

**Duration:** 2011-2014

**Critical analysis of the research theme and summary of the study**

Experiments were conducted to record the impact of the botanical formulation from few selected plants viz., *Lobelia nicotioaneafolia* leaves, *Erythrina indica* seeds, *Acacia concinna* leaves and pods, and *Chromolina odareta* leaves. Crude extracts were prepared from the plant materials and by adding suitable additives formulation were prepared. The formulations were tested against various pests. The formulation was also tested for its residual toxicity and shelf life.

**Scientific findings and contents**

The extract prepared from the leaves of *Lobelia* and seeds of *Erythrina* when fed to the larvae of *S. litura* gave significant mortality compared to other two plant materials. A formulation named as "PESTILL" was developed using the weed *Lobelia nicotianeafolia* with a residual toxicity of 6 to 7 days and a shelf life of more than 8 months. It was found effective against various pests in nurseries and plantations. The formulation showed broad-spectrum activities like mortality agent, insect growth regulator, anti-feedant, repellent and reproductive inhibitor.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The formulation is said to be a safe, effective, eco-friendly and cost-effective alternative for synthetic insecticides. Therefore, use of this formulation may be advocated.

5. **Microbial biosynthesis of polyhydroxyalkanoates (PHA) from wood waste**

**Principal Investigator:** Dr. A. Muthu Kumar, Scientist – C, IWST, Bengaluru

**Duration:** 2011-2014

**Critical analysis of the research theme and summary of the study**

The PHA is considered as substitute to synthetic plastics. Therefore, the principal intention of this project was to indentify PHA producing microbes and its mass culturing using wood waste. For this purpose 7 filamentous fungal species viz. *Daedoliopsis nipponica, Hypoxylon stygium, Phanerochaete chrysosporium, Phlebia radiate, Trametes versicolor, Phellinus lamaensis and Trametes pini* were tested for their ability to grow on wood waste and their wood degradation potential. Further, the wood degraded by fungal strains was subjected to culturing of various bacterial strains and in turn production of PHA by the bacteria.

**Scientific findings and contents**

Out of various fungal species, *Trametes versicolor* was found most effective for biodegradation of wood waste. Among the various bacterial strains *Pseudomonas lignicola* was found effective in producing PHA. In the present case, wood waste was tried as a novel carbon source for mass culturing of the mibrobes.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Strains of *Trametes versicolor* and *Pseudomonas lignicola* may further be tested for their potential for wood degradation and PHA production respectively.

6. **Shisham mortality: Finding solution for future plantations**

**Principal Investigator:** Dr. N.S.K. Harsh, Scientist-G
**Co Principal Investigator:** Dr. Subhash Nautiyal, Scientist-G and
Dr. Ashok Kumar, Scientist-E, FRI, Dehradun

**Duration:** 2010-2014

**Critical analysis of the research theme and summary of the study**

Shisham is a prime timber species of north Indian states. High mortality of this species has disrupted the economic target of beneficiary and the losses run in to crores of rupees. Therefore, this project was under taken to identify the reasons of mortality and also to search for disease resistant clone of Shisham. Detailed investigation on diseases, physiological and genetical aspects of the host have been carried out. Control measures to various diseases and screening of susceptible and resistant clones from various locations have been conducted. Various clones were evaluated for their growth suitability in water logged, high moisture and low moisture conditions. Genetical diversity and similarity coefficient in 49 clones of Shisham from the state of Uttarakhand, Uttar Pradesh, Punjab and Haryana have been worked out.

**Scientific findings and contents**

Strains of fungal pathogens like *Fusarium solani* and *Ganoderma lucidum* were found mainly responsible for Shisham mortality. Biological control of diseases by fungal antagonists like species of *Trichoderma* has been found effective in combination of *Pseudomonas fluorescens* and salicylic acid. Disease resistant clones, high moisture tolerant and drought resistance and genetically similar and divergent clones have been identified out of the project works.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Information generated on various aspects of Shisham mortality, pathological, physiological and genetical aspects of various clones will definitely prove useful to the various stakeholders. Disease resistant clones with high growth performance in field identified through this project works may be promoted for plantation.

7. **Studies on the incidence and management of culm rot and bamboo blight disease in Assam**

**Principal Investigator:** Dr. R.K. Borah, Scientist –E, RFRI
**Co Principal Investigator:** Dr. A. Tapwal, Scientist – C, RFRI, Jorhat

**Duration:** 2008-2009

**Critical analysis of the research theme and summary of the study**

This project encompasses on the distribution, cause, nature and intensity of damages caused by culm rot and bamboo blight disease and to evolve suitable Integrated Pest and Disease Management (IPDM) strategies for growers. The project was carried out in different districts of six agro climatic zones of Assam. The incidence of culm rot and blight disease was recorded in different species of bamboos viz., *Bambusa balcooa* and *B. tulda* in different localities. Highest incidence of bamboo blight was recorded in *B. balcooa* of Jugighupa village of Bongaigaon district having 55.26%, whereas culm rot (60%) was observed in *B. tulda* of Jorabari village of Nagaon district followed by 45.22% culm rots in Jorhat district of Assam. *Fusarium udum* E. Butler was identified as the causal organism. *In vitro* efficacy of fungicides against the pathogen revealed 100% inhibition at 0.05% concentration by Bavistin (Carbendazim 50% WP), (Propiconazole 25% EC), Indofil M-45 (Mancozeb 75%) and Saff (Carbendazim12% + Mancozeb 63%) and were tried in field condition in Nagaon (on *Bambusa tulda) and* Jorhat district (on *B. balcooa)* of Assam. Bavistin @ 0.1 % was found to be the best among the treatments.

**Scientific findings and contents**

It was found that culm rot and bamboo blight disease was more or less prevalent throughout the length and breadth of Assam. The disease is causing a great loss to the farmers/growers. Soil drenching of Bavistin @ 0.1 % before and after emergence of new shoots can significantly reduce the incidence of culm rot and bamboo blight disease. Carbendazim may be one of the component of Integrated Pest and Disease Management (IPDM) against the disease.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The development of Integrated Pest and Disease Management (IPDM) strategies against the disease will increase the productivity of bamboo plantation which in turn will give economic benefit to the rural masses.

8. **Management of insect-pest and pathogens of seeds of *pinus gerardiana* wall. in storage**

**Principal Investigator:** Dr. Pawan Kumar, Scientist –C, Forest Protection Division, HFRI
**Co Principal Investigator:** Dr. R.C. Sharma, Department of Pathology, YS Parmar University of Horticulture & Forestry

**Duration:** 2010-2013

**Critical analysis of the research theme and summary of the study**

Seeds of Chilgoza pine (only Indian edible pine nuts) are damaged by a variety of insect pests and fungal pathogens during storage. Therefore, this project was undertaken to study on pest and pathogens and to develop management practices. Apart from various insect pests, the *Plodia impuctella (Catermena tubuerculosa)* was identified as major insect seed borer. Likewise, ten storage fungi were identified on the Chilgoza seeds, where *Penecillium citrinum* was recorded as dominant storage fungus. Study on management of insect pests and pathogens of seeds of Chilgoza conducted reveals that the freezing treatments i.e. seed storage at 0°C and 5°C is very effective against insect pests attack on Chilgoza seeds. Various methods were tried for safe storage of seeds. Neem powder, fumigant like Meta dinitrobenzene and others were tried for their efficacy towards storage pests and pathogens.

**Scientific findings and contents**

It was observed that the cones of Chilgoza pine are heavily infested by lepidopteron borers but least by pathogen in natural environment. Cones are heavily attacked only by *Dioryctria abietella* in natural condition. *Penicillium citrinum* is the most predominant fungus affecting Chilgoza seed in the storage. For chilgoza seeds collected from Kilba and stored in cotton bags for three years, Neem powder was most effective in control of Chilgoza seed damage followed by Robust, Fursa and Praghat treatments respectively. The same treatments on Chilgoza seeds when stored in plastic jars show that Robust Fursa and Neem have almost same impact. For Chilgoza seeds collected from Jhangi and stored for three years in plastic jars and cotton bags it was found that Neem powder was most effective whereas, Praghat show minimum impact on control of seed damage from insect pests. Neem powder and fumigant like Meta dinitrobenzene were found effective against the storage pest and fungi.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Finding of the study may be useful in effective management of insect borers as well as the pathogens attacking the seeds of *Pinus gerardiana* during long term seed storage.

9. **Biological control of *lantana camara* and *parthenium hysterophorus* by fungal pathogen**

**Principal Investigator:** Dr. Amit Pandey, Scientist E, Forest Research Institute, Dehradun.
**Co Principal Investigator:** Dr. R.C. Sharma, Department of Pathology, YS Parmar University of Horticulture & Forestry

**Duration:** 2002-2007

**Critical analysis of the research theme and summary of the study**

Weeds drastically reduce the productivity per unit area in forestry and agriculture sectors and threaten biodiversity in ecologically fragile systems. Various methods have been applied to control the weeds among which application of fungal pathogens is now seen as a potential alternative in this direction. With this view, the present study was undertaken for the screening of pathogens of *Lantana camara* and *Parthenium hyterophorus* for assessing their ability as potential biocontrol agents against these weeds. Effect of different herbicides integrated with fungal pathogens was also analysed. Seven fungi namely *Cladosporium herbarum, Phomopsis archeri, Fusarium solani, Alternaria alternate, Fusarium moniliforme, Curvularia lunata* and *Colletotrichum gloeosporioides* were isolated from Lantana camara and 02 pathogens namely *Sclerotium rolfsii* and *Alternaria alternata* from the *Parthenium hyterophorus.* Isolated pathogens were tested as bio-control agent against their host weed. Herbicides viz. paraquat, glyphosate, 2, 3 D, atrazine, pendimethalin and alachlor were tried against the weeds as well as in combination with fungal pathogens.

**Scientific findings and contents**

*C. gloeosporiodes* killed 92.59% of the inflorescence while *P. archeri* killed all the inflorescences of *Lantana camara, while Sclerotium rolfsii* was found effective against *Parthenium hysterophorus*. All the herbicides used in the present study were toxic to all the fungal pathogens tested. Thus, the application of herbicide and pathogen must be sequential. However, integration of glyphosate with *Phomopsis archeri* for field trials against *Lantana camara* may be conducted. *Sclerotium rolfsii* can be employed for controlling *Parthenium hysterophorus* plants, which are less than one month old. However, the host specificity testing must be conducted before wide scale use.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Fungal pathogens can be used for the effective management of weeds. For killing of *Lantana* and *Parthenium* plants, sequential sub-lethal dose of herbicides followed by pathogen application may be used. However, host specificity testing and efficacy of pathogens and herbicides need to be tested in field condition.

10. **Interaction between *pseudomonas fluorescens* and AM fungi on *dendrocalamus strictus***

**Principal Investigator:** Dr. Y. P. Singh, Scientist E, Forest Research Institute, Dehradun

**Duration:** 2010-2015

**Critical analysis of the research theme and summary of the study**

This project was undertaken to study the interacting effect of *Pseudomonas fluorescens*, AM fungi (*Glomus etunicatum*) and NPK fertilizer on growth attributes of *Dendrocalamus strictus,* an economically important bamboo species under controlled condition. Bacterial isolates were collected from rhyzosphere soil of the *Dendrocalamus strictus* stand from different places in the states of Uttarakhand, Punjab and Haryana. Biochemical properties of these isolates were studies. Various experiment to study the interaction effect with and without combination of the said constituents on growth parameters of the bamboo species were conducted. Results of effect of individual and integrated constituents were recorded. Growth promoting and biocontrol properties of 127 fluorescent *Pseudomondas* isolates and *Glomus etunicatum* were studied. Amongst the bacterial isolates, P solubilization, siderophore and HCN production potential was also studied.

**Scientific findings and contents**

Biochemical characterization of fluorescent *Pseudomonads* showed that out of a total of 84 isolates, only 14 were of *Pseudomonas fluorescens* and 56 of them were of *Pseudomonas putida.* This indicates that *Dendrocalamus strictus* rhyzosphere support the growth and biocontrol population of fluorescent *Pseudomonads*. Growth attributes of *Dendrocalamus strictus* in terms of collar dia., height, shoot weight, rhizome number and weight and P content were found higher in case of inoculation of *Pseudomonas fluorescens* and *Glomus etunicatum* individually in comparison of the control. However, co-inoculation of these microbes along with half dose of NPK was found most effective showing synergistic effect on the growth attributes.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Combination of *Pseudomonas fluorescens, Glomus etunicatum* and half dose of NPK may be tested in field for large scale plantation of *Dendrocalamus strictus* in waste land particularly deficient in Phosphorus.

11. **Biocontrol potential of native isolates of entomopathogenic nematodes for management of insect pests of teak**

**Principal Investigator:** Dr. Nitin Kulkarni, Scientist –G, TFRI, Jabalpur
**Co Principal Investigator:** Dr. N. Roychoudhury, Scientist –G, TFRI, Jabalpur

**Duration:** 2011

**Critical analysis of the research theme and summary of the study**

The project focuses on the evaluation of bio-control potential of native entomopathogenic nematodes (EPN) isolates from central India against the defoliator insect pest of teak and determination of best effective combination/ formulation of the selected EPN and its efficacy against target pests. Bio-efficacy of six native (TFRIEPN- 15, 23,49,50,56, 57) and two exotic (NBAII, Bangalore strains: *Heterorhabtidis indica* and *Steinernema carpocapse*) population against teak defoliator and skeletonizer larvae in laboratory and field conditions was tested. The native EPN isolates (*Steinernema dharanaii* n.r., TFRIEPN-15; *Steinernema* SPP., TFRIEPN-23,49,56,57; and *Heterorhabtidis* spp. TFRIEPN-50) have potential infectivity against teak defoliator and skeletonizer. Water and gel based formulation of EPN and insecticides were also tried for effective use against the target pest.

**Scientific findings and contents**

TFRIEPN- 56 and *H. indica* exhibited significantly superior mortality over control in teak skeletonizer larvae, even at the lowest dose of 3 $IJsL^{-1}$. TFRIEPN- 23, 50, 56 and *S. carpocapsae* required minimum dose of 10 $IJsL^{-1}$ to exhibit significantly superior mortality in teak defoliator. Except TFRIEPN- 56, other EPN population showed dose –dependent mortality with over 80% larval mortality at and above 3 $IJsL^{-1}$. Lower than recommended concentration of chlorpyriphos 20% EC (0.02%), imidacloprid and monocrotophos when combined with two EPN doses; 5 an 10 IJs $L^{-1}$, exhibited significantly higher mortality in teak skeletonizer and defoliator larvae as compared to insecticides and IJs alone. Higher mortality in teak defoliator and skeletonizer was exhibited by combination of all EPN populations including exotic population as compared to sole insecticides and EPN of that respective experiment. In field mortality was significantly higher in gel formulation of 1% as compared to water based formulation of 100 IJs $ml^{-1}$. Increase in the concentration of gel negatively affected mortality.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Combination of entomopathogenic nematodes (EPN) with lower doses of safer and recommended insecticides, either in water based formulation or in 1% gel formulation, may be used against the target pest.

12. **Innovative approaches for augmentation of composting and biofertilizer production in hot arid regions**

**Principal Investigator:** Dr. K. K. Srivastava, Scientist – F
**Co Principal Investigator:** Dr. Sangeeta Singh, Scientist– D and
Dr. Neelam Verma, Scientist- B

**Duration:** 2011-2015

**Critical analysis of the research theme and summary of the study**

The purpose of the study was to reduce the rotation period of composting/ vermicomposting by using indigenous bio-agents (Fungi and Bacteria) for rapid decomposition of plant waste material and also to develop technology package for forest nurseries. The compost and vermicompost samples were analysed for microbial status. The total number of thirteen mycoflora i.e., *Aspergillus niger, A. flavus, Alternaria* sp., *Mucor* sp., *Tichoderma viride, Trichoderma* sp., *Fusarium* sp., *Acremonium* sp., *Penicillium* sp., *Coprynus* sp., *Actinomycetes, Mycela strila* and Bacterial colonies (unidentified) were isolated and identified.
Microbial population was recorded at different depth of composting heap. *Aspergillus niger, A. flavus, Trichoderma, Mucor* sp. and *Penicillium* sp. Were found dominant, *Mycelia strila* and bacterial colonies were common and other microflora were found rare at various depth of the compost.
In the litter of different tree species namely Khejri *(Prosopis cineraria),* Neem *(Azadirachta indica),* Khari badam *(Terminalia catappa), Alestronia* sp. and Ashok *(Polyanthia longifolia)*, total ten fungi *i.e., Alternaria alternata, Phoma* sp., *Aspergillus flavus, A. niger, Curvularia* sp., *Colletotrichum* sp, *Cercospora* sp., *Fusarium* sp., *Trichoderma sp.* and *Phyllosticta* sp. were isolated and identified. Saprophytic fungi *i.e., Aspergillus flavus, A.niger, Fusarium* sp. and *Trichoderma* sp. were found commonly in all the tree species. About six pathogenic fungi were also isolated. *Elseniafetida* (Red earthworm) was selected for the study. Microorganisms were found responsible in decreasing the duration of compost preparation and within 50 days compost was ready to be used.

**Scientific findings and contents**

Various bedding material namely, neem leaves + cow dung, *Alestronia* dried leaves + cow dung and mixed leaves + cow dung completed vermicomposting cycle within 45-60 days whereas, Cordia *myxa* couldn't decompose completely even after 120 days. In various treatments of vermicompost samples, the organic carbon (OC) ranged between 4.5-5.13mg/kg, organic matter (OM) ranged between 7.758 - 8.792 mg/kg, Ammonia (NH4) 13.493- 21.463 mg/kg and nitrate (NO3) was ranged 90.277-103.344 mg/kg. In anaerobic composting (pit method) with the amendment of indigenous strain of *Trichoderma viride* (500gm in 20 kg FYM) + PSB (250ml in 20 lit. of water) and dried leaves, the composting process took 90 days compare to traditional process, which takes 120 days in winter. The nutrient status and microbial population was also recorded high with the amendment of *Trichoderma* and PSBs.
The seedlings treated with *Rhizobium* + *Trichoderma viride* + *Bacillus thirungiensis* (BT) was found best enhancing growth and vigour of *P. cineraria* and *Dalbergia sissoo* seedlings. In case of *Ailanthus excelsa* (ardu) combination of AM + *Azosprillum* + PSB was found best as compare to other treatments.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The findings can be utilized by farmers, NGOs and state forest department for rapid decomposing process by using indigenous bio-agents for hot arid region

13. **Evaluation of antifungal potential and identification of broad spectrum antifungal compound from selected tree/shrubs/weeds of Indian arid region**

**Principal Investigator:** Bhawana Sharma
**Co Principal Investigator:** Dr. K. K. Srivastava and
Dr. Mala Rathore, AFRI, Jodhpur

**Duration:** 2009-2015

**Critical analysis of the research theme and summary of the study**

Fungal infection of plants is a major problem. This results in huge economic losses. Continual treatment of plants with chemical fungicides leads to the formation of stable residues containing high concentration of metals which remain in the soil for long periods and adversely affect soil fauna and flora. Therefore, in the present study the inhibitory effect of different plant extract against five plant pathogenic fungi (*Rhizoctonia solani, R. bataticola, Fusarium moniliforme, Fusarium solani* and *Alternaria alternata*) was evaluated. The seven plant species used were *Balanites aegyptiaca, Tephrosia purpurea, Citrullus colocynthis, Tribulus terrestris, Agremone Mexicana, Solanum xanthocarpum and Datura stramonium*. After study of antifungal activity of all seven species it is found that the antifungal properties of certain species only target a limited number of fungi. Likewise, one extract which inhibit growth of certain species of fungi don't show any inhibition against other fungi. The effectiveness of the plant extract varies according to fungus species. All fungi which responded to plant extract shows inhibition percent varied according to concentration of extract. With increase in concentration of extract an apparent increase in antifungal activity was observed in all extract. In most of plant extract evaluated in this project showed that ethanolic extracts perform more antifungal activity against the targeted fungi as compared to aqueous extract which showed limited antifungal activity. Ethanolic extract of *Datura stramonium* leaves has been identified with most potent broad spectrum antifungal activity among all the tested extracts.

**Scientific findings and contents**

Maximum antifungal activity was shown by leaf and minimum antifungal activity was shown by root of *Datura stramonium.* In case of *Balanites aegyptiaca* prominent antifungal activity was shown by leaf and fruit than root and bark. The ethanolic extract of *Balanites aegyptiaca* leaf exhibit maximum inhibition against *Rhizoctonia solani* (68.3%) followed by *Fusarium solani* (54%). Extract of *Tephrosia purpurea* leaves and fruit showed higher antifungal activity while flower and root extract could not show significant antifungal activity against target fungi. The ethanolic extract of *Tephrosia purpurea* leaves exhibit maximum inhibition against *A. alternata* (82%) followed by *Rhizoctonia solani* (73%). Extract of *Citrullus colocynthis* fruit and leaves showed prominent antifungal activity while flower and root extract could not show significant antifungal activity against target fungi. The ethanolic extract of *Citrullus colocynthis* fruit exhibit maximum inhibition against *A. alternata* (78%) followed by *Rhizoctonia solani* (74%). Extracts of leaves and fruits of *Tribulus terrestris* showed greater antifungal activity than flower and root against target fungi. The ethanolic extract of *Tribulus terrestris* leaf exhibit maximum inhibition against *Fusarium solani* (72%). *Argemone mexicana* fruit showed better antifungal activity than root. The maximum inhibition percentage with ethanolic extract (50%) for *Rhizoctonia solani,* was 70%. *Solanum*

*xanthocarpum* fruit showed maximum antifungal activity while root showed least antifungal activity. The ethanolic extract of *Solanum xanthocarpum* fruit exhibit maximum inhibition against *Rhizoctonia solani* (82%) followed by *Alternaria alternatea* (73%).

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The present study leads to the conclusion that ethanolic extract of *Datura stramonium* contain significant antifungal potential against some important plant pathogenic fungi and thus could be used as alternate of chemical fungicides for management of fungal infection in plant. The current investigation also leads to source of new antifungal compound in future.

14. **Screening of poplar genotypes against *alternaria alternata* toxins**

**Principal Investigator:** Dr. Y. P. Singh, Scientist E, and
**Co Principal Investigator:** Dr. Vineet Kumar, Scientist E, FRI, Dehradun

**Duration:** 2011-2014

**Critical analysis of the research theme and summary of the study**

Clones of Poplar are susceptible to various diseases caused by fungal pathogens. The *Alternaria alternata* is one amongst such fungal pathogens, which causes leaf spot as well as tip blight in the Poplar resulting in to losses of economic significance. Therefore, the present project was undertaken to screen the 04 commercial clones of *Populus deltoids* namely G-48, WSL-39, Uadi and WSL-22 for their susceptibility/resistance towards *Alternaria alternata* infection. For this purpose, toxins from 37 strains of *Alternaria alternata* were isolated and used for developing pathogenic symptoms artificially on the host leaf and juvenile shoots and in turns screen the resistance/ susceptibility of the particular clone suitable for large scale plantations. DNA analyses (through RAPD) of the various strains of *A. alternata* was also carried out to study the variability and relatedness amongst of the virulent pathogenic strains.

**Scientific findings and contents**

A quick and reliable leaf bioassay method for 04 coomercial poplar clones (G-48, WSL-39, Uadi and WSL-22) was standardized against toxins of *A. alternata,* an emerging pathogens. The protocol is based on varied parameters of pathogen (isolate, virulence, concentration and volume of toxins) and host (clone, age, leaf portion). Base on the experiment, toxins of *A. alternata* strain Alt23 was found most injurious on G-48 clone of Poplar on higher concentration of 80-100% of crude toxin. Younger, pricked leaves were found more prone to the toxin and they exhibited earlier symptoms irrespective of pathogens strains. Highest genetic distance was noiced between pathogen isolate no. Alt21 and Alt22.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Toxin bioassay method may be useful in quick screening of resistance in various clones of poplar against infection by the *A. alternata.* This method can also be applied for screening virulence of those pathogens, which produce host specific toxins.

15. **Selection, evaluation and identification of efficient bio-inoculats for quality seedling production of selected fast growing native tree species**

**Principal Investigator:** Dr. V. Mohan, Scientist - E, and
**Co Principal Investigator:** Dr. A. Karthikeyan, Scientist - D, IFGTB, Coimbatore

**Duration:** 2009-2012

**Critical analysis of the research theme and summary of the study**

In the present project, efforts have been made to study the status of beneficial microbial diversity associated with six fast growing native forestry tree species viz. *Ailanthus excels, A. triphysa, dalbergia latifolia, Gmelina arborea, Melia dubia and Neolamarckia cadamba*. Isolates of Plant Growth Promoting Rhizobacteria (PGPR-26) and Arbuscular Mycorrhyzal (AM-25) fungi were made and maintained at in lab at IFGTB. All the PGPR were screened for their IAA production and phosphate solubilization efficacy in *in-vitro* condition. Further, the potential isolates were screened for their efficacy on growth promotion of the selected tree species. Persistence of the inoculated PGPR and AM fungi was also determined. Molecular characterization of some of the PGPR was also carried out and the nucleotide sequences of 13 PGPR were submitted to EMBL and NCBI.

**Scientific findings and contents**

Results of the screening indicates that the combined application of all the PGPR (*Azotobactor, Azospirillum, Phosphobacteria*) and AM fungi had better growth performance over control. The specific triple and dual inoculation has also showed significant improvement in the growth of the seedlings, when compared to the control.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Use of superior AM fungal and PGPR bio-inoculants for improvement in seedling growth is advocated. The farmers, tree growers and SFDs may adopt the technique for intended benefit.

16. **Studies on *trichoderma* strains inhabiting different forest ecosystems of North East India**

**Principal Investigator:** Dr. Shailesh Pandey, Scientist – C
**Co Principal Investigator:** Dr. R.K. Borah, Scientist – F and
Dr. Gaurav Mishra, Scientist – C, RFRI, Jorhat

**Duration:** 2013-2014

**Critical analysis of the research theme and summary of the study**

The project was intended to know the status of species diversity of *Trichoderma* from the forest area of North East India comprising states of Manipur, Tripura, Arunachal Pradesh, Meghalaya and Nagaland covering tropical semi-evergreen forest, sub tropical pine forest, east Himalayan lower bhabar sal, secondary moist bamboo brakes, mixed forest and plantation forests, etc. so that the same may best be utilized as bio-control agents of diseases of forestry importance. These forests are dominated by the members of four important clades of the Trichoderma (Harzianum, Green spored, Viride and Asperellum/Hamatum) that contain the most promising bio-control agents. A total of 15 species were detected using phenetic characters and sequence analysis of internal transcribed spacer (ITS) region of rDNA. *T. harzianum, T. asperellum, T. virens, T. erinaceus*, and *T. koningiopsis* were found to be the major soil dwelling species. *T. reesei,* the anamorph of *Hypocrea jecorina*, was isolated from the cut stump of *Albizia* sp. and one unknown wood sample. One strain of *T. harzianum* was isolated from a polypore. One strain of *T. erinaceus* was isolated from bamboo culm. The other species detected were *T. viride, T. parareesei, T. longibrachiatum, T. hamatum, T. aureoviride, T. koningii, T. caribbaeum, T. ovalisporum,* and an unknown *Trichoderma* sp. Out of isolated species of the *Trichoderma*, the *T. harzianum* was tried for its efficacy as biocontrol agent against the seedling pathogen of *A. malaccensis*.

**Scientific findings and contents**

A total of 15 species were detected using phenetic characters and sequence analysis of internal transcribed spacer (ITS) region of rDNA. *T. harzianum, T. asperellum, T. virens, T. erinaceus*, and *T. koningiopsis* were found to be the major soil dwelling species. Lab-based studies demonstrated the effectiveness of *T. harzianum* against *Fusarium* sp. associated with the dying of *A. malaccensis*. *T. harzianum* was also found effective in field study and in greenhouse studies. *Trichoderma* treated *Aquilaria* seedlings planted at Medicinal and Aromatic Plant Garden, Panbari, Golaghat, did not show any symptom of wilting and dying even after 16 months of treatment, showing it as a potent bio-control agent.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Three *Trichoderma* strains have been deposited in National fungal culture collection of India (NFCCI accession number: 3990,3991 and 3992) Pune, and three strains deposited in Microbial culture collection (MCC accession number: 1291 1292 and 1293), Pune. Effective strains can be best utilized to develop Trichorderma based bio-formulations for use by the State Forest Departments, farmers and plantation companies.

17. **Counterbalancing the detrimental effect of Sponge Iron Factory Emitted Particulate Matters (SIFPM) with the protective effect of Vesicular Arbuscular Mycorrhyza (VAM) on the growth of seedlings of important tree species**

**Principal Investigator:** Dr. Rupnarayan Sett, Scientist –D
**Co Principal Investigator:** Dr. R. K. Verma, Scientist –E, TFRI, Jabalpur

**Duration:** 2010-2015

**Critical analysis of the research theme and summary of the study**

Sponge Iron Factory Emitted Particulate Matters (SIFPM) are comparatively more harmful to the vegetation in comparison to the SPM from other sources like Thermal Power Plant or other factories. Therefore, in order to see the potential of VAM inoculation on the growth of the tree seedlings in the SIFPM loaded soil, this project work was undertaken. Site of the study were in Raipur and Rajgarh in Chattishgarh and Ghugus in Maharashtra. In the present study, 10 tree species namely *Tectona grandis, Azadirachta indica, Scleichera oleosa, Embilica officinalis, Peltaforum ferrgneum, Butea monosperma* and *Gmelina arborea* were considered. Biochemical parameters like foliar phenol, proline, ascorbic acid, carbohydrates, chlorophyll and soluble protein were estimated from the leaves of seedlings under various treatments to see the content profile. Growth data in terms of height, collar dia, nos. of leaf and number of branches were considered for inferring the result.

**Scientific findings and contents**

Findings indicate that VAM treated plants performed the best while only SIFPM treated plants were poorest performers. This also indicates the SIFPM is causing ill effect on the plant growth and the VAM is effective in reducing the ill effect of SIFPM on plant growth. The amount of phenol, proline and carbohydrate were found higher in the toxic SPM treated plants than the control and VAM treated and reverse trend was evident in case of the amount of chlorophyll, ascorbic acid and soluble protein.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

VAM inoculation in SIFPM loaded soil has been found useful in reducing the ill effects of pollutant on the growth of the plants. This practice may also prove helpful in case of other plants and pollutants as well.

18. **Biodiversity of wood inhabiting fungi in the rainforest of Makutta, Western Ghats**

**Principal Investigator:** Dr. A. Muthu Kumar Arunachalam, Scientist – C
**Co Principal Investigator:** Shri Y. B. Srinivasa, Scientist – E, IWST, Bengaluru

**Duration:** 2009-2012

**Critical analysis of the research theme and summary of the study**

The present works was undertaken to quantify the taxonomic diversity of wood inhabiting macrofungi in the Dipterocarp forests of the Central Western Ghats at Makutta, their seasonal variation and to develop a manual for field identification of macrofungi of the study area. The region falls in low altitude rainforest in Karnataka. The study was conducted following transect of 50x20m. The specimens of macrofungi were collected in pre-monsoon, Monsoon and post-monsoon seasons. The fungal specimens were characterized, photographed and preserved.

**Scientific findings and contents**

A total of 50 species of macrofungi belonging to 29 families and 38 genera were recorded from pre-monsoon, monsoon and post-monsoon seasons. Monsoon and Post monsoon seasons showed the highest diversity of the macrofungi. Species recorded mostly belongs to the order Polyporales under the class Basidiomycetes and order Agaricales of the class Agaricomycetes. *Aborteporus biennis, Calastoma cinnabarina, Coprinus comatus, Pseudofistulina radicata and Stereum ostrea* were reported for the first time from the Western Ghats. Amongst the macrofungi recorded from the study area, many are saprobic in nature, while some are plant pathogenic and few are reported as poisonous and medicinal mushrooms.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

A manual has been printed and published on, 'A field guide to Macrofungi of Makutta, western Ghats' for the benefit of the end users.

19. **Anti-insect secondary metabolites from fungal endophytes of selected tree species**

**Principal Investigator:** Dr. N. Senthilkumar, Scientist-D, IFGTB, Coimbatore
**Co Principal Investigator:** Dr. S. Murugesan, Scientist-G, and Dr. V. Mohan, Scientist-F, IFGTB, Coimbatore

**Duration:** 2011-2014

**Critical analysis of the research theme and summary of the study**

The losses of crops and yield caused by insects are quite high due to which synthetic organic insecticides have emerged as chief major tools of pest management. The use of endophytic microorganisms to control insect pests and pathogens is receiving increased attention as a sustainable alternative to synthetic pesticides. In the present study, an attempt has been made to isolate and identify endophytic fungi of entomopathogenic significance from native tree species viz. *Tectona grandis, Ailanthus excelsa* and *Gmelina arborea* and also to screen their secondary metabolites of anti-insect properties to develop novel insecticides. A sum of 18 species of endophytic fungi belonging to 13 genera and 58 strains were isolated from young and mature leaves of *T. grandis, Ailanthus excelsa* and *Gmelina arborea*. Teak leaves harbored 18 species of endophytic fungi belonging to 13 genera and 29 strains followed by 10 species with 7 genera and 17 strains were isolated from *Gmelina* leaves. *Aspergillus flavus, A. niger, Botryodiplodia theobromae, Nigrospora sphaerica, Colletotrichum gleosporidies, Phyllostica sp., Clasporium cladosporioids, Phomopsis sp., Phoma sp., Alternaria sp.* are some of the major endophytic fungi isolated from the leaves of teak, *Ailanthus* and *Gmelina*. The genera, *Fusarium* and *Aspergillus* are dominant among the 13 genera isolated. Among them *A. flavus, N. sphreica, B. theobromae* and *Phomopsis sp.,* were found to have entomopathogenic significance.

**Scientific findings and contents**

Characterization of extracts of the fungi revealed that the compounds namely, dodecanoic acid (Lauric acid) (18.02%), tricyclo undecane 1-bromo (adamantine derivative) (9.56%) in *A. flavus* extract and benzoic acid-2(methylthio methyl ester) (25.04%), 2,5,cyclohexadiena-1,4-dione, 2-(1,1-dimethyl) (Duroquinone) (17.81%), 2-(2-cyanoethyl) 3-isopropyl 4 and 5-cyanoisoxazolidine (9.19%) in *N. sphaerica* extracts recorded as major compounds which are not reported in endophytic fungi earlier, might have shown promise to use as a source of insecticide. Dodecanoic acid ethylester, phthalic acid, octyl 2-pentyl ester isolated from *Phomopsis sp.* might be the reason for insecticidal activity of *Phomopsis sp*. A compound namely, 1-(2'desoxy-3'5' octetraisopropyldisiloxane, 3diyl3-beta riborotroxy) is recorded as a major compound with 77.75% in *Phomopsis sp.* Compounds namely, 3-methyl-3-benzofyranyl (14%), (3R*, 4S*)-3-(2-Nitro-4-methoxyphenyl) (8%) and (2,4-Dimethoxyphenyl) phenylphosphin (8%) were found to be major constituents in the extract of endophytic fungus *B. theobromae*. The presence of phytochemicals such as dodecanoic acid ethylester, phthalic acid, pentyl tridec-2-yn-1, phthalic acid, butyl tridec-2-yn-1 might be the reason for insecticidal activity of *B. theobromae*. Compounds such as cycloheptasiloxane tetramethyl and cyclobutanecarboxylic acid were found to be reported first time from endophytic fungus B. theobromae. The extracts of these fungi were evaluated against teak and *ailanthus* defoliators viz. *H. purea, E. narcissus indica* and *A. fabriciella* found to have 65-89% mortality.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Endophytic fungi offer great potential in plant protection, imparting tolerance against several biotic and abiotic stress factors. Endophytic fungi of entomopathogenic significance viz. *A. flavus, N. sphareica, B. theobromae, Phomopsis sp.,* and *Phoma sp.,* may be considered as potential biocontrol against early developmental stages of insect pests of forestry importance since their extracts contain compounds of various anti-insect properties. However, endophytic-host interactions may turn to a pathogenic interaction, if susceptibility of host and/or virulence of the endophytic increase. However if the metabolites responsible for the beneficial effect can be isolated and exploited, then the risk of pathogenicity can be avoided. Structural elucidation of secondary metabolites will help in defining modes of action as well as in preparation of right formulations for field application.

20. **Integrated management of vascular wilt disease of *azadirachta indica* (neem), *emblica officinalis* (amla), and *gmelina arborea* (khamer) in forest nurseries**

**Principal Investigator:** Dr. K.K. Soni, Scientist – E
**Co Principal Investigator:** Dr. R.K. Verma, Scientist – E, TFRI, Jabalpur

**Duration:** 2010

**Critical analysis of the research theme and summary of the study**

The major objective of the project was to develop integrated management plan for control of vascular wilt disease. The integrated approach was evaluated with minor modification of sanitation and cultural practice along with effective dose of systemic fungicides for production of healthy seedling stock. Incidence of wilt in *Emblica officinalis* (Amla), *Azadirachta indica* (Neem) and *Gmelina arborea* (Khamer) was surveyed in different forest research and extension nurseries located in Madhya Pradesh and Maharashtra. Commercially available fungicide was screened in different concentration to find out appropriate dose that kills the pathogen under laboratory and field conditions. Integrated approach involved the potentially growing the culture of *Trichoderma* as bio-control agent and solarization of nursery bed/ potting mixture with mild treatment of systemic fungicides (0.05-0.1% Bavistin/ ridomil 0.1% / Dithane M45 0.2%). The fungicide Ridomil commercially available from Syngenta (Metalaxyl - M (Mefenoxam) 04% + Mencozeb 64% WP) gave good results in 0.1 % and 0.2% concentration depending upon the severity and extent of damage. Ridomil 0.1 % was used to drench soil and potting mixture to prevent inoculum build up which later on cause vascular wilt whereas Ridomil 0.2% was used to treat infected seedlings.

**Scientific findings and contents**

The disease incidence was recorded between 06-26% in different provenances and different species. Incidence of wilt was highest in Khamer followed by Neem and Amla respectively. The vascular wilt disease incidence caused by *Fusarium solani* was recorded in grafted Amla in Research and extension Nursery Seoni and Balaghat districts of Madhya Pradesh. The disease was managed in cultivated varieties of Amla wilt with monthly spray of Ridomil (Metalaxyl-M (Mefenoxam) 04% + Mencozeb 64% w.p.) 0.2% regular cleaning and modification of watering schedule to avoid predisposing factor. In case of neem ten provenances of Neem have been evaluated against vascular wilt disease. Out of ten provenances Bargi was found more susceptible as compare to other provenances. Infection of wilt due to *Fusarium solani* was successfully managed with Ridomil 0.2%

sprays at monthly intervals and avoid extra shade during the month of August- September. On the basis of nursery experiments it is recommended that fungicides metalxyl + Mencozeb (Ridomil) or Carbendazim (0.2%) should be applied at regular intervals during June-August when monsoon activity is high to control the vascular wilt disease of Amla in nursery. Bavistin 0.2% was found quite effective against wilt pathogen when good sanitation practices were strictly followed. Maintaining proper aeration and moisture level in potting mixture are the preventive measures to manage or minimize the disease.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Integrated plan was found effective for management of wilt diseases of the host plant in nursery. Therefore, the same may be extended to the farmers, SFDs and other nursery growers.

21. **Investigations on fungal diseases and insect pests in forest nurseries of selected forestry species and their management**

**Principal Investigator:** Dr. H. C. Nagaveni, Scientist E
**Co Principal Investigator:** Dr. R. Sundararajan, Scientist F, IWST, Bengaluru

**Duration:** 1997-2012

**Critical analysis of the research theme and summary of the study:**

In the present study, attempts were made to study the diseases and pest problems and their management in the selected plant species. The plant considered for the study were *Dysoxylum malabaricum Bedd., Garcinia gummigata (L.) Robson, Myristica malabarica Lam., Vateria indica* L.*, Azadirachta indica* A. Juss*, Pongamia pinnata, Emblica officinalis* Gaertn. and *Sapindus emarginatus* Valph. Periodical observations reveal that leaf spot and blight were common disease found in all nurseries. Leaf spot was very severe in Bangalore area and blight was common in Western Ghat nurseries with 100% severity. Disease starts manifesting from July onwards and reaches peak in October-November and starts receding from December onwards. In Western Ghat area, blight was common in all season with little variation in severity in different duration. Neem is free from disease. Causal organisms viz. *Fusarium, Pestalotiopsis, Colletotrichum gloeosporioides* and *Alternaria* species were identified from infected seedlings.

Entomological studies show that insect population varied with location and season. Hebbal nursery possesses 46%, followed by Sulikere, 32%, Udane 12%, and Medinadka 9%. Total 12 different species of insects were found associated in different nurseries. Among them *Homeocerus* sp. and *Trilophidia annulata* were present throughout the year. *Myllocerus viridanus* and *Lamprosema niphaelis* were prevalent during November to May. *Myllocerus viridanus* was found in the month of August and *Lamprosema niphaelis* was skeletonising the plant severely (more than 70%). Infestation was more severe in plains when compare to nurseries of Western Ghat area. Control measures using pesticides such as Deltamethrine, Azadiractine, Imadaclopride, Manocrotophos, Chlorophyiphose and Cypermerthrine were tried.

**Scientific findings and contents**

The study revealed that a wide diversity of mycoflora and entomofauna are associated with seeds

and seedlings of the selected plants. From the control measure experiment, it was found that disease could be controlled up to 80% with botanicals like *Cleistanthus collinus* and *Prosopis juliflora* leaf and bark extract. Out of all pesticides, Chlorophyriphose was most effective (60%) against the various entomofaunal pests.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Present study clearly demonstrates that extracts of P. *juliflora* and *C. collinus* have better use as biofungicide to control disease in seedlings. Chlorophyriphose was found effective against various entomofaunal pests. Use of the same have been advocated.

22. **Diversity of mycorrhizal associations with *Dipterocarpus* and *Shorea*species in Assam**

**Principal Investigator:** Dr. Ashwani Tapwal

**Duration:** 2012

**Critical Analysis of the research theme & summary of the study**

The species of *Dipterocarpus* and *Shorea* are very important for the requirement of timber and wood in the northeast region of India. Although, the natural regeneration of these species is good, but to meet the demand, various afforestation and reforestation programmes are being undertaken, where mycorrhizae play an important role in establishment, survival and growth of these species. This project was aimed to study the diversity of mycorrhiza and its efficacy for the improvement in the growth of seedlings in nursery and field trials. The diversity of mycorrhizal fungi was studied in lower Assam (Amsoi, Kulsi and Dhupdhara) for *Shorearobusta* and in upper Assam (Jeypore, Digboi and Margerita) for *Dipterocarpusretusus* and *Shoreaassamica*.Ectomycorrhizal, AM and other macrofungi were recorded. The seedling of *Dipterocarpus*and *Shorea*were inoculated with mycorrhizal fungi at the time of seed sowing. The present study gives information on the mycorrhizal, saprophytic and parasitic fungi associated with *D.retusus* and *S.robusta* in the forests of Assam along with the technique of inoculation and efficacy of mycorrhizal fungi in the improvement of growth of the selected species.

**Scientific findings & contents**

- More than 15 mushroom species were ectomycorrhizal on selected host species.
- Russula and Amanita were found associated with all of selected tree species irrespective of study sites.
- Since *R.amoena* was dominant among all species, it was selected as for nursery applications. The pure cultures was raised on wheat grains.
- An inventory of macrofungi associated with *Dipterocarpus* and *Shorea* was prepared. More than 30 fruit bodies of other macrofungi were collected. Most of these fungi were saprophytic and found growing soil or dead plans debris and seems to be secondary colonizers.
- Eleven AM fungal species belonging to four genera (*Acaulospora, Glomus, Gigaspora, Sclerocystis*) were recorded from the rhizosphere soil of selected tree species. Irrespective of tree species the percent colonization and spore density was highest in rainy season followed in winter and summer seasons. Since *Glomus* was dominant genus representing five species, highest relative occurrence frequency, therefore selected for mass multiplication and nursery

applications. Due to obligatory association of AM fungi, the mass inoculum has been raised with living host (wheat) in earthen pots.

- Maximum increase has been observed for the seedlings inoculated with ectomycorrhiza followed by seedlings inoculated with ecto and endomycorrhiza inoculated with endomycorrhiza alone and minimum in control.
- Artificial inoculation of *Dipterocarpus* and *Shorea* seedlings with a specific mycorrhizal fungus produced better seedling growth and development and produced quality seedlings, which had better survival rate in field conditions, is advisable.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Research findings can be used in mycorrhizal inoculation programmesin nursery for the selected tree species.

23. **Effect of Potassium Application on Diseases and Pests in *Gmelina arborea* Roxb. grown under Chhotanagpur Plateau Soils**

**Principal Investigator:** Dr. S. Nath

**Duration:** 2014

**Critical Analysis of the research theme & summary of the study**

*Gmelinaarborea* Roxb., known for its reliable timber quality is a common species of Jharkhand. The species in its natural habitat and plantations is reported to be infested by defoliators, stem and shoot borer, sap suckers and leaf mining caterpillars in addition to some diseases like leaf spot, root rot, stem rot, leaf and shoot blight, etc.Nutrients may either increase or decrease the resistant of the tolerance of plants to pathogens and pests depending on the type of nutrient, the nutritional status of soil and the plants. Mineral fertilizer application may thus substitute or at least reduce the demand of chemicals for disease and pest control.In the present study major diseases and pests associated with *G.arborea* in nursery and plantations of Jharkhand was identified relation between disease and pest infestation in the species and soil and plant nutrient status with special reference to potassium was studied.

**Scientific findings & contents**

- Based on symptoms of insect attack and infestation by pathogens and damage caused, the severity indices were worked out and correlated with the soil and plant nutrient status.
- A number of insect/ pests belonging to stem borers, leaf miners, defoliators, sap suckers and root feeding insects associated with *G.arborea* were identified. Three fungal pathogens responsible for leaf spot, root rot, leaf and shoot blight and stem rot have also been identified.
- Soil and foliar K and Ca levels maintained negative relationships with the most of the damage parameters as well as overall severity of symptoms associated with the insect attack and infection by pathogens.
- It was observed that severity of disease symptoms strongly decreases with increase in K content of the leaves. Potassium deficient plants are most susceptible than K-sufficient plants to parasitic disease of both facultative and obligatory parasites of bacterial and fungal origin.

- The role of N in increasing the susceptibility of host plants to obligate fungal parasites is a matter of great concern.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The research outcome provides valuable information and guidelines for formulation of integrated pest and disease management for *Gmelinaarborea* in Jharkahand.

24. **Studies on root rot and stem decay diseases in *Acacia* catechu and their control**

**Principal Investigator:** Dr. R.K.Verma, Scientist-F

**Duration:** 2012

**Critical Analysis of the research theme & summary of the study**

In Madhya Pradesh and Maharashtra khair mortality was observed in 9-20 years old plantations due to root rot disease caused by a fungus, *Ganodermalucidum* which varies from 0-93% in both states. In the present project khairmortaliy in central india particularly, in Gwalior forest circle in Madhya Pradesh and Yavatmal circle in Maharashtra was studied and fungi associated with*Acacia catechu*were identified. Study for assessing the losses due to disease in *A. catechu* and identifying preventive measures were also the objectives. Many of the inferences were drawn from the information gathered from secondary sources.

**Scientific findings & contents**

- The disease can be suppressed by drenching with an aqueous solution (10 L water) of 500 g urea and 250 g superphosphate per tree along with 0.2% Bavistin.
- *Fusarium* sp. also caused 5% mortality in one year old plantation at Akoli beet, Pandherkawda (MS).
- Total 18 fungi were found associated with different stages of khairmortaliy which include 6 fungi, namely *Haplopilusnudulans, Lenzitespisolotii, Monodictyscastaneae, Resinicium bicolor, Rigidoporusvinctus* and *Trameteshirusita* recorded for the first time on khair from Central India.
- There was little mortality in Thane circle, particularly in Khairagarh, Durvesh and Haloli ranges, therefore these areas need to be encouraged for khair plantation and preservation of existing plantations.
- The mortality can be minimized by avoiding pure plantation.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

More experiments and studies are needed

25. **Utilization of Vesicular Arbuscular Mycorrhizal diversity for the quality stock production of some useful forest plant/s species of Nongkhyllem Reserve Forest, Nongpoh, Meghalaya, India**

**Principal Investigator:** Dr. Vipin Parkash, Scientist-E

**Duration:** 2012

**Critical Analysis of the research theme & summary of the study**

The endomycorrhizal status of Nonkhyllem Reserve Forest, Nongpoh, Meghalaya and predominant native VAM strain for future bio inoculation of seedlings for the production of quality stock in nurseries and their better survival in adverse conditions was studied in this project. Due to this overexploitation and other biotic stresses the rhizospheric microbial diversity is also affected and results in disappearance of many useful strains of rhizospheric microflora. Nine survey tours were conducted to visit forest ranges for the collection of useful plants and rhizospheric soil samples. A total of 117 rhizospheric soil samples along with plants of these two ranges namely Umtasor and Nongpoh were collected.

**Scientific findings & contents**

- There are a total of 63 families have been reported with 116 genera and 117 species. The dominant families are grouped into six positions.
- The families, Asteraceae and Euphorbiceae were represented by 6 genera and 6 species. Next was Rubiaceae with 5 genera and 5 species. Others were Acanthacea, Fagaceae, Lauraceae, Verbenaceae and Labiataeare with 4 genera and 4 species except one family i.e. Acanthaceae is represented by 3 genera only.
- All 117 collected rhizospheric soil samples were screened for endomycorrhizal qualitative and quantative analysis.
- The low E- conductivity (6.66) in rhizospheric soil was observed in Eryngiumfoetidum.
- The high conductivity (199.7) was observed in Trevesia sp.
- Analysis of per cent organic carbon of rhizospheric soil samples showed the range from 0.09% (lowest in *Macarangia denticulate*) to 3.48% (highest in *Aquilariaagallocha*)
- The quantification of AM spore numbers showed the range from 7 (lowest) in *Caryotaurens*to 903 (highest) in *Solanumkhasianum*.
- Per cent total colonization in roots was also low in scrubs and trees than herbs and shrubs.
- Climbers were having the high total colonization in roots.
- The plant species according to different compartments and GPS data along with the elevation of Nongkhyllem Reserve Forest, Nongpoh was also analyzed.
- The lowest elevation was 432amsl observed in Diphu-sydang compartment of Nongpoh range
- The highest elevation 628 amsl was recorded in Mawdkhar compartment of Umtasoar range.
- The endomycorohizal inoculation improves the quality stock production of Aquilaria agallocha seedlings than non-inoculated control seedlings.
- The *Acaulospora* species treatment was best single/alone treatment of Endomycorrhizal inoculation followed by Glomus species +*Acaulospora* species synergistic treatment for quality stock production of *Aquilaria agallocha* seedlings.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

For conserving rhizospheric microflora (VAM fungi i.e. *Glomu*s sp. and *Acaulospora* sp.) and some

useful forest plant/species this study was done by employing VAM technology so that the useful forms of microbes could not be lost irrevocably. With the help of this technology, some of useful plant/species were cultivated by incorporating with VAM inoculation so that exploitation stress can be lessened for meeting the future needs. The identified bioinoculants may be applied in nursery for raising better planting stock.

26. **Disease spectrum of arid zone tree species**

**Principal Investigator:** Dr. K.K. Srivastava, Scientist-D

**Duration:** 2002

**Critical Analysis of the research theme & summary of the study**

Survey of pathological problems in forest nurseries and plantations of arid and semi-arid tree species was undertaken. Fungicidal and silvicultural management was evolved for economically important diseases. Major and minor diseases of arid zone tree species such as*Acacia nilotica, Prospis cineraria, Tecomellaundulata, Dalbergiasissoo* and other important tree species of arid and semi-arid zone was surveyed.

**Scientific findings & contents**

- On neem (*Azadirachtaindica*), seven nurseries diseases and two plantation diseases were recorded.
- Charcoal root rot in *Azadirachtaindica*, charcoal root rot in *Tecomellaundulata* and seedling blight in *Hardwickiabinnata*was recorded.
- Ganoderma root rot was reported as a serious disease in *Acacia tortilis*, *Albizzialebbeck*, *Dalbergiasisoo* and *P.cineraria*. The disease could be managed by making isolation trenches and soil drenching with Carbendazim.
- *Ailanthus excelsa* and *Prosopisjuliflora* are found resistant to this disease.
- Checklist of major and minor diseases in forest nurseries and plantations raised by State Forest Department Mehsana and Gandhinagar was prepared.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The results may be communicated to the stakeholders

27. **Studies on Fungal Infestation, Mycotoxin Elaboration and Induced Biochemical Changes in Edible Oilseeds of Forest Origin.**

**Principal Investigator:** Dr. Punam Kumari Singh

**Duration:** 2003

**Critical Analysis of the research theme & summary of the study**

**The present project** was undertaken to study the fungal infestation, mycotoxins and induced biochemical changes particularly the fatty acid content, starch and protein level associated with edible oilseeds of forest origin. Based on the economic and commercial potential, seed kernels of *Buchananialanzan Spreng* (Chironji), *Juglans regia* Linn. (walnut), *Prunus armeniaca* Linn. (Apricot) and *Shorea robusta* Gaertn. (Sal) were selected.

**Scientific findings & contents**

- A total of seven fungi viz., *Aspergillus flavus, A. niger, Alternaria alternate, Fusarium pallidoroseum, F. verticillioides, Pencillium citrinum* and *Rhizopus stolonifera* were isolated from fresh samples of oilseeds.
- Nineteen fungi were isolated from the stored samples of oil seeds.
- Nine fungi were recorded from the seed kernels of *B. lanzan*.
- Highest percentage incidence was recorded of *A. flavus* (35%) followed by *C. lunata* (15.4%), *A. niger* (13.5%) and *P. citrinum* (13.2%)
- Highest percentage incidence was recorded in case of *A. flavus* (25%) followed by *A. niger* (23.2%) and *A. ochraceus* (19.2%)
- Stored kernels of *Shorea robusta* exhibited presence of nine fungi. Highest incidence recorded was of *C. cladosporioides* (31%) followed by Phoma sp. (23.6%), *R. stolonifera* (23.3%), *A. alternata* (22.5%) followed by other fungi.
- *A flavus, A.niger* and *P. citrinum* were recorded as the most frequently occurring fungi in seed kernels of *B. lanzan, J. regia, P. armeniaca* and *S. robusta*

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Standardization of harvesting, collection and storage practices are required to avoid mould infection. Development of mechanism for grading healthy seed kernels and screening them for aflatoxins presence is important. Further research is needed in this direction.

28. **Studies on Improving tree productivity of *P.cineraria* through VAM/other Biofertilizers**

**Principal Investigator:** Dr. Neelam Verma, Research Officer

**Duration:** 2006

**Critical Analysis of the research theme & summary of the study**

In the present study diversity of AM association with *P.cineraria* under harsh arid environment / field condition was studied for improving productivity. The factors such as optimum population needed for maximum benefit, survival, establishment, dependency and growth of *P.cineraria* was investigated.

**Scientific findings & contents**

- The present results clearly indicates the diversity of AM association with *P.cineraria* under harsh arid environment.
- The optimum population needed for maximum benefit was found to be 400 infective propagules 100 $g^{-1}$ soil.
- The results showed *Glomus aggregatum* as most efficient strain for establishment and growth of *P.cineraria*.
- The maximum mycorrhizal dependency on *P.cineraria* was 56.28% by *Glomus aggregatum*.
- The survival percentage was noticed maximum i.e. 85% in VAM inoculated as compare Thus, the inoculated seedling with AM fungi were survived better in field/ stress conditions.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The mycorrhizal dependency of*P.cineraria*on *Glomus aggregatum* has been recorded. Its inoculation could improve the productivity; hence need to be extended to stakeholders.

29. **Screening for disease resistance in genetic material raised under tree improvement programme**

**Principal Investigator:** Dr. N.S.K. Harsh, Scientist-F

**Duration:** 2006

**Critical Analysis of the research theme & summary of the study**

The study was conducted to bring out useful information of practical application in field about the disease resistant and susceptible clones of *Dalbergiasissoo*. In disease prone areas resistant clones should be used for plantations for obtaining desired growth and yield.In Haryana and Punjab *Ganodermalucidum* root rot is the major cause of mortality in *Dalbergiasissoo*. In this study resistant clones of *Dalbergiasissoo* against *Ganodermalucidum* root rot in the field were identified. The poor performing clones with respect to phytological characters and root rot mortality were identified

**Scientific findings & contents**

- Resistant clones of *Dalbergiasissoo* against *Ganodermalucidum* root rot in the field were clone Nos. 219 (Comp. No. Birpur 4A, Bhambhar Beat, Tulsipur Range, Gonda Forest Division, U.P.), 266 (Comp. No. 3, Lalpani Beat, Rishikesh Range, Dehradun Forest Division, Uttarakhand) and 304 ( Beat Uttrinala, Shayampur Range, Dehradun Forest Division,

Uttarakhand) 257 (Comp. No. 2, Lalpani beat, Rishikesh Range, HaridwarForest Division, Uttarakhand).

- These clones were best performers for height growth, girth, clear bole and disease resistance. It was recommended that these clones should be used for *G.lucidum* under conditions prevailing in Haryana and Punjab states.
- The poor performing clones with respect to phytological characters and root rot mortality were identified as Clone Nos. 88,193,81, 57, 101, 94, 281, 272, 290,291, 298, 288, 289 and 293, which should best be avoided for raising *D.sissoo* plantations.
- Since breeding for disease resistant plants for forest trees is time consuming unlike agriculture plants, identifying disease resistant material and propogating them is the best bet.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The methodology developed in the study can be used for identifying disease resistant clone for other tree species as well. The information can well be used for the identification of disease resistant genes using molecular technology and introducing them using somatic hybridization and recombinant DNA technology for developing diseases resistant seed/ embryos. Hybridization programme can be followed for developing disease resistant hybrids by crossing better form parents and disease resistant poor form parents. Seed collection from the identified disease resistant clones in the CSOs and SSPAs for raising planting stock or using them for vegetative propogation would provide a solution to the problems of shisham mortality, particularly in Hayana and Punjab.

30. **Studies on bacterial and viral diseases of teak, *Gmelina* and *Albizia* and their management**

**Principal Investigator:** Dr. K.K. Soni, Scientist-D

**Duration:** 2008

**Critical Analysis of the research theme & summary of the study**

There are no comprehensive accounts of tree disease caused by bacteria in India, only few incidence of bacterial disease in tree crops have noticed. Some research work has been carried out regarding their incidence and management.Bacterial and viral disease samples were collected from forest nurseries.Bacterial diseases on teak andkhamer were recordedViral infections on *A.lebbek, A. procera, T.grandis*and *G.arborea*. Bacterial isolates were purified and sensitivity test carried out to assess suitability of antibiotics for their application in nursery.

**Scientific findings & contents**

- Overall 250 bacterial/ viral disease samples were collected from 27 forest nurseries. Out of them 245 of bacterial wilt and collar rot (teak, khamer) and 5 with virus infection (*A.lebbek, A. procera, T.grandis, G.arborea*) were recorded.
- Around 2-5% economic losses were recorded in different nurseries caused by bacteria and viruses.
- Total 9 bacterial isolates were purified and sensitivity test carried out to assess suitability of antibiotics for their application in nursery.
- An experiment has been laid out in nursery to control wilt and collar rot disease of teak, *A.procera, A. lebbek and Gmelinaarborea.*

- Incidence of *Xanthomonas* leaf curl and stunting in young teak plantations at Raipura, South Panna division noticed.
- Disease was successfully controlled with the application of streptocyclin 0.1% in combination with monocrotophas 0.036%.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The information regarding bacterial / viral disease identification of these forest nursery species and their management needs to be disseminated to the stakeholders.

31. **Assessment of Shisham Dieback (Decline) in Northern India and its Remedial Measures**

**Principal Investigator:** Dr. A.N. Shukla, Scientist-F

**Duration:** 2008

**Critical Analysis of the research theme & summary of the study**

The project assessed the mortality of *Dalbergiasissoo* in India, its causes and effective management strategies. Surveys were conductedat various locations in different states and the affected areas were identified. For testing resistance against wilt, seeds were collected from all over the country from healthy trees in heavily infected localities from Uttarakhand, Punjab and Himachal Pradesh.The pathogenicity was proved in seedlings of *D.sissoo*. After inoculation with the pathogen, very resistant, moderate resistant, susceptible and very susceptible germplasm were identified.

**Scientific findings & contents**

- Surveys were done in various locations in different states and the areas were identified.
- In order to test the genetic resistance of trees against wilt, seeds were collected from all over the country from 107 healthy trees in 25 heavily infected localities as the germination of most of the provenances was poor, limited number of provenances from Uttarakhand, Punjab and Himachal Pradesh were used for further study.
- The pathogenicity of the pathogen was proved on 45-60 days old seedlings of *D. sissoo* and Koch's postulates was confirmed by reisolating the same strain.
- All the test provenances were inoculated with three strains of *Fusariumsolani* f. sp. *Dalbergia* and on the basis of survival of seedlings the provenances were grouped in very resistant (91-100% survival), moderate resistant (51-80% survival), susceptible (31-50% survival) and very susceptible (<30% survival).
- All very resistant and resistant provenances were further tested by stressing them by flooding the pots for 10 days and the resistance was found to persist in at least two seed sources of RakhBhuru, Amritsar and Thano range, Dehradun.
- All others seedlings succumbed to flooding or were showing insignificant survival statistically.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Resistant germplasm needs to be propagated in field and monitored in multilocationaltrials for durable resistance.

32. **Characterization of Marine Lignicolous fungi in Traditional Wooden Craft**

**Principal Investigator:** Dr. M. Balaji, Scientist-D

**Duration:** 2013

**Critical Analysis of the research theme & summary of the study**

Biodeterioration of timber under marine conditions have shown that the degree of resistance of timber varied considerably from region to region along India's long coastline. Thus species occurrence also varies from one harbor to another The traditional wooden craft like catamarans, stitched boats, etc., are used in marine water for fishing for nearly 8 hours and landed on open hot beach stands when not in use i.e. about 16 hours. This alternate wetting and drying creates conductive conditions for fungal infestation. Marine conditions.

**Scientific findings & contents**

- Surveyed four fishing villages, viz., Pedajalaripeta, Bhimunipatnam, Pudimadaka and Bangarammapalemin Vishakapatnam District for fungal infested traditional wooden craft. Fungal infested wood samples collected into sterilized polythene covers.
- In the laboratory, mixed culture of fungi was made using appropriate culture media.
- Morphologically different fungal strains were separately inoculated and pure cultures of different fungi was maintained.
- Test coupons of *Mangiferaindica* and *Anogeissusacuminata* of 5x2.5x0.5 cm size were treated toa gradient of CCA retentions.
- After through drying of the test coupons, they were exposed to individual fungal strains for their efficacy to different CCA concentrations.
- Generally, test coupons treated to lower absorptions of CCA were infested with fungi whereas higher absorptions resisted the infestations.
- Controls exposed along with treated coupons were infested with the fungal strains. Based on the result, the threshold absorptions of CCA required to prevent fungal infestations were arrived at.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The optimized treatment protocol needs to be shared with stakeholders. In future newer preservatives and treatment methods needs to be tested.

33. **Induction of systemic acquired resistance in rohida (*Tecomella undulate* (Sm.) Seem.) against stem canker**

**Principal Investigator:** Dr. Sangeeta Singh, Scientist-D

**Duration:** 2014

**Critical Analysis of the research theme & summary of the study**

*Tecomella undulate* has become important capital earning species in arid and semi arid regions for the production of quality timber in addition to fuel wood and fodder. *T.undulata*, one of the co-dominant species in the desert forest of Rajasthan along with*Prosopsiscenerareia*(Khejri). The wood is very hard, strong, and grayish to yellow brown in colour and used for making toys, fine carving work furniture and agricultural implements. Stem canker disease is a tree deformity disease pertaining to hollowness in the main trunks of the trees which reduced the quality of the timber. The infection occurs in the form of splitting of bark of the bole, which spread upward and downward. In the present study, surveys were conducted to collect pathogens responsible for causing stem canker. Their pathogenicity testing was conducted and infection process, biochemical changes and anatomical studies of infected and healthy seedlings were also done. Role of two chemicals viz., salicyclic acid and jasmonic acid and a biocontrol agent in disease management was studied.

**Scientific findings & contents**

- Surveys were conducted to collect pathogens responsible for causing stem canker in rohida. Out of six fungi collected *Lasiodiplodia theobromae* was able to prove pathogenicity on two years old seedlings.
- Infection process of canker was studied in the form of biochemical changes (total protein, sugar, phenolic and PAL) and anatomical studies of infected and healthy seedlings. Physiological study was done by measuring the rate of photosynthesis with the help of photometer of infected and healthy seedlings.
- The seedlings were then transplanted in field in RBD design and two chemicals Salicyclic acid and Jasmonic acid (10mM each) and one biocontrol agent was inoculated. Samples were collected after 30 days interval upto 90 days and thereafter at an interval of 60 days and 90 days to study the induction of defense gene in the form of increase or decrease in level of defense related enzymes.
- Out of these chemicals and bioagentssalicyclic acid was found (10mM) was found to be effective in management of the disease but should be introduced in early stage of infection.
- Use of chemical like salicyclic acid was found to be a successful tool for developic systemic acquired resistance (SAR) against phyto pathogens like *Lasidipliodia theobromae* causing stem canker disease in rohida

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Use of chemical like salicyclic acid is a successful tool for developic systemic acquired resistance (SAR) against phyto pathogens like *Lasidipliodia theobromae* causing stem canker disease in rohida and may be popularized by developing suitable pragmatic and cost effective formulation for easy administration at suitable time.

34. **Evaluation and selection of efficient strains of AM fungi & *Rhizobium* for *Acacia*nilotica and *Ailanthus excelsa* in western Rajasthan**

**Principal Investigator:** Dr. Neelam Verma, Research Officer-I

**Duration:** 2014

**Critical Analysis of the research theme & summary of the study**

*A.nilotica* and *Ailanthus excelsa*being important multipurpose tree species were selected for the present study. Periodical survey of nine ecologically different sites for *A.nilotica* subsp. *indica*; five sites for *A. nilotica* subsp. *cupressifornis* and eight sites for *A. excels.*The presence of AM fungal genera was recorded and on the basis of resting spore morphology genera were identified. A high diversity of AM fungi was observed and spore population for different sites in all the tree species was recorded. The percent colonization in the roots of all the tree species were observed. The intensity of AM colonization in the roots and spore in the rhizosphere in nursery and plantation sites varied with the age of plant and site conditions.

**Scientific findings & contents**

- Periodical survey of nine ecologically different sites viz. Barmer, Bikaner, Jodhpur, Ganganagar, Hanumangarh, Sikar, Nagaur, Pali and Sirhohifor *A.nilotica* subsp. *indica*; five sites for *A. nilotica* subsp. *cupressifornis* and eight sites for *A. excelsa* revealed the presence of five AM fungal genera namely *Acaulospora, Gigaspora, Glomus, Scutellospora* and *Sclerocystis*.
- On the basis of resting spore morphology the following species belonging to above genera were identified. Over all endomycorrhizal genera viz., *Acaulospora* sp. (4); *Gigaspora* sp. (4); *Glomus* sp. (27); *Sclerocystis* sp. (6) and *Scutellospora* sp. (4) were frequently found. A high diversity of AM fungi was observed and it varied from site to site.
- The spore population varied from site to site in all the tree species. It varied between 163 to 480 propagules (100 $g^{-1}$) soil of *A.nilotica* subsp. *indica;* and 178 to 500 propagules (100 $g^{-1}$) soil of *A.nilotica* subsp. *Cupressiformis* and 195 to 670 propagules(100 $g^{-1}$) rhizosphere soil of *Ailanthus excelsa*.
- The percent colonization in the roots of all the tree species also varied from place to place. It varied from 40 to 78% in *A. nilotica* subsp. indica; from 48 to 79% in *A. nilotica* subsp. *Cupressiformis* and from 47 to 79% in roots of *Ailanthus excela*.
- The intensity of AM colonization in the roots and spores in the rhizosphere of *A.nilotica* subsp. *indica* and *Ailanthus excela*in nursery and plantation sites varied accordingly to the age of plant and site factors including soil nutrient, moisture and other environmental conditions.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The beneficial microbes may be used as inoculant

35. **Potential Pathogens and Insects responsible for the low seed production in teak seed orchards and their management.**

**Principal Investigator:** Dr. V.S. Dadwal, Scientist-C

**Critical Analysis of the research theme & summary of the study**

In this project identification of the potential pathogens and insect attacking teak inflorescence was done. The impact of pathogens and insect on seed productivity of teak seed in teak seed orchards was studied.

By application of integrated pest management practices in the Teak Seed Orchards, fruit productivity issue was addressed.

**Scientific findings & contents**

A total of 35 fungi were recorded during the inflorescence immature seed and mature seed stage of teak seeds, out of which 33 fungi belong to the class deuteromycetes while 2 were from basidiomycetes. Different combinations of *Bacillus thuringiensis*, *B. amyloliquefaciens,* Monocrotophos 0.05%, Bavistin 0.02%, Rallistracel 0.2% and Planofix 20 ppm were applied in 16 year old teak seed orchards at Nandigram (Seoni) during last week of July and First week of August 2012. The result of the experiments shows that Monocrotophos (0.05%)+ Bavistin (0.02%) in the month of July and 2$^{nd}$ dose during 1$^{st}$ week of August can enhance fruit productivity in TSO's.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The results are of practical utility

36. **Digitization & Development of Software Database System for Pathology Herbaria of FRI Dehradun**

**Principal Investigator:** Er. Neelesh Yadav, Scientist-C

**Critical Analysis of the research theme & summary of the study**

The forest Informatics Division, Forest Research Institute is working for all information and knowledge generation related research activities of Forestry and biodiversity domain via software development and GIS/ RS technique. Digitization & Development of Software Database System for Pathology Herbarium (Fungarium) of FRI, Dehradun was envisaged to digitize the collection. Database development, collecting of data and thereafter in entry, digital photo capturing of each specimens of herbarium, barcoding of each and every specimen with its proper labeling and its proper software retrieval mechanism was conducted.

**Scientific findings & contents**

Digitalization of Forest Pathology Herbarium (Fungarium) of Forest Research Institute, Dehradun was done and its proper software retrieval mechanism was developed.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The database must be made available to Forest Pathology Discipline of Forest Research Institute forupgradation by adding information on synonymy, latest taxonomic position etc., and other information as this Fungarium is property of FRI, Dehradun. The database should be made ready for online access.

37. **Studies on Diseases of Important Medicinal Plants and their Biocontrol**

**Principal Investigator:** Dr. V.S. Dadwal, Scientist-C

**Critical Analysis of the research theme & summary of the study**

This project developed a strategy for biological control of diseases of medicinal plants. Survey and collection of disease samples for isolation and identification of pathogens responsible for causing disease in *Rauvolfia serpentine, Withaniasomnifera* and *Chlorophytumborivillianum*was done. Mode of infection, conditionsfavourable for disease development and effective biocontrol were also investigated. Survey was conducted in Jabalpur, Seoni, Chhindwara and Raipur, Bialpur at the farmers field and nursery of forest department. Diseases and their incidence in *C.borivillianum, R. serpentina* and *W.somnifera* in various localities were recorded.

**Scientific findings & contents**

- Important disease of *Rauvolfiaserpentina, Chlorophytumborivillianum* and *W. somnifera*were recorded from Madhya Pradsesh and Chattisgarh.
- Some biocontrol agents viz. *Streptomyces* sp., *Bacillus amyloloiquefaciens*, *Trichodermaharzianum* and biopesticide alone or in combination were applied in the field.
- The results of the expiremtns revealed that Bavistin 0.05% *Streptomyces* sp. in the month of July and August had been proved effective in protecting leaf spot and inflorescence disease and for better seed production in *R.serpentina.*
- Foliar spray of *Streptomyces* sp. showed less disease incidence in *C. borivillianusm* and better tuber yield.
- Root diseases in *W. somnifera* were effectively managed by adding 50% neem caked in the potting mixture. Application of 50% neem cake as a modified potting mixture significantly managed the root knot disease of *W.somnifera*.
- Overall response of biocontrol agents, biopesticide and modified practices had significantly reduces the disease infestation during growth and development of all the three medicinal plant species. Field application of these bioagentswere also helpful in increasing the root and shoot biomass and improved overall health of medicinal plants.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The results need to be disseminated to the stakeholders for early management.

38. **Application of growth promoting microbes and soil amendments to produce improved seedlings of forest trees**

**Principal Investigator:** Dr. R.K. Verma, Scientist-E

**Critical Analysis of the research theme & summary of the study**

In this project attempt was made for application of growth promoting microbes and soil amendments to produce improved seedlings of forest trees. Attempt was made to develop germplasm bank of growth promoting microbes for *Gmelinaarborea, Dalbergiasissoo, Santalum album* and *Jatropha curcas*and screened efficient strains of growth promoting microbes. Interaction of growth promoting microbes and soil amendments was studied.

**Scientific findings & contents**

- Growth promoting microorganisms were isolated from soil samples collected from 26 different places from Madhya Pradesh.
- Experiment on *Gmelinaarborea, Dalbergiasisssoo* and *Jatropha curcas* were conducted in root trainers and growth promoting organisms were selected for these species.
- Twenty different fungi isolated from rhizosphere soil were screened for plant growth promoting properties. Out of them *Aspergillus* sp. and four *Trichoderma* spp. were found growth promoting and selected for use in nursery.
- Application of plant growth promoting microbes (AM fungi, *Aspergillus* sp. *Azospirillim* sp. and soil amendments (mix of Lucaena, teak leaves and FYM in equal ratio v/v) increased 10-20% survival fo sandal seedlings when planted out in the field, it also increased plant height up to 43%.
- Two field experiments were conducted on sandal and *Jatropha curcas* to demonstrate the technique to users.
- Application of growth promoting organisms (AM fungi and *Azospirillum*) on *Gmelinaarborea* was also done at Demonstration village, Moiyanala.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The research findings of the project will enhance the quality of seedlings by protecting them from root disease and further lowering the mortality when planted in the field. The findings derived from the project could also be utilized and disseminated through publication of brochure/ training, etc to users, SFDs, nursery growers, NGOs, etc.

39. **Development of bio-fertilizers and standardization of their application in relation to productivity of forest tree species under degraded lateritic soil condition**

**Principal Investigator:** Dr. S. Nath, Scientist-SE

**Duration:** 2002

**Critical Analysis of the research theme & summary of the study**

Surveys in nurseries, plantations and natural forests have been conducted, samples were collected from forest divisions of south West Bengal. Rhizosphere soil samples and nodule samples were collected for Rhizobium isolation. Azotobacter cultures from rhizosphere soil were isolated. Distribution study for AM fungi in rhizosphere soils under different plantations ecosystems and natural forests were done. The propogated cultures were utilized for nursery trial for efficiency study. Some organic matters were screened for effective biofertilization.

**Scientific findings & contents**

1. Field Survey in nurseries, plantations and natural forests were conducted and samples from 35 locations within 11 ranges of three forest divisions of south West Bengal were collected. On each location 1 to 20 species were studied and Rhizosphere soil samples and nodule samples were collected.
2. Rhizobium from 11 species out of 13 sites were isolated, cultures were maintained.
3. Azotobacter cultures from rhizosphere soil of 21 sites were isolated.
4. Distribution study for AM fungi in rhizosphere soils under different plantations ecosystems and natural forests were done. Three species each of *Glomus, Acaulospora* and *Sclerocystis* were identified and 21 nursery cultures of pure spores were prepared.
5. Pure culture of AM fungi was developed under laboratory condition in funnels with maize as the host species. The propogated cultures were further multiplies in pots with maize and the nurse cultures thus produced were utilized for nursery trial for efficiency study. Apart from vermin-compost and compost which address the nutritional and physical requirements, cheap organic sources like bamboo litter, saw dust, rice husk and coconut coir were found to be beneficial in augmenting the role of biofertilizers.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The technology could be refined after field trials with the recommended treatments and host species for biofertilizer efficiency.

40. **Role of Fungi in Biodeterioration of Timber under Marine Conditions**

**Principal Investigator:** H.C. Nagaveni, Scientist-C

**Duration:** 2007

**Critical Analysis of the research theme & summary of the study**

Study was conducted for identification of wood destroying fungi in wood in marine conditions. The fungal biology on infested wood was studied and extent of damage due to fungal infestation and also efficacy of treatments was taken in account.

**Scientific findings & contents**

*Monilia sitophila* was first time isolated under marine condition. Treatment has good effect in controlling fungal infection. Percentage of infection increased with the increase of duration and reached peak in 6 to 7 months. Different species of Aspergillus fungus were more predominant when compare to other species. The study has helped to understand the diversity of marine fungi. Understanding the interaction of fungus and borer and foulers helps to control the biodeterioration. The findings revealed that bio-film formation is an ecological phenomenon, which in turn facilitate the growth of higher fungi, and foulers, which lead to massive destruction of wood structures in the marine condition.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Further work can be taken up in different coastal region on both tidal and inter-tidal region to understand the biodiversity of marine fungi and their antagonism or mutualism with the other organisms.

41. **Isolation and anti- fungal activities of the chemical compounds of *Baccaurea courtallensis* Muell. Arg.-a wild edible plant of Western Ghats**

**Principal Investigator:** Dr. S.Mohan

**Duration:** 2009

**Critical Analysis of the research theme & summary of the study**

Baccaurea is a genus of flowering plant belonging to the family *Euphorbiaceae*. ***Baccaurea courtallensis*** Muell. Arg is one such tree species, which is endemic to Western Ghats. Local tribal population harvests the fruits for its medicinal value. The fruits contain 2-4 seeds in them. In the present study extracts from seeds fruits, bark and leaves were analysezed and anti-fungal activities of the chemical compounds present were studied

**Scientific findings & contents**

Extraction from seed

Various extracts were obtained from seeds, fruits, bark and leaves and were quantified. Petroleum ether extract, Ethyl acetate extract,

Methanol extract, Hexane extract, Ethyl acetate extract were obtained. The extracts were tested for the presence of organic compound groups.

Antifungal screening results indicated that fruit rind extract exhibit excellent anti-fungal activity against the pathogen used in the study. All the 3 dilutions tested exhibited growth inhibition of test

fungi. But there were variations observed in the fungal growth in the 3 dilutions. The growth of fungi is inversely proportional to the concentration of target solutions. In the case of 1% dilution, maximum fungal growth was identified. 1.5% dilution shows, moderate fungal growth and 2% dilution shows limited fungal growth. *Fusarium oxysporum* is important plant pathogen which causes various seedling disease and *Baccaurea courtallensis* fruit rind extract had good chemotherapeutic importance and can be exploited as a good anti -fungal agent against pathogenic fungi.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

Further studies on the medicinal properties, anti insecticidal activity of the extracts/ chemical compounds could be undertaken. The chemical compounds obtained can be used as fungicide.

42. **Studies on wood- decay and its control of stored tropical timber in forest depots**

**Principal Investigator:** Dr. C.K. Tiwari, Scientist

**Duration:** 2012

**Critical Analysis of the research theme & summary of the study**

Fungal decay reduces both the quality and quantity of timber and thus hamper the basic purpose of forestry, which aims at producing quality timber. Millions of rupees are lost annually in India because of the bio- deterioration of wood by microorganisms. Sapwood of all timbers is usually destroyed within a year or two by fungi when wood is placed on the ground or exposed to the environmental conditions in a tropical country like India. On the other hand, the durability of the heartwood of different timbers varies considerably with species and the locality of installation. Therefore, developing an efficient method for prevention of bio-deterioration of timber in wood depots would enhance the revenue tremendously. In the present study wood depots were surveyed and specimens of wood decaying fungi on hosts werecollected from Central India (Madhya Pradesh, Maharashtra, Chhattisgarh and Orissa).

**Scientific findings & contents**

- Survey was conducted in 68 wood depots and collected 1159 specimens of wood decaying fungi on 34 hosts from Central India (Madhya Pradesh, Maharashtra, Chhattisgarh and Orissa).
- The specimens of wood decaying fungi belonging to 47 genera and 83 species were collected.
- Out of them 4 genera (*Ceriporiopsis, Hapalopilus, Postia*and *Schizopora*) and 7 species (*Ceriporiopsismerulinus, Hapalopilusnidulans, Postia placenta, Pycnoporuscoccineus, Pycnoporuscinnabarinus, Schizoporaparadoxa and Trametesochraceae*) were reported for first time on some locations.
- 29 wood decaying fungi were screened and cultured on potato dextrose agar medium.
- Wood decaying fungi specimens were maintained in the Mycology Herbarium of Forest Pathology Division of the Institute.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The information regarding different fungal species in wood depots have been generated and would serve as reference.

43. **Development of certification criteria and production of microbial inoculants for application in forest nurseries and plantations**

**Principal Investigator:** Dr. R.K. Verma, Scientist-F

**Duration:** 2014

**Critical Analysis of the research theme & summary of the study**

The present project was undertaken to develop certification criteria for inocula of plant growth microbes *Axospirillum*, AM fungi, PSB and *Rhizobium.*Products (inocula) and criteria for certification of microbial inoculants for application in important tree species was developed and role of biofertilizers on lesser researched tree species, like mahua, bija-sal, bael, tinsa, etc. was investigated.Study of AM fungi in terms of identification of species and root colonization in selected species was done and cultures were produced. Nursery experiments were conducted and AM fungi, associated N2 fixing bacteria, PSB and other growth promoting organisms were used in nursery trials.

**Scientific findings & contents**

- Study of AM fungi in terms of identification of species and root colonization in selected species was done.
- Cultures of AM fungi were produced in specially designed cement concrete beds.
- For standardization of different microbial inoculants, the numbers of propagules per unit volume were determined by most probable number method.
- The minimum number of infective propagules was standardized for each inoculum for application in a particular tree species.
- Nursery experiments were conducted in root trainers, polybags as well as in nursery beds in CRD, AM fungi, associated N2 fixing bacteria, PSB and other growth promoting organisms were used in nursery trials.
- Dry weight, P concentration in shoots and root colonization were determined to assess effect of different growth promoting microbes used.
- Role of plant growth promoting microbes were tested on lesser researchers tree species: bael, bija-sal, mahua and tinsa.
- Application of AM fungi along with *Azospirillum*, enhanced dry biomass and shoot P content of bael seedlings
- Application of growth promoting microbes produced maximum height, in seedlings of bija-sal treated with *Aspergillus niger*.
- In case of mahua, application of microbes produced significant increased in plant height and diameter of seedlings at collar height, which was the maximum in *Azospirillum*sp. followed by AM fungi and *Trichoderma* treatments.
- In case of Tinsa, application of AM fungi produced higher biomass.
- Application of vermicompost during field planting has further enhanced growth of saplings.

**Suggestions regarding follow up patenting possibility, utilization aspects, and prototype**

The developed protocols need to be popularized among stakeholders.

# Forest Botany

1. **Study on wood anatomy of Indian shrubs for the purpose of their identification and efficient utilization**

**Principal Investigator:** Dr Sangeeta Gupta, Scientist- F, FRI, Dehradun

**Critical analysis of the research theme and summary of the study**

Project completion report covers studies on the microstructure of 253 wood samples belonging to 44 plant families covering 133 genera of 200 species. The main research output was aimed at developing a dichotomous key as an aid in the identification of shrubaceous species of Indian flora. Microstructure on 47 families in total are mentioned while in "overview" 44 families are mentioned. The objectives given in PCR does not mention regarding working on the wood samples housed in the Xylarium. Whereas the 1st objective mentions as "*to survey and collect wood samples of the shrubs"*. If that being the fact then the wood samples must have voucher herbarium specimens as cited in the monumental work of JS Gamble's Manual of Indian Timbers. The objectives 3 & 5 make part of methodology. Therefore, number of objectives should be reduced. With regards to the artificial dichotomous key provided in the report conspicuous presence and absence, and quantified unit of characters it appears justified and workable but qualitative characters such as "wood moderately hard/ heavy compared to wood lighter" as given for the distinguishing characters between *Hippophae rhamnoides* Linn. and *Hippophae salicifolia* D. Don need to be quantified. Taxonomically in field both the species are identified by microscopic characters of the presence or absence of hairs on the scales of lower leaf surface. Measuring scale of plants described should be in centimeter, meter above sea level (ASL) not in inches, Lbs (Pounds), cubic feet and inches (*vide* description first paragraph under *Indigofera heterantha*). Each species described needs to be cited with nomenclature in short, synonym, voucher specimen housed in the Herbarium of Forest Research Institute, Dehradun for conformity. Example: Species: *Wikstroemia indica* (Linn.) C. A. Mey. Synon. *Daphne indica* Linn. *Daphne cannabina* Lour.

**Scientific findings and contents**

Study reports an account on the anatomical features of 253 authenticated wood samples housed in Xylarium of Forest Research Institute, Dehradun. Treatise deals with c. 200 species belonging to 133 genera distributed among 44 plant families. Standard methodology with standard laboratory procedure was used for microscopic examination of wood samples of shrubaceous species using Reichert microtome. Photomicrography was carried out for each of the species of wood samples-examined. Deserving to mention that the terminology of International Association of Wood Anatomists (IAWA, 1989) was used. The scrutiny of literature covers old and recent publications. Analytical key developed using technical terms along with supporting micro-photographs of anatomical structures of wood samples is very significant component of the report. The studies in the form of publication shall provide important information on the lesser-known woody species, therefore contributing immensely to the academic knowledge in the field of botanical sciences. The dichotomous key is quite useful part of the report with taxonomic units judiciously chosen with quantifiable features. The scientific findings of the work elucidated in the report mainly based on microscopic studies carried out with precision on the authenticated wood samples housed in the xylarium of Forest Research Institute, Dehradun. It would be worthwhile if an illustrated analytical key based on microscopic features of parenchyma, vessels, fibre and rays is incorporated in the consolidated when published.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The report of the project work carried out can be published in a book and in digital forms as a manual with a copyright. The title of the work is suggested as "*Manual on Wood Anatomical Approach for Identification of Indian Shrubs*". A large number of arborescent species of Indian flora have economic importance from the point of view of utilization for medicinal, food, fibre, composite structures and other values. It deserves a mention here that by and large shrubs studied in the report are lesser known from the viewpoints of anatomical studies and fullest utilization. The species anatomically dealt are typically from the repository of a standard xylarium. Whereas there is immense further scope of work based on the fresh collections of species diversity covering arborescent climbers of different forest sub-types and types as well. It is suggested that the specimens of wood samples used for studies can be cited along with the herbarium specimens housed in the Herbarium of Forest Research Institute. It is suggested that the manual should have an illustrated glossary of technical terms, brief account with diagnostic characters, distribution of species and xylarium/ herbarium accession details. For taking a publishing process whose prototype is based on the aforementioned note the design and layout of the book needs a spectacular cover representative of works embodied, understandable diagnostic features based on consolidated works, glossary, index. With an SDP book and cover designer, our authors receive the best, professional design layout possible.

2. **Edible shoot production of selected bamboo species and extension of shoot production period through cultural practices**

**Principal Investigator:** Dr S Nath and
**Co Principal Investigator:** Dr Animesh Sinha, IFP, Ranchi

**Duration:** 2010-13

**Critical analysis of the research theme and summary of the study**

Project Completion Report (PCR) is found quite significant from the point of view of income generation and enhancement of bamboo resource typical of rural part of the state of Jharkhand. The main objectives of the project have been to assess the production potential of edible shoots of bamboos, both indigenous and exotic, soil improvement for the enhancement of shoot production, management of bamboo clumps and standardization of extraction methods. Studies are based on village surveys in as many as 16 districts during the year 2010 to 2012. The species aimed for studies are *Dendrocalamus strictus* (Roxb.) Nees*, Dendrocalamus asper* (Schult.) Backer*, Bambusa nutans* Wall. ex Munro*,* and *Bambusa vulgaris* Schrad. ex JC Wendl. Aforementioned bamboos are not provided with nomenclatural citation with illustrated diagnostic features of bamboo clump, culm, culm sheaths and external morphology of growing edible shoots. *Bambusa bambos* (Linn.) Voss locally called *Kanta Baans* occurring in Jharkhand and having edible shoots has not been explicitly dealt. Marketability of edible shoots of bamboo has been depicted after having gathered value of the harvests from Rs 21095.3 to Rs 53050.3 per village per season. As much as Rs 67305.00 of revenue has been reported to have been generated per village in Sariakela – Kharsawan district. Report comprehensively deals with the projected bamboo shoot production, earnings and manpower engaged in collection. There appear gaps in knowledge on the gregarious and sporadic flowering **of**

bamboos providing sufficient quantity of edible shoots (*Karil*) by sale to the dependent communities to sustain their livelihood, traditional approach towards growing, harvesting and value addition covering processing of the shoots as crushed and fermented wet as *Sandhana*, and fermented dry as *haua*.

**Scientific findings and contents**

Project completion report provides village level characterization of bamboo resource in the state of Jharkhand from the point of view of survey, collection, marketability, market trends per season and management through cultural operation of edible shoots. It deserves a mention that for the management of bamboos for the production of edible shoots through cultural practices using silvicultural and agronomic measures field trials were undertaken by the project implementing institute at Ranchi. Management of bamboo clumps of selected species, namely *Dendrocalamus strictus*, *D. asper* and *D. nutans* for the production of edible shoots was carried out for three years from 2010 to 2012 with specific reference to the effect of thinning of bamboo clump, soil amendments, shoot harvest etc. Deserving to mention that the village level data from collection to harvesting to marketing of village bamboos highlights the major achievement of the project. Studies reveal that thinning operation and removal of 50 percent of clumps of over two years old support maximum emergence of edible shoots, while 50 percent of extraction of emerged shoots support maximum emergence of shoots. The project activities provides initial framework towards the development of strategies for bamboo sector. There is need to develop a package of practice for the rural communities of the state of Jharkhand to carry out extensive production of edible shoots in order to generate income through sustainable utilization and value addition.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Studies carried out under project reveal that the rural communities of Jharkhand of selected areas surveyed for the consumption and marketing of bamboo of homesteads and forest areas have prospects for registration as geographical indicators (GI). It can be done once the bamboo shoots preferably of *Bambusa nutans* are examined for specific taste and flavor being widely consumed specifically as *Sandhana* and *Hadua*. This owes to the important locality factors of micro-environment. Deserving to mention that GI is an indication of geographical location which indicates the product associated with a certain area or region for having special quality and established reputation. It is the sign used on the products that have the regional origin. It is very much pertinent for the region and specific location covered in the project on edible shoots of bamboo species **typical** of the state of Jharkhand.

It is suggested that extension materials (booklets in regional language, brochure etc) should be developed on package of practices based on project findings on choice of community for specific species of bamboo, cultural operation based on soil amendments, silvicultural management and marketability. There is need for the value addition of the end products with a view to promoting the product and better income. Noteworthy to mention that the bamboo shoots are consumed in raw, boiled, fermented, frozen and forms while its shelf life is short. The fresh bamboo shoots of species like *Bambusa nutans, Dendraocalamus strictus, Dendrocalamus strictus* of the state of Jharkhand and typically dealt in the project-completed are healthier and nutritionally rich. The bamboo shoots being utilized in different project sites of rural Jharkhand is found traditional, non-standardized, seasonal and region-specific and, by and large without any value addition. There exists a great

opportunity, especially for the organized food processing sectors to take up the processing of bamboo shoot-based food products in an organized manner.

The young shoots of the species can be consumed after fortification, processing into a wide range of food products with longer shelf-life and better organoleptic qualities. For organoleptic evaluation and the standardization of food value the material can be sent to CSIR-Central Food Technological Research Institute (CSIR-CFTRI), Mysuru, Karnataka from the point of view of developing technologies to increase efficiency and reduce post-harvest losses, add convenience, increase export, reduce costs, and modernize.

The most preferred species of bamboo by the rural communities needs marking for clonal characterization, propagation, distribution, introduction as an agroforestry species etc.

3. **Exploration of diversity and utilization potential of Sphagnum species of forestry importance in North-east India**

**Principal Investigator:** Praveen Kumar Verma and
**Co Principal Investigator:** DP Borah, RFRI, Jorhat

**Duration:** 2013

**Critical analysis of the research theme and summary of the study**

*Sphagnum* Linn. which is a bryophyte, popularly referred as Peat Moss is solitary genus in the Sphagnaceae family under Bryophyta. The plant is reported to be found abundantly in bioclimatic region of mountain forest ecosystem of Northeast and eastern Himalaya. The plant has remarkable capacity of holding water in its foliar biomass and for that it is used as good substrate for propagation by air layering of species of forestry and economic importance, and potting of plants of horticulture and floriculture values. The various activities accomplished under the completed project covered literature scrutiny, field explorations, collection, identification based on microscopic dissection of the materials and consultation of authenticated collection in the standard herbaria for conformity, taxonomic treatise, citation of herbarium specimens- examined and demonstration to the user groups on the use of Sphagnum moss as substrate for air layering technique of propagation. The number of species of Sphagnum in India covering Himalayan and Northeast India is differently given as "18" under overview and "16" under results on page 25 of the PCR. While solitary species is mentioned from Sikkim whereas distribution of several species are reported from different states of northeastern region as well. Deserving to note that all the eight species of Sphagnum occurring in NE India are provided with taxonomic account with nomenclatural citation, specimens examined and figures showing details of dissected parts. The specimens examined in the herbaria of Shillong (ASSAM) of Botanical Survey of India and others have not been cited in the account. The page 43 with the Fig.6. has been repeated as 44. It is a lacuna on the illustrations of dissected parts of microscopic features of plant on Figures 1- 8 having not indicated with scale to judge the magnification used. Besides, mentioning about the species of Sphagnum used as substrate for propagation of various species of forestry, horticultural and floricultural importance it would be worthwhile to work on the content of nitrogen, potassium and phosphorus in 100, 250 and 1000 gms of different species of sphagnum applied as substrate in air-layering for the propagation. Grammatical / orthographic mistakes need correction as given here: Page 7, 20 & 21: *Rhynchostylis*

*retusa*; page 14: in beginning of the project an appraisal survey was conducted ; page 73…is the only genus in the family…Page 74: The three species……which are easily available in Meghalaya.

**Scientific findings and contents**

The scientific findings of the project completion report cover taxonomic treatise on eight species of Peat Moss, Sphagnum, namely 1. *Sphagnum pseudocorymbifolium,* 2. *Sphagnum papillosum*, 3. *Sphagnum subsecundum*, 4. *Sphagnum khasianum*, 5. *Sphagnum squarrosum*, 6. *Sphagnum cuspidatulum*, 7. *Sphagnum nemorum,* and 8. *Sphagnum junghuuhnianum.* As many as 20 locations were floristically explored with record of geo-coordinates of 19 specific habitats in the states of Meghalaya and one Sikkim. Systematic documentation was done with collection of herbarium specimens. The physico-chemical properties of the bryophyte was dealt along with the studies on water holding capacity of species which is more than the 20 times of the dry biomass of plant; pH ( 3.7-4.8), conductivity and determination of nitrogen, phosphorus and potassium of dried plant samples. The biomass selected species of Sphagnum was used as substrate media for the vegetative propagation using air layering approach. The species of forestry and economic importance used *Elaeocarpus angustifolius, Guadua angustifolia, Gmelina arborea, Cinnamomum veram (Syn. Cinnamomum zeylanicum*), *Litchi chinensis, Citrus limon* and orchids. The conservation of the germplasm of different species of Sphagnum was undertaken in the shade house of the Rain Forest Research Institute, Jorhat, Assam. Mass multiplication of readily available species of *Sphagnum khasianum* was successfully carried out through vegetative fragmentation from stem and capitulum branches and through spore for rapid production of a large number of clonal gametophores. As an extension activity the project team conducted awareness, training and demonstration programmes in different rural areas of northeastern India with regards to the important uses of sphagnum moss. Two research publications (Praveen Kumar Verma et al.: Vegetative propagation through air layering of *Guadua angustifolia* Kunth- a commercially important bamboo. *Indian Forester* 139 (12) : 1088-1091, 2013; PK Verma et al. effect of Sphagnum spp as substrate media on rooting response of *Cinnamomum verum* Presel. through air layering. J. NTFP 20 (3): 179-182, 2013) by the researchers of the completed project were made.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

It is suggested that a package of practice can be prepared as extension material based on the findings on application of Sphagnum moss as substrate media for propagation by air layering on the related species of *Elaeocarpus angustifolius, Guadua angustifolia, Gmelina arborea, Cinnamomum veram (*Syn. *Cinnamomum zeylanicum*), *Litchi chinensis, Citrus limon,* orchids (*Rhynchostylis retusa, Dendobium nobile*) and other species of forestry, horticulture and floriculture importance.

A taxonomic treatise cum field guide covering 18- 21 species of Sphagnum is suggested for publication with illustrated account, geo-coordinated maps of distribution, repository of germplasm and propagation methods. There should be threat value assessment and conservation measure with regards to the extraction and subsequent sustainable utilization of Sphagnum occurring in different bioclimatic zones of Himalayas and northeastern region of India.

Sphagnum moss is widely used in gardening, potting and as substrate for air layering, moss sticks, composting etc. It takes years for the moss to develop, and harvesting makes an adverse impact on its regeneration and microhabitat. The project activities must emphasize on sustainable extraction of Sphagnum moss from different bioclimatic areas of occurrence, restoration and reintroduction in

sites of declining resource and loss for the conservation of the bryo-diversity in India. Each of the species of Sphagnum found in specific area of Himalayas and Northeast India needs treatise made monographically with account on nomenclatural citation, local name, description with diagnostic note on field identification, microscopic feature of taxonomic entity based on external and internal morphology, GPS enabled exact location of occurrence as cited in project completion report, distributional map, ecological note with mention about the associated forest species, propagation both natural and applied, uses with respect to different forestry and other economic important species of Sphagnum used as substrate media. This may also cover the study that may be undertaken on the release of different nutrients and maintenance of requisite pH and level of micro-precipitation through hydration and exchange of cations. The extension materials are needed to be published and developed in electronic audio-visual forms in English, Hindi and regional languages for developing awareness and capacity building from the viewpoint of sustainable utilization of Sphagnum moss.

Further studies are suggested for phyto-chemical characterization of different species of Sphagnum for medicinal properties. Deserving to mention that the whole plant bears antiseptic property. It makes an excellent wound dressing for its absorptive properties and has been used to save lives of soldiers in World Wars. Dr Sas. Biswas visited in August 2018 a village in England (Devon) which was accredited with civil awards to the community for providing aircraft load of Sphagnum moss for the wounded soldiers during the World War II. Another potential use of Indian sphagnum moss is in exploring the possibility for making diapers and sanitary napkins. It is noteworthy to mention that Johnson & Johnson (Ref. Johnson & Johnson: Sanitary pads containing peat moss, 1991; and Gottesfeld & Vitt: Selection of Sphagnum for diapers by indigenous North Americans, Evasia 13 : 103-108 1996) is reported to have used *Sphagnum megellanicum,* exotic to India, for very thin sanitary napkins that has an absorbent core of processed moss derived from peat deposits.

4. **Inventorization and ex-situ conservation of Bamboo and Rattan resources of Mizoram, Tripura and Baral Valley of Assam**

**Principal Investigator:** Dr TC Bhuyan and
**Co Principal Investigator:** Mr. HR Bora, RFRI, Jorhat

**Duration:** 2009-2012

**Critical analysis of the research theme and summary of the study**

Co-Principal Investigator is found quite significant from the point of view of the enhancement of bamboo and rattan resources typical of the union states of Mizoram, Tripura and Barak valley of Assam. The main objectives of the project have been to: Short Term i. To study the species diversity of Rattans and Bamboos in Mizoram, Tripura and Assam (Barak Valley), ii. To establish ex-situ conservation plots/ germplasm bank of bamboo and rattan; Long Term objective aims at assessing the diversity and conservation of bamboo and rattan resources of the mentioned states of northeastern region of India. The studies cover five districts of the state of Mizoram, three of Assam in Barak valley and four districts of Tripura. The methodology adopted was through preliminary reconnaissance survey, personal contact with local communities and concerned state forest department, field identification, collection of herbarium specimens and live germplasm for ex-situ conservation in nursery in the campus of Advanced Research Centre for Bamboo & Rattan

(ARCBR) located at Aizawl, Mizoram of Rain Forest Research Institute (RFRI), Jorhat under Indian Council of Forestry Research & Education (ICFRE), Dehradun. The germplasm of several species of bamboo and rattan are reported to have been introduced in the plots adjoining to the sites of field surveys undertaken.

The report mentions about the information gathered on uses through interaction with the local rural communities of different forest ranges and villages but it appears that a questionnaire was not prepared and interviews on any structured format used for gathering information. The various uses mentioned in the tables (I to XII) and on page 33 such as *cane furniture, police stick, old man stick, cane chair*, *decorative purposes* etc do not seem from any interactive meeting with the communities. Besides, socio-economic surveys of species in villages for evaluation of the uses although mentioned of having been undertaken but it is not through any standard approach. Stepwise methodical approach for the ex-situ measures undertaken for the collection of germplasm such as wildings and propagating materials need elaboration. The species, namely *Licuala peltata, Borassus flabellifer* mentioned in the PCR (page 28) as indicator of existing occurrence of rattan species need more observation with respect to original vegetation and ecological succession. Present status on policies and institutional support (vide page 37) with regard to the bamboo and rattan resources under the jurisdiction of different forest departments and other agencies need to be given for suggestive measures. Key observations on ecological diversity needs characterization of later, extent of occurrence of species under decline and the area of occupancy of available resource needs evaluation integrating remotely sensed data from North-Eastern Space Applications Centre, Umiam, Meghalaya.

The rattan species systematically enumerated (vide page 39-43) are not provided with author citation and synonym to authenticate nomenclaturally. Reference citation of the published account particularly in existing regional floras and the herbarium specimens collected for identification have not been provided. There is no mention about collection of specimens whether deposited in the herbarium of RFRI or FRI. Consultation of the regional herbariums of Botanical Survey of India (ASSAM), Shillong and universities has not been provided in the report.

There appears gaps in knowledge on the gregarious and sporadic flowering of bamboos and seeding in rattans for collection and management of germplasm through in-situ measures.

**Scientific findings and contents**

Project completion report provides forest-cum rural level inventorization and characterization of bamboo and rattan resource occurring in different districts of Assam (Barak Valley), Mizoram and Tripura. Report mentions about the occurrence of 22 species in as many as 12 Forest Divisions encompassing different districts of the states surveyed. It deserves a mention that ex-situ conservation of certain species of bamboo and rattan was done through the establishment of nursery and repositories in the campus of Advanced Research Centre for Bamboo & Rattan (ARCBR) located at Aizawl, Mizoram under Rain Forest Research Institute (RFRI), Jorhat. Plot or block-wise representation of the rattans introduced through ex-situ measures indicate 34 accessions from 5 districts of Mizoram; 13 from three districts from Barak Valley of Assam; and 7 from three districts of Tripura. Bamboo resources of area covered in present project completion report indicates that the state of Mizoram has 7 species of bamboo in the district N. Vanlaiphai and 13 in different localities of district Khawruhilan. Ten species are mentioned growing in homestead gardens. Muli bans

(*Melocanna baccifera*) and associated Rawnal bamboo (*Dendrocalamus longispathus*) are widely distributed covering large areas of forest. The findings show that as many as 270 of bamboo and 105 accessions of rattan (*Calamus flagellum*) germplasm as seedlings and propagules were introduced in different plots or blocks of the campus of the Advanced Research Centre for Bamboo & Rattan, Aizawl. The nursery seedling stock and macro-proliferated culm cuttings of 2420 of seven species of bamboo and 550 of rattan, *Calamus flagellum* are reported. Germplasm of as many as twenty different species of bamboo is reported to have been collected for ex-situ conservation.

As many as 41 references are annexed ( pp 54-56) in the report but several of those cited under literature review are not mentioned (vide Baccari 1908, 1913 and 1918; Saxena and Dhawan 2004; Khan 1972).

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

It is suggested that the final outcome of the report when published must correct, modify and include the points mentioned under Critical analysis of the research theme and summary of the study as above to fill the lacunae in the knowledge on bamboo and rattan resources of the region covered under the project**.** Besides, there should be an assessment of values of threat to different species due to biotic factors. Inventorization in different under-explored bamboo and rattan rich tracts in various districts of Assam (Barak Valley), Mizoram and Tripura necessitates incorporation of distribution maps of species characterized and their germplasm collected for introduction, conservation and management. Each of the picture plate must have suitable caption, many of these are without any captions in the report submitted. The lesser known uses of rattans mentioned can be of importance from the point of view of value addition for food, medicine, handicrafts etc. An illustrated field guide/ manual are suggested for different user groups specific to the areas inventorized. A package of practice on the nursery techniques of rattans of socio-economic and forestry value can be prepared. Extension activities can be conducted by Advanced Research Centre for Bamboo & Rattan (ARCBR) located at Aizawl, Mizoram and Rain Forest Research Institute (RFRI), Jorhat and other organizations of Assam, Mizoram and Tripura. Following papers are suggested for incorporation of research findings pertinent to the project completed when published as a treatise of ICFRE / RFRI- ACBR.

# Biodiversity and Climate Change

1. **Inventorisation and monitoring of biodiversity of threatened wetland sites of Doon valley and surroundings, Uttaranchal**

**Principal Investigator:** Dr. Sas Biswas, FRI, Dehradun

**Duration:** 2008

**Critical analysis of the research theme and summary of the study**

The research Project on 'Inventorisation and monitoring of biodiversity of threatened wetland sites of Doon valley and surroundings, Uttaranchal' was conducted in five different swamps of Doon Valley with following objectives:

- To study the floristic status of threatened wetland sites of Doon Valley and surroundings.
- To inventorize and monitor the changes in the habitat, population phenology phytogeography and endemicity of rare and threatened species typical of the project area.
- Introduction of rare, threatened and spectacular species in the suitable sites of original distribution
- To integrate the floristic-cum-phytogeographical data base on sites and specific elements of the region.
- To prepare botanical treatise on the significant elements for ready reference

Floristic investigation of wetlands sites was made under the study with special emphasis on Mothronwala Swamp which has been a Botanists paradise and very well studied swamp by the Botanists of Doon Valley

**Scientific findings and contents**

Mothronwala swamp flora has degraded in last four decades. Tree vegetation reported earlier from the swamp is almost vanished (Only few stumps remaining). *Quesrcus lecotriphora* (Ban oak) was earlier reported to habitat the swamp is now almost disappeared. Dense vegetation tree height (12-15 m) is not seen now. Many shrubs recorded earlier are not present now. Compared with that of Kanjilal exploration (1901), Dakshini (1968), Somadeva (1974) which serve as a good baseline information on status of vegetation about 100 years back. Trees on ridges have vanished, few *Shorea robusta* and *Quercus* trees are now restricted to swampy zone only.

Similarly for other swamps flora has been considerably reduced. Many areas have been converted into grassy patched and devoid of any shrubby growth. Severe encroachment, land conversion for various other purpose. In many cleared off areas *Ipomea* has attained invasive form. Area under freshwater swamp reduced considerably over decades.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

ICFRE through its network on Institutions should identify area unique in their vegetation composition like wetlands, swamps; grasslands etc. and make an updated inventory of such critical ecosystems. The information will be useful in predicting changes in vegetation composition because of human interventions, environmental factor such as climate change etc. Study of flora of wetlands in Doon Valley has been botanists (taxonomists) paradise for last 100 years. Lot of information on floristic composition is available at periodic intervals. The current study is important from the inventorisation and floristic point of view.

2. **Investigations on tree ring analysis (Dendrochronology) of certain species in Western Ghats to monitor climate changes and its relevance to wood quality**

**Principal Investigator:** Vijendra R. Rao, IWST, Bengaluru
**Duration:** 2011

**Critical analysis of the research theme and summary of the study**

Dendrochronology is the science to study the growth rigs of the trees to understand the past climate. Annual growth rings of the trees provide a wealth of information about the response of forest to a variety of environmental changes. The methodology can be applied to infer the climatic changes in the past. The project has been undertaken with following objectives:

- To test the sensitivity of the species to the changes in the climate and develop chronologies based on growth rings or expression of growth periodicity and vessel morphology in teak and *Myristica fatua*
- Infer available information on temperature fluctuations, rainfall, soil types atmospheric disturbances to ring analysis and wood quality.

A good wealth of information on application of the science of dendrochronology in India and abroad has been given by the PI, however, work on dendrochronology has not undertaken in India at significant scale. This is an area where ICFRE could take lead as it has full fledged wood anatomical laboratories for tree growth ring analysis at FRI Dehradun and IWST, Bengaluru.

PI has surveyed important forest areas of Western Ghats to identify species like teak and *Myristica* for dendrochronology and dendroclimatology studies.

Various computer models/ programmes were used for standardization of rings and response of climate on tree growth. Use of anatomical, entomological and edaphic data was used to predict variation wood quality.

Various climatic and non climatic factors are responsible for tree growth. Ring width and specific gravity, Vessel morphology (Vessel density, diameter, length) were also studied.

**Scientific findings and contents**

Most of the teak samples from all the sites show significant juvenile effect except Chandrapur. Teak has been found to have good potential to know rainfall pattern, mostly the drought year. The low rainfall year found by tree chronologies from Madikeri and Mundagod matches with most drought year of India. The timber like *Myristica* has not reflected prominent annual growth rings hence no analysis could be made. Findings have been concluded on response exhibited by samples from specific locations Medikeri, Mundagod, Thane and Chandrapur.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Project is well conceived. Such projects are needed to be developed for more bamboo species in the NE region of the country. Also based on the harvested biomass of different bamboo species and different age series, allometric equation of bamboo would be very useful for developing base line information on bamboo mitigation potential of the NE region. This information will add value to the scientific forestry literature which can be further used when bamboo will become a potential species for carbon trading in India.

3. **Study on ecosystem goods & services imparted by reserve forest in Mussoorie forest division**

**Principal Investigator:** Shri M.P. Singh, IFS, Head, CCFI Division
**Duration:** 2012

**Critical analysis of the research theme and summary of the study**

Forests are integral part of natural ecosystems and provide a life supporting system for all living beings. These support systems are also essential for survival of human beings as well. These services which are essentially products of various processes of ecosystem are collectively known as ecosystem services. Payment for ecosystem Services is now happening in many countries where communities are paid for maintaining good quality forests for continual supply of ecosystem services. In India although there are lot of discussion on mode of Payment for Ecosystem Services (PES). However, the concept is still in its infancy. These are good number of studies, in Indian context as well, where valuation of goods and services from ecosystems has been made. The methodology adopted has also given in details that can be adopted in Indian circumstances as well. Many of the Himalayan states have been demanding Green Bonus from Union Government for the Services rendered to the nation by Himalayan forests. The study on valuation of ecosystem services by FRI was undertaken with following objectives:

Short term objective:

- To carry out assessment of ecosystem services imparted by reserve forests in Mussoorie Forest division
- To conduct multi-location studies for assessment of various parameters of services
- To develop database on ecosystem services of reserve forests of Mussoorie Forest Division and publication of report

Long term objectives:

- To develop models for continued environmental services imparted by forests
- To document and develop strategies for conserving such forest area through controlling insect, pest, diseases, fire etc. and other management practices
- To develop data base for such forest areas in India and publication of report reviewing comprehensive information on these aspects.

**Scientific findings and contents**

A detailed review of literature and a menu of methodologies available for the valuation of ecosystem services have been discussed in the PCR. While citing similar work done by FRI PI has quoted number of similar other studies. The major part of the study is devoted to carbon assessment (one of the most widely publicized Ecosystem service) of the Mussoorie forests.

Biomass of pure stands of 4 important tree species (i) *Shorea robusta* (sal), (ii) *Pinus roxburghii* (Chir pine), (iii) *Quercus leucotrichophora* (Oak) and (iv) *Cedrus deodara* (Deodar) were estimated using allometric equations. The allometric equation model adopted has not been very well explained. How these models have segregated biomass of various tree components (Bole, Branch, twig and leaves) is not clear, Biomass has not been converted to carbon or $CO_2$ eq. Below ground biomass (Root component) has not been taken into account. Roots accounts for 26 to 30% of total tree biomass. Area under miscellaneous forest has also not been considered. Therefore significant

amount of biomass have left unestimated. This might have resulted in underestimation of Biomass and eventually carbon mitigation service rendered by these forests. Fuelwood, fodder production, assessment of medicinal plants and other NTFPs, agriculture production, assessment of water resources and soil conservation etc were assessed through survey conducted in 17 villages within the forest division.

The methodology used is not very much convincing, IPCC good practice guidance could have been used for estimation of carbon in these forests. PCR has been very casually written. At number of places name of 4 major forest on which study is conducted, their names are not written correctly. The biomass estimate ranges from 192.93 tonnes /ha for chir to 534.8 per ha for sal.

A proxy estimate of ecosystem services has been given based on the values assigned by Costanza (1997). Ecosystem services from Mussoorie Forest Division have been valuated worth Rs 246 crores. It is absolute value or annual value has not been mentioned. Costanza has given valuation on per annum basis. Costanza has further evaluated these values in 1997 that too under United States conditions. This may not fit under Indian situation.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Valuation of Ecosystem Services is a very apt study. ICFRE should have conducted in all major forest types of India. An All India coordinated Project will be a welcome step in this direction. Himachal Pradesh is so far the only state where PES has been introduced by the government. Now the states are asking for 'green bonus' from the successive finance commissions for the ecosystem services rendered by their forests. In the absences of information on ecosystem services of different forests it becoming difficult for finance commissions to devise an acceptable formula/model to deliver the value of these ecosystem services.

4. **Phytodiversity assessment of Khasi sub tropical wet hill forests in Meghalaya**

**Principal Investigator:** Sh. M.P. Singh, IFS, Head, CCFI Division
**Duration:** 2012

**Critical analysis of the research theme and summary of the study**

Comprehensive enumeration of the studied area for the first time provides baseline information to monitor impact of various ongoing, climate change, developmental activities and ecotourism. Flora of Khasi and Jaintia hills is most studied and is most saturated by eastern Asiatic elements. Region is most important centre of the survival of tertiary flora of eastern Asia. The study has been undertaken to study phyto diversity in the Riat Khwan forest of Meghalaya with a long term objective of 'Assessment of Phytodiversity for conservation management'

The Short term objectives of the study are:

- To study the floristic composition.
- To study the phytodiversity.

It is a short term duration study (1 year) in of the Important Bird Area (IBA). The study of phyot-diversity in Riyat Khwan Reserve Forest is significant due to this reason as well.

**Scientific findings and contents**

Voluminous review f literature has been mentioned in one year study which was conducted from June 2010 to July 2011. Study area is subtropical forest of Khasi hill.

Study area was stratified into 3 altitudinal zones through stratified random sampling. Floristic composition was analysed by laying down 100 nested quadrats for trees, shrubs and herbs. Basic phyto-Sociological parameters i.e. frequency, abundance and Importance Value Index (IVI) of vegetation was recorded. The study has documented 413 plant species belonging to 299 genera and 102 families of higher plants. Herbs are predominant among species. Family Asteraceae assumes dominance in the floral components.

Study concluded with objective of assessing phyto-sociology for conservation management. It is kind of enumeration of plant species. Herbarium collection were deposited in RFRI and BSI herbarium Shillong. Study also recorded ethenobotanical observations on 44 plants utilised by the local population for etheno-botanical use. Phyo-sociological studies in different altitudinal gradient were also conducted. Phyo-sociological analysis of trees shrubs and herbs were done separately.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Data base will be useful in scientific and industrial research. Study on plant diversity is important in understanding the structure and functioning of a forest ecosystem. Species diversity index could have been added value to the study.

5. **Vegetation carbon pool assessment in six districts of Andhra Pradesh**

**Principal Investigator:** G. Ravi Sankar Reddy
**Duration:** 2013

**Critical analysis of the research theme and summary of the study**

The project' Vegetation Carbon pool Assessment in six districts of Andhra Pradesh' has been undertaken as a part of national programme to generate geospatial data of the terrestrial biomass and carbon pool of the study area.

Terrestrial vegetation carbon survey and estimation of biomass was of the area was undertaken by ground sampling. Sample plots selected based on Forest types, density of vegetation, agro-climatic zones through a consultation workshop. The study was financed by IIRS and 72 teams from different Universities/ Institutions worked on the study. The objectives of the study were as follows:

- Laying permanent field plots, inventory of all plant species and their identification
- Measurement of growth character sticks if trees and biomass of trees, shrubs and herbs
- Create database of all plant species in all the plots for carbon pool assessment.

A common methodology was used across the Institutions as agreed in the consultation workshop.

**Scientific findings and contents**

Project progress reports were submitted to IIRS and data/information/findings have been shared with ICFRE/ IFB Hyderabad. All the quantitative measurements on vegetation were recorded in the formats given by IIRS and the data/ information supplied to the funding agency directly.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

It is yet another research project on Carbon Pool assessment of forest vegetation. Once forest was recognised as tool for climate change mitigation, lot of research programme on assessment of Forest carbon Pool, carbon sequestration potential of vegetation, has come to the fore. There is need for measuring various carbon pools following a uniform methodology including use of remote sensing and GIS tools. This can be achieved through an AICRP on assessment of various carbon pools forests. If necessary FSI can be associated with the study because FSI has been periodically measuring Forest carbon pool in India's forests as part of its regular report of India State of Forest Report

A similar PCR on 'Vegetation Carbon pool Assessment -Andhra Pradesh north region' has been submitted by Dr. N. Rama Rao.

6. **Studies on carbon sequestration in different forest types of Rajasthan**

**Principal Investigator:** G. Singh
**Duration:** 2013

**Critical analysis of the research theme and summary of the study**

Soil organic carbon is one of the important and largest terrestrial carbon pools and plays very crucial role in global carbon cycle. Being the largest terrestrial carbon pool it offers enormous opportunity of climate change mitigation and at the same time if not managed properly it can also act as a big source of carbon emission. The research project on 'Studies on carbon sequestration in different forest types of Rajasthan was proposed because of varied climatic conditions and floral wealth in different physiographic regions of Rajasthan lacks reliable data on carbon contents of forests. The study was undertaken with following short term and long term objectives:

Short term objective:

- To estimate Carbon stocks in forest soils
- To estimate carbon stocks in forest litters
- To estimate carbon stock in above ground and below ground biomass

Long term objective:

- Provide an estimate of carbon stocks of forests of Rajasthan for its utilization in planning and execution afforestation/reforestation programmes in the region

Total carbon content estimation in different components of forest ecosystems (Above ground and blow ground biomass, dead biomass, and soil both organic and inorganic) of Rajasthan have been studied. Enormous review of literature on the subject has been made by the PI.

The study has covered whole of the state of Rajasthan. A stratified random sampling covering 903 sample plots all 33 districts of covering different forest blocks of Rajasthan were studied. Study was conducted by laying down 0.1 ha sample plots. All tree species of >10 cm were measured for height and diameter. Plots of 5x5 m for shrubs and 1x1 m for herbs were laid down as nested plots. Biomass of shrubs, herbs, litter and coarse woody debris were recorded and samples collected. Biomass of tree species were estimated by harvest method using stratified tree technique. Study has also attempted to measure root biomass (Below ground Biomass) as well. In Indian forestry literature information on root biomass is very scanty. Soil organic carbon contents have been measured

following standard protocols.

**Scientific findings and contents**

The study has identified 31 subtypes of forests in Rajasthan. Soil pH was higher in 0-30 and 30-60 cm layers in '*Dry Grass land types' whereas* it was lowest in *'Euphorbia scrubs' and Cassia auriculata scrubs'* Electrical conductivity was highest in dry grassland areas. Dominant tree species observed in >10% sampling sites were *Prosopis juliflora* (37.7%) *Anogeisus pendulata* (23.7%0 *Acacia tortilis* (22.8%), *A. leucopholea* (21.4%), *A. Senegal* (19.1%), *Butea monosperma* (16.2%), *Prosopis cineraria* (13.2%), *Capparis decidua* (12.0%) *Diospyros melanoxylon* (11.4%) and *Maytenus emerginata* (10.3%), *Prosopis juliflora* and *Lantana camara* were the two most invasive species recorded in 37.7% and 7.4% in 32 and 12 districts respectively.

Percent soil organic carbon was highest in Tropical riverain forests in 0-30 and 30-60% cm layer. SOC was observed lower in '*Desert dune Scrubs'*. Soil inorganic carbon ranged from 0.22 % in *Acacia catechu* type forest and 1.75% in '*Dry Savannah'* types.

Study has also analysed district wise and bioclimatic zone wise density of Soil organic carbon. The total Soil Carbon stock on 0-30 cm soil in different districts of Rajasthan varies from 0.07 million tonnes in Churu and 14.56 million tonnes in Udaipur.

Forest floor biomass (litter layers) ranged between 0.25±0.15 tonnes per ha in 'Rann saline thorn forest' and 2.71±1.42 tonnes per ha in '*Northern mixed secondary mixed dried deciduous*' forests. Herbaceous biomass ranged between 0.18±0.05 tonnes per ha in '*Dry teak forests'*, (5A/C1) and 1.45±0.32 tonnes per ha in '*Dry grasslands'*

Allometric equations have been developed for predicting total biomass (Above ground and below ground) for *Prosopis juliflora* by felling 36 trees from 7 districts of Rajasthan. Regression models were developed for total biomass of under shrub species as well. Average dry total biomass (Above ground and below ground) of 43 tree species have recoded under the project. Tree above ground biomass indicated lowest and highest values in *Euphorbia* scrubs (6E1) and 5/2S2 (somehow this forest type was not reported from Rajasthan by FSI) forests respectively with 55% variation in these forest types. Lesser variation on shrub biomass was observed.

Finally PI has estimated that total carbon available in the forest of Rajasthan is 305.19 million tonnes, of which 142.6 million tonnes is Soil inorganic carbon (SIS), 121.6 million tonnes is SOC, 1.24 million tonnes is Dead material (Litter) ,0.77 million tonnes herbaceous biomass and 38.98 live biomass (AGB+ BGB). The study shows Soil Carbon (SIC and SOC) is enormously high as compared to carbon stored in vegetation pools.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

It is one of the exemplary projects that attempted to estimate carbon comprehensively at forest ecosystem level. Similar other studies have also been done on these aspects by various ICFRE Institutes most of them at selected stand level or forest division level. Similar studies can be undertaken by ICFRE institutes under AICRP using uniform methodology. Development of allometric equations has been the important aspect this project. The Allometric equation for estimation of biomass and eventually carbon for forestry species is lacking in Indian forestry literature. ICFRE must take lead in assessing forest carbon at national level by adopting a uniform methodology accepted under UNFCCC/IPCC.

7. **Screening of tropical forest tree species for their potential as carbon sink in Madhya Pradesh and Chhattisgarh**

**Principal Investigator:** Avinash Jain
**Duration: -**

**Critical analysis of the research theme and summary of the study**

The project is focussed on role of various tropical timber species in different agro-forestry systems for Carbon sequestration in Central India with a long term objective 'to popularise high carbon sequestration tree species in agro-forestry systems and State Forest Departments'

Short term objectives of the project are:

- To select 2-3 forest species in different Agro-forestry Systems of Madhya Pradesh and Chhattisgarh and screen them for Carbon Sequestration potential.
- To observe effect of periodic removal of tree species as well as agricultural crops on Carbon Sequestration
- To determine photosynthetic rate of selected tree species in different Age/Girth classes, seasons and agro-forestry systems
- To determine residue carbon pool in Rhizosphere spoils of different agro-forestry systems

Under the study *Tectona grandis* (teak), *Dalbergia sissoo* (shisham), *Shorea robusta* (sal) and *Eucalyptus eurograndis* based agro-forestry systems were developed with agriculture crops like, wheat, Gram, Wild Oat, Barley and Ashwagandha.

Photosynthetic rate of selected tree species was determined by applying regression equations. For agriculture crops carbon sequestration was determined by harvesting the crops. Trainings on agro-forestry and climate change to farmers staff of State Forest Department, tree growers and other stakeholders were also conducted under the project.

**Scientific findings and contents**

Estimation of Carbon in different Agricultural crops under teak, shisham and eucalyptus based agro-forestry system was made. 15 years old teak and Shisham trees planted at 2x2 m spacing sequestered 14.65 and 14.75 tonnes of Carbon per ha per year respectively. Agricultural crops when cultivated between trees increased carbon sequestration potential of system due to addition of crop litter in the soil. At the same time production of agricultural crops reduced significantly because of the competition for the available resources. 9, 14 and 24 months old plants of *Eucalyptus eurograndis* planted at 3x1 m spacing were found to sequester 3.40 , 4.55, 26.75 t/ha of per ha carbon respectively. Production of wheat was reduced when cultivated with *E. eurograndis*. The carbon sequestration of22 year old *Shorea robusta* was 18.95 tonnes /ha /year while 41 years old plantation of *Tectona grandis* was found to sequester 22.66 tonnes of carbon/ha/annum.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Ideally it should have been a 'stratified tree technique' and biomass of different tree components could have been given. Abstract of results were presented. During experiment on biomass number of tree species of different age group were harvested. Detailed data on biomass of different components (bole, branches, twigs, leaves) would have been useful information for developing biomass allometric equations and Biomass Expansion Factors (BEF) for tree species used in the experiment. Information on BEF is very scanty in Indian forestry literature. More information on biomass if tree species need to be conducted. Such information will be useful in developing policies and programme for achieving India's forestry sector NDC to the Paris Agreement.

8. **Carbon footprint mapping of FRI, Dehradun**

**Principal Investigator:** Sh. T. Johri, DCF
**Duration:** 2013

**Critical analysis of the research theme and summary of the study**

A carbon footprint measures the total greenhouse gas (GHG) emissions caused directly and indirectly by a person, organisation, event or product. It is measured in tonnes of carbon dioxide equivalent (tCO2e). The carbon dioxide equivalent ($CO_2e$) allows the different greenhouse gases to be compared on a one single unit basis relative to one unit of $CO_2$.

The project has been undertaken with following long term Objectives:

- To reduce the GHG foot print of FRI generated due to core forestry research related activities.
- To document and develop mitigation strategies to moderate the generation of GHGs
- To become a pioneer in developing FRI Dehradun to be a green research Institute

The Short term Objectives of the project are:

- To develop data base /inventory of all GHG emitting sources of FRI along with Carbon being emitted by them as per average usage hours
- To prepare a carbon accounting map and carbon foot print of FRI campus
- To prepare mitigation strategies for reducing GHG emission including optimisation of resources through appropriate technology and logical strategies

Ideally a carbon footprint should consider all six of the Kyoto Protocol greenhouse gases: ($CO_2$), Methane ($CH_4$, $N_2O$, HFCs, PFCs and $SF_6$).

The project was approved by RAG/RPC with very ambitious long term and short term objectives. Unfortunately none of the objectives (short as well as long term) have been fulfilled by the PI

**Scientific findings and contents**

Carbon footprint has been explained as per definitions and concept available in the internet /web based sources. Along with a justification as to why Carbon foot print is calculated. Review of literature mostly retrieved from web based sources. A detailed menu of methodologies (List only) have been given for estimation of carbon foot prints.

PCR has identified potential sources of GHG emission within FRI Campus (Ideally it has to be New Forest campus not FRI Campus), GHG Sources from residential area certainly out number the GHG emission from FRI research divisions.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Further it is suggested that data/quantitative information on GHG emission from the various activities within FRI campus be generated following the study. Emissions from all the activities across the organisation, including buildings energy use, processes and vehicles should be estimated.

9. **The study of biology and conservation management of endemic plants of Kalakadu Mundanthurai Tiger Reserve, (KMT) Tamil Nadu and Kerala**

**Principal Investigator:** by Sh. K. Rajagopal
**Duration:** 2014

**Critical analysis of the research theme and summary of the study**

Western Ghats are second only to the eastern Himalayas as a treasure of biodiversity in India. The forests of Western Ghats have a high proportion of endemism comprising of 1720 endemic species, about 40% out of circa 4500 species. The current project on 'The study of biology and conservation management of endemic plants of Kalakadu Mundanthurai Tiger Reserve, (KMT) Tamil Nadu and Kerala has been undertaken with a long term objective to find out additional factors if any responsible for the endemism of plant biodiversity apart from geographical locations, edaphic and climatic factors

To develop conservation strategies, both *in-situ* and *ex-situ* of the strictly endemic texa of KMT Reserve

The short term objectives are:

- To study plant population distribution and association pattern exhibited by strictly endemic species.
- To study the reproductive biology of strictly endemic species
- To study and find out microorganism if any which are responsible and support the survival of endemic species in their particular phyto geographic regions.
- To study the seed biology of the endemic plants so as to suggest visible proposition of species recovery programme.

All (long term and short term) objectives of the project revolve around strictly endemic species. However, survey and repeated walks (Perambulation) have been done with an aim of studying 5 strictly endemic plants as species recovery programme of KMT reserve. It is not clear that there are only 5 endemic plants or KMT reserve authorities have species recovery programme for 5 species only.

**Scientific findings and contents**

The project is undertaken for conservation of endangered endemic species of the KMT Reserve. Aspects of reproductive biology have been dealt at greater length. Nurseries were established for seed germination trials and vegetative propagation. Results are presented in the form of progress report. Discussion part is rather poor.

Nurseries were established in KMTR and also at IFGTB campus for seed germination trials, raising seedlings and vegetative propagation experiments. Vegetative multiplication procedures and protocols, seed germination status of the targeted endemic species is described in the PCR.

Methodology and other descriptions (p 22) reveals that 5 critically endangered endemic species *Phyllanthus singampattianus, Eugenia singampattiana and Palaquim bourdillonii* were studied (Two others)

*Phyllanthus singampattianus* stem cuttings only showed successful growth rate in root and shoot formation in all the hormonal treatments. *Eugenia singampattiana* exhibited hypogeal type of germination, in this species formation of fruits ripen during September. Fruits are utilised by local tribals thus resulting in scarcity of seeds for regeneration. *Palaquim bourdillonii* were neither flowered nor fruit formation tool place in past two years of study period. However, it produces lot of seedlings through root suckers.

10. **Monitoring the impact of climate variable on plant diversity in Bhimashankar permanent preservation plot of Sub tropical hill forest of Maharashtra**

**Principal Investigator:** Dr. P.K. Khatri, Scientist-D
**Duration:** 2014

**Critical analysis of the research theme and summary of the study**

Preservation plots are miniature nature reserves to study long term vegetation dynamics in perpetuity. The present study was undertaken in one of the preservation plots located in Bhimashankar Wild life sanctuary with a long term objective of periodical monitoring of forest composition in the permanent preservation plots for establishing cause effect relationship between threat to biodiversity due to climatic factors.

Short term objectives of the study are:

- To study structure and composition of the forest.
- To study phonology and regeneration status of important plant species
- To monitor changes in plant diversity in relation to climatic variables

Standard ecological methodology has been used to study the structure and composition of the forest, regeneration status of important tree species was also evaluated

**Scientific findings and contents**

Forest community comprised of 29 tree species, 6 species of climbers and lianas, and 11 species of shrubs in the preservation plot in the habitat of threatened Giant Indian Squirrel. As compared to 2002 change in canopy composition and structure has been observed in 2014. Study has attempted to correlate the structure and composition of forest with change in climatic variables. Density of some of the tree species increased during the study period. However, locality factor has been more prevalent for influencing vegetation and establishment of species than broad climatic factors.

Temporal and structural change in structure and composition of preservation plot was studied. Regeneration of the native species was found to be better at lower altitudes. Species change matrix indicated changes in structure and composition of the forest community.

*Syzygium cumini, Olea dioca* and *Mangifera indica* have a high representation in higher size class but have a relatively lower representation in lower size class. The population structure of species like *Dimorphocalyx lawianus, Garcinia talbotii, Lansium anamallayanum, Litseajosephi, Xantolis tomentosa, Memecylon umbellatum, Mallotus philippensis* and *Atalantia racemosa* shows increasing trend in the studied community indicating change in the community composition.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Long term study of vegetation in perpetuity need to be studies in all major forest types of India. During British period preservation plots were laid down in all major forest types of India with this objective only. However, systematic study on preservation plots was discontinued after 1980s. There is need to revive this important aspect of long term ecological studies, especially when expected vegetation shifts are reported because of impact of climate change. Various climate models are also predicting large scale vegetation shifts in India's forests.

ICFRE may initiate a nationwide All India Coordinated project for revival of preservation Plots and develop a networking of PIs working on this aspect. MoEF&CC has also initiated studies on long term ecological observation Plots. ICFRE and its institutes can develop synergy with MoEF & CC on this aspect.

11. **Rehabilitation of degraded Jhum land through potential bamboo species with reference to carbon sequestration and livelihood development**

**Principal Investigator:** Dr. Indrani P. Bora, Scientist-B
**Duration:** 2015

**Critical analysis of the research theme and summary of the study**

Shifting cultivation, commonly known as Jhuming or Jhum cultivation has been one of the main causes of forest degradation in the North Eastern Part of India. The situation is becoming worse with reduction in fallow period which hampers the natural rehabilitation of these Jhum lands. Additional man made efforts to rehabilitate such areas can effectively contribute in reversing the forest cover loss. Bamboo is one of the most important species of the NE region of India which is deeply embedded in socio-economic and cultural life of NE India. This project was undertaken to rehabilitate the degraded Jhum lands through application of bamboo species in the Karbi Anglong (An Autonomous district of Assam) with a long term objective to establish Carbon sink in degraded Jhum Agro-ecosystems.

The short term objectives include:

- Rehabilitation of degraded through selected bamboo species
- Assess the rate of increment of carbon pools
- Economic analysis of bamboo for livelihood development, and
- To generate environmental awareness

**Scientific findings and contents**

Rehabilitation of Jhum lands was done using three Bamboo species, (i) *Bamboosa balcoa*, (ii) *Bambusa tulda* and (iii) *Bambusa nutans.* Four to six months old seedlings with 4-6 shoots were macro-proliferated and individual rhizome separated, likewise multiplied 4-6 times. Two months old seedlings were used for field plantations. Dry Biomass, Biomass carbon and Soil organic carbon were estimated, comparative growth rate of Rhizome and seedling origin bamboo has also been estimated. *Bambosa balcoa* raised from rhizome yielded higher biomass followed by *Bambusa tulda* and *B. nutans*. Plantations raised through seedlings yielded less biomass. Bamboo makes a valuable carbon sink in NE region. It requires less investment for rehabilitation of degraded lands. Potential of bamboo based rehabilitation package for NE region was explored in the present study. *Bambusa tulda* has high potential for biomass carbon sequestration and SOC as well followed by *Bambusa balcoa* and *Bambusa nutans*. Soil Organic carbon (SOC) was also high in rhizome raised plantations. Maximum SOC was recorded in *Bambusa tulda* plantations (1025 t/ha) and minimum on *Bambusa nutans* (782.3 t/ha) after 4$^{th}$ year of rhizome raised plantations

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Bamboo is becoming increasingly important species in rural economy as a superior wood substitute. Growth and yield information on Indian Bamboo is very scanty. Information on Root/Shoot ratio of many Indian species is not available. This project has generated this information as well. The information generated through the project is very useful in developing biomass/ allometric equations for estimation of growth and yield data of bamboo in an age series of plantations.

Project has resulted in generating huge data on growth and yield of bamboo. Study need to be continued for variety of other land uses in different states

Replication of such studies with other bamboo species grown in NE region will be useful for estimation of carbon capture by bamboo species in view of India's NDC targets to UNFCCC.

12. **AICP on elevated $CO_2$**

**Principal Investigator:** Dr. Hukum Singh, Research Officer
**Duration:** 2015

**Critical analysis of the research theme and summary of the study**

Increase in concentrations of GHGs in atmosphere is resulting in increase in global mean temperature. Increase in concentration of $CO_2$ is likely to alter the structure and functioning of the terrestrial ecosystems as well. $CO_2$ acts as food for plants ($CO_2$ fertilization) as such it acts as sink of carbon and at the some productivity of natural ecosystems is likely to be affected adversely by the warming caused by ever increasing concentration of GHGs. The current study has been undertaken to understand how the tree species will respond to increasing concentration of atmospheric $CO_2$. The study has been taken as an AICP with following objectives:

Short term objective:

- Establishment of open top chamber facility with controlled and automation and FRI Dehradun
- Characterization of growth dynamics of forestry species under elevated $CO_2$, temperature and humidity
- Biochemical analysis and allocation of nutrients in various parts of forestry species under elevated $CO_2$, temperature and humidity

Long term objective:

- Adaptive characterization of forestry species under increased level of $CO_2$ and temperature in scenario of climate change

Long term on response of elevated $CO_2$ on trees has not been conducted in India. Few such studies are available for agriculture crops. The primary focus of the study is investigate the impact enhanced $CO_2$ concentration on tree species with special reference to adaptive behaviour of forestry species to elevated $CO_2$ and temperature. A number of technologies have been practiced for study of elevated $CO_2$ on plants. FRI has used open top chamber technology (OTC) with control and automation was used to assess response of important forestry species to elevated $CO_2$ and temperature conditions.

Study will provide a holistic understanding of the response of vegetation under changing climatic conditions. The finding will be useful to plant scientists' ecologists, plant physiologists, tree breeders, climate change scientists and modellers.

**Scientific findings and contents**

Seedlings /clones of 6 forestry species were selected for study (i) *Eucalyptus* hybrid FRI-PH4, (ii) *Eucalyptus citriodora*, (iii) *Eucalyptus terticornis*, (iv) *Melia composita*, (v), *Populus deltoids* and (vi) *Dalbergis sissoo*. Tree seedlings were exposed to 800 ppm of $CO_2$, elevated temperature of $+2^0$C in addition to ambient and simulated humidity on plant performance in terms of growth, morphology, physiology and biomass partitioning in various parts of seedlings/ clones was considered. All tree species used in the experiment have shown positive growth response to elevated $CO_2$, elevated temperature, simulated humidity and their combination. The increased photosynthesis because of $CO_2$ fertilization effect resulted in increased plant height, stem diameter, number of leaves and number of branches. The shoot biomass of all the clones increased significantly when the plants were grown under high $CO_2$ concentration. The maximum rate of

photosynthesis was recorded for clones under elevated $CO_2$ followed by elevated temperature and simulated humidity. Transpiration rate also decreased when clone exposed to $CO_2$ enrichment conditions in comparison to ambient. Rising temperature showed increased rate of transpiration. Stomatal conductance was also decreased under elevated $CO_2$ conditions. Clones grown under elevated $CO_2$ condition also showed improved physiological water use efficiency. Physiological water use efficiency enhance with decreased stomatal conductance.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

OTC technology was used for the time by FRI, although IFGTB, Coimbatore already used this technology in their experiments. Under current study only one concentration of CO2 has applied. It is suggested that different concentrations of $CO_2$ can be applied to find CO2 concentration for optimum plant growth under controlled conditions. IFGTB Coimbatore is also working on response of tree species to elevated $CO_2$. Morphological, physiological and biochemical responses including activity of Rubisco and carbonic anhydrase of seedlings of different fast growing tree species exposed to elevated $CO_2$ levels (600-900 ppm) was also conducted. Although it is a novel experiment, the results were presented in a standalone manner i.e. species wise only. A comparative assessment of elevated $CO_2$ in different species and different parameters have not been discussed.

13. **Ecological studies on the distribution patterns and food plant resources of butterflies along altitudinal gradients in different forest ecosystems of the Eastern Himalayas (Arunachal Pradesh)**

**Principal Investigator:** Dr. Arun Pratap Singh, Scientist-E
**Duration:** 2015

**Critical analysis of the research theme and summary of the study**

Arunachal Pradesh with its 80% forest cover is endowed with great diversity of flora and fauna. Information on butterflies of the state of Arunachal Pradesh is very scanty. The project has been successful in generating baseline information on butterfly fauna of the state and their ecological affinity with the forest types, their altitudinal distribution and larval food plants. The data base contains distribution on spatial scale plotted on GIS based map for each species along with other relevant information about the species. This information will be useful in comparing current distribution amplitude of the species and also in future as projected climate change is expected to change in distribution of the species. First hand comprehensive information on butterflies of Arunachal Pradesh

The long term objective of the project is 'to identify distribution pattern of the butterflies sensitive to environment/ climate change in East Himalayan forest ecosystems'

Too many short term objectives have been set for the project. The prominent among them are:

- To develop baseline information on species composition relative abundance of butterflies in the eastern Himalayan forest ecosystems at different altitudinal gradients.
- To study seasonality, distribution pattern, food resources (Larval and nectar plants) and life history of butterflies.

To develop a GIS database supported by image on distribution of butterflies that can be compared with data of same area in future

**Scientific findings and contents**

It was a four years study conducted in 20 districts and 16 forest type groups from an altitude of 100 to 2700 m. Data on 413 species found in the state generated along with Geo-coordinates, Altitudinal range of location, time and season of collection and site. The study resulted in 10 new distribution records. 77 species of conservation priority were identified based on their Wildlife Protection Act, 1972 status, location, forest type association, altitude and temperature range. Data on temperature range of 312 species reveals that it varies from 17.5 to 33.5$^{0}$C while the range for relative humidity varies from 51 to 98%. This compilation included 10 new distribution records from the state.

A three day training module on identification, ecological value of butterflies and potential of butterflies inclusive ecotourism in the state.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The baseline information on status and distribution of butterflies across different forest ecosystems along altitudinal gradients in Eastern Himalayas is the first hand comprehensive information on GIS platform.

Project has proposed strategies for conservation of butterflies and their habitats at landscape level. Rare and endangered species identified along with food plant resources helped in planning conservation strategies.

Study is of immense importance for the rainforest ecosystems of North eastern Himalayan region. Such baseline information on butterflies of North east region will add value to the understanding of ecology of these important groups of animal kingdom.

A knowledge product of the Project was published as "Butterfly Atlas of Arunachal Pradesh"

This reference guide will attract butterfly/nature lovers and boost tourism in the state

14. **Assessment of carbon stock in forest types of Shimla forest circle, Himachal Pradesh**

**Principal Investigator:** Dr. R.K. Verma, Scientist- F.
**Duration:** 2016

**Critical analysis of the research theme and summary of the study**

Studies on Carbon dynamics in forest ecosystems is gaining importance in view of role of forest in climate change mitigation. Studies on 'Assessment of Carbon Stock in Forest Types of Shimla Forest Circle, Himachal Pradesh' was conducted with following objectives:

- To assess the carbon stock in different forest types
- To estimate the soil carbon stock in different forest types

(Ideally there could have been one single objective of assessing carbon stocks of forests of Shimla forest circle)

Studies on Carbon sequestration potential also gained importance in recent past in view of carbon being used as tradable commodity in form of carbon credits, a global market mechanism being used for climate change mitigation. Under this pretext a precise assessment of carbon contents in a forest ecosystem is imperative. The Above ground biomass was estimated by destructive and non destructive sampling. Detailed survey for selection of study sites under different forest types within the Shimla Forest Circle was conducted. For each forest types above ground biomass was estimated by destructive and non destructive sampling. Default factors were used for estimation of below ground biomass. Soil organic carbon was estimated using standard methodology.

**Scientific findings and contents**

Among 11 forest types groups studied in Shimla forest, total biomass was found highest in Kharsu Oak (1124.67 t/ha) at Larot, followed by Mohru oak (869.70 t/ha, deodar (790.06 t/ha, and fir spruce forest (754.01 t/ha. Total above ground biomass for Alpine pastures varied from 3.81 to 10.41 t/ha. Soil Organic Stocks of forest types and alpine pastures up to 45 cm depth was highest in Alpine pastures (128.34 to 163.26 t/ha) followed by Deodar (88.03 t/ha). The study resulted in generation of information on carbon status (Above ground+ below ground + SOC) of different forest types of Shimla Forest Circle biomass carbon

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

The study will be useful for State forest Department as baseline information for various state/ national programmes, implementing National REDD+ strategy or developing a state REDD+ Action plan. It is yet another study on assessment of forest carbon stocks of a forest ecosystem (In this case Shimla Forest Circle) under taken by ICFRE Institutes. Similar other studies have also been done on these aspects by various ICFRE Institutes most of them at selected stand level or forest division level. Similar studies can be undertaken by ICFRE institutes under AICRP using uniform methodology. For example this study measured SOC up to the depth of 45 cm, while other studies on SOC done by ICFRE Institutes have assessed SOC from 0-30 cm and 30-60 cm. Different methodologies for same parameter may pose problem when harmonising data at national level.

15. **Studies on ecological and ethno mycological aspects of wild mushrooms of Meghalaya**

**Principal Investigator:** Sh. Rajesh Kumar, Scientist – D
**Duration:** 2017

**Critical analysis of the research theme and summary of the study**

Meghalaya in North Eastern India is one of the high rainfall areas in India and endowed with rich biodiversity of Mushrooms. Under the project diversity of wild mushrooms along with their uses in food medicine of the state of Meghalaya have been attempted. Edible wild mushrooms are consumed as food by the people of North East India. Often deaths of local tribals are also reported by consumption of wild poisonous mushrooms.

The project has been undertaken with an objective of developing a data base on ecological and ethno-mycological information on wild mushrooms of Meghalaya and maintenance of their important strains.

**Scientific findings and contents**

Under the study edible mushrooms sold in market were documented and studied for their market potential etc.

Chemical composition (Mushroom protein, fat, carbohydrate and ash contents have been analysed. Based on survey, a distribution map of important edible mushrooms on GIS platform is also prepared. For *ex-situ* conservation of wild mushrooms, culture of major wild mushrooms were also raised and maintained in laboratory for future reference. 138 different species of macro fungi belonging to 38 families and 75 genera were documented. Out of this 121 species are first reported from Meghalaya and 18 are first report from India. 5 wild species are also successfully cultivated in laboratory.
Project has achieved its stated objectives.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

As an extension activity two training programmes were conducted. A four day training programme on cultivation of wild mushrooms was also held at RFRI. 25 entrepreneurs from Meghalaya were also trained for self employment. Project also led to awareness programme on identification of non consumable mushrooms in different localities of Meghalaya. Although Meghalaya tribes can distinguish poisonous and non poisonous mushroom because of their traditional knowledge, however deaths due to mushroom poisoning are prevalent in NE region. Such studies are important for wild mushroom rich NE region and need to be replicated in other NE states.

It is a valuable study. It seems that macro fungi flora of NE region is not very well explored. The study conducted in Meghalaya discovered 121 species of macro fungi reported for the first time from Meghalaya out of which 18 are first report from India. Such studies are recommended for entire NE region. ICFRE may get leadership in this endeavour.

16. **Restoration of sand stone mining area of Vindhyan region through microbial technology**

**Principal Investigator:** Dr. Kumud Dubey
**Duration:** 2017

**Critical analysis of the research theme and summary of the study**

The project 'Restoration of sand stone mining area of Vindhyan region through microbial technology' has been taken up to restore stone mining affected areas through conditioning of soil with microbes, broadcasting of fodder grasses and planting of tree species. The Long term Objectives of the project is 'Restoring of stone mining affected area through application of Microbial Technology'

The Short term Objectives are as follows:

- To study the Phyto-sociological conditions of stone mining
- To study the Soil characteristics and conditioning of soil through microbial inoculation of and Bio-amendments
- Establishment of surface covering vegetation through grass fodder species
- Establishment of plantation trial of microbe- inoculated seedlings species and selection of suitable species
- To develop suitable methodology for restoration of the stone mining area.
- Extension of developed methodology to forest department

In this study soil amendments have been applied to restore the stone mining affected areas through conditioning of soil by microbial technology, broadcasting of fodder grass and plantations activities. Plantation species were selected through stakeholders consultation process.

Vegetation survey (Phyto-sociology) of stone mines affected areas and nearby undisturbed forest were done. Conditioning of soil was done through microbial inoculation of bio-amendments, exposed surface has been covered through planting of grasses. Plantation trials of microbes inoculated seedling species and selection of suitable species was done.

**Scientific findings and contents**

35 species (13 trees, 9 shrubs and 13 herbs from undisturbed sites and 22 species (7 trees, 6 shrubs and 9 herbs from disturb sites were recorded.

Bio-remediation has been successfully achieved using microbial biofertilizers by various workers in difficult sites therefore patenting chances are very bleak as no or innovative technology has been applied by the PI.

Preferable species for restoration were selected based on socio-economic survey. Most respondent favoured *Mangifera Indica* (mango), *Madhuca indica* (mahua), *Dalbergia sissoo* (shisham), *Tectona grandis* (teak) and *Acacia catechu*. However, species planted were not the preferred species by the villages except Mahua. However, species planted for restoration are: *Leucaena leucocephala, Holoptelia integrifolia, Gliricidia sepium, Heplophragma adenophyllum, Pithecellobium dulce, Melia dubia, Jatropha caracas, Cassia siamea, Ficus religeosa*, and *Madhuca indica*. Thus selection was based on utility of species and its adaptability to the site.

Growth performance of these species at seedling stage was recorded. By treating the site with Biofertilizer and FYM. Survival of biofertilizer inoculated seedlings was higher as compared to control (untreated). Biofertilizer inoculation resulted in better establishment of plants. Poor growth rate of all species was attributed to extreme weather and climatic conditions and difficult terrain.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Opencast mining practiced in the area resulted in barren, unproductive degraded soils. Suitable methodology for restoration of stone mines areas has been developed. Restoration is imperative to check landscape restoration. The technology developed need further testing and replication in similar areas before the large scale application of the technology is recommended to the forest department and other agencies. Extension of the project activities were also made among officials of State forest Department.

Soil seasoning with microbes and plantation of inoculated seedlings may speed up restoration process. Microbes like *Rhizobium*, Azotobecter, Azospirillum, Phosphate solubilizers and Mycorrhiza can be used for seasoning and restoration of such problem soils

17. **Carbon sink and fertility status relation of soil under different land use systems of some of the states of NE India**

**Principal Investigator:** Dr. P.K. Das Scientist- 'C'
**Duration:** 2012

**Critical analysis of the research theme and summary of the study**

Soil organic carbon is one of the important and largest terrestrial carbon pool and plays very crucial role in global carbon cycle. Being the largest terrestrial carbon pool it offers enormous opportunity of climate change mitigation and at the same time if not managed properly it can also act as a big source of carbon emission. The stud on 'Carbon Sink and fertility status relation of soil under different land use systems of some of the states of NE India/ was conducted by RFRI, Jorhat with following objectives:

- Characterization of the soil with selected forest and other vegetations
- Assessment of soil carbon sink under selected forest and other vegetations
- Correlation of carbon sink and nutrient status of soil.

Enormous review of literature on the subject matter has been compiled by the PI. Soil sample from 0-30 cm layer were collected and sample prepared as per standard soil sampling protocol. A total of 313 soil samples from the region were collected for analysis from different land uses. The land uses are Jhum lands, tea plantations, Coffee plantations, Rubber Plantations, Cardamon plantations and forest plantations. Information on 99 soil samples collected earlier from different forest type groups of NR region were also utilised in this study.

**Scientific findings and contents**

Standard Walkley and Black (1965) method was used for analysis of soil organic carbon. Physico-chemical properties and nutrient status (Available potassium, Available phosphorus and nitrogen) of

sampled soils were analysed. Wide variation in soil organic carbon content (SOC) was found among the eight land use systems. Soil organic carbon content (SOC) under these eight land use systems varied from 2.6 to 200.6 tonnes per ha. Highest SOC 200.6 t/ha was recorded under sub alpine and alpine plantation soils of Arunachal Pradesh. Wide variation among Nitrogen content was also observed different land use types. Available phosphorus was also found low in most of the areas. Available phosphorus range in soil varied from 0.2 to 105 tonnes per ha. Available potassium varied from 0.6 to 2.64 tones/ ha

Soils are loamy and sandy textural classes under all eight land use systems.

Statistical analysis was performed to analyse correlation between soil organic carbon and nutrient status. Positive strong significant correlation (at 1% level) was found between SOC and available nitrogen under plantations and nearby non forest areas. Negative weak insignificant correlation was found between SOC and available phosphorus for seven land use systems except for Jhum areas. Positive strong correlation was found (at 1% level) was found between SOC and available potassium (K) under plantation forest areas. Positive week correlation (at 1% level) was found between SOC available potassium (K) under jum land and rubber plantation areas. SOC showed negative strong significant correlations (at 1% level) with the bulk density of soil for plantation forest, nearby non forest areas. It was found that with increase in Soil Organic Carbon bulk density of soil decreases significantly under all land uses.

**Suggestions regarding follow up patenting possibility, utilization aspects and prototype**

Project has generated good amount of information on SOC and other physico-chemical properties of soils under different land use systems of NE region. PI has developed a good correlation between SOC and various other physico-chemical parameters. Such study may be taken as AICRP to generate updated information of various forest types, non forest areas and other land use system. Once this base line information is developed it will also help in correctly quantifying the additional carbon sequestered by forest ecosystems to meet India's achievements on forestry sector NDC because soil is the largest carbon pool of terrestrial ecosystems including forests. Standard methodologies have been used by the PI therefore there are no chances of any Patent from this study.

# Forest Products

1. **Investigation on wood properties of teak in relation to variation in age and site factors**

**Principal Investigator:** C. Buvaneswaran

**Duration:** 2003

**Significant Findings**

The Studies on wood traits were carried out in two sites representing southern (Tirunelveli) and western zones (Coimbatore) forest divisions. On an average, the heartwood produced was in greater proportion in trees at Tirunelveli (80% of total disc area) than in Coimbatore (74% of total disc area). However, there existed lesser difference in the mean wood density, between the two zones studied.

**Comments**

This is an interesting study. Such studies in more zones of the country may reveal interesting results in wood traits as well as wood properties**.**

2. **Biocomposites from engineered natural fibers**

**Principal Investigator:** Ajay Karmarkar

**Duration:** 2003

**Significant Findings**

A novel vinyl monomer with isocyanate functional group, namely m-Isopropenyl-α, α-Dimethylbenzl-isocyante (m-TMI), was grafted onto isotactic polypropylene (i-PP) using dicumyl peroxide (DCP) as the initiator in a batch processes (using Brabender Plasticoder) and in a continuous processes (using twin screw extruder).The study showed that the –NCO group in m-TMI is less reactive to water, because link to an isopropyl moiety makes -NCO less sensitive to water. Addition of wood fibers, at all levels, resulted in more rigid and tenacious composite, but had lower impact energy and elongation percentage. Also significant improvement in tensile and flexural properties of the composites could be achieved.

The increase in mechanical properties demonstrates that m-TMI-g-PP has effectively functioned as compatibilizer. The study exhibited a linear increment in dynamic MOE with wood content.

**Comments**

A very good study on WPC. To be compiled with other such studies.

3. **Studies on fiber Formation in wood**

**Principal Investigator:** S.P.S Rawat

**Duration:** 2005

**Significant Findings**

Crystallization with simultaneous polymerization was found to be the most plausible mechanism for forming microfibrils. Creation of amorphous phase was accompanied by an entropy gain. Variation of fibril angle provided an optimum combination of stiffness (small microfibril angles) and extensibility (large microfibril angles) in response to the actual mechanical demands in fibers in various parts of a tree. A model based on thermodynamic parameters is reported to have developed for the description of the formation of one-dimensional fibrils from disordered fluid. Creation of disorder in crystalline lattice of cellulose was accompanied by entropy gain. Creation of amorphous regions within crystalline cellulose was a decrease of enthalpy.

**Comments**

Many analyses that were made are not reflected clearly. The results section is too brief and reads like a conclusion section. Some group interested in theoretical aspects of wood structure and science may follow up this study.

4. **Analytic studies on Visco-elastic behaviour of wood and tree biomechanics**

**Principal Investigator:** S.P.S Rawat

**Duration:** 2005

**Significant Findings**

A model was developed on the principles of viscoelasticity to explain the experimental results of creep and stress relaxation. Activation volume, energies, elastic and viscous constants were calculated through this model. Spring of the Maxwell body describing instantaneous elastic behavior is represented by crystalline portion of the cellulose. Kelvin body with spring and dashpot in parallel was linked with delayed elasticity, which was resulting from cross-linking of woody constituents.

**Comments**

A good modeling study. The developed models may have been presented at least in a tabular form so that other workers could use them.

5. **Control of biodeterioration of wood with help of eco-friendly preservatives and bioactive substances on staining and decay fungi under terrestrial conditions**

**Principal Investigator:** H.C Nagaveni

**Duration:** 2005

**Significant Findings**

Rubber wood (*Hevea brasilienesis*) treated with different concentration of aqueous solution of chromic acid (2.5%, 5%, 7.5%, and 10%) imparted considerable water repellency and resistance to white rot due to formation of chromic acid-lignin water insoluble complex. A steam volatile product obtained by steam distillation of creosote oil was found to be as effective as natural creosote against wood rotters, mould and stain fungi, termites but with added advantages like improved colour and lessened obnoxious odour. Bark extract from *Persea macrantha* (Jigat) showed significant antifungal potential against *Fusarium oxysporum* and *Rhizoctonia solani*. Different concentrations of alcoholic extract of *Dalbergia latifolia* heartwood, combinations of copper incorporated Cashew nut shell liquid (CNSL) and Neem seed oil showed usefulness in protection of rubber wood. Flowered bamboo was found more resistant to decay compared to non-flowered ones which is attributed to depletion of starch during flowering of the plants.

**Comments**

Good studies on the preservative aspects of rubber wood. Efficacy of more recent preservatives on this wood needs to be carried out by the Wood preservation group if not already done.

6. **Evaluation and standardization of the methods employed in identity of the medicinal plants employing woods of Himalayan and sub-Himalayan tract**

**Principal Investigator:** Sangeeta Gupta

**Duration:** 2005

**Significant Findings**

Wood anatomy (microstructure and/or ultrastructure) of the twenty species studied in the Himalayan and sub- Himalalyan tract is found to be of diagnostic value and can be used in their identification upto species level. However, in four species, the anatomy of the woods was found to be of limited diagnostic value.

**Comments**

A good study. Needs to be spread to other regions also.

7. **Evaluation of treatability of selected refractory species of timber**

**Principal Investigator:** P Narayanappa

**Duration:** 2006

**Significant Findings**

It is found that there is a progressive increase with ponding time in the absorption of preservatives (ACA and Copper Sulphate) in the ponded samples of *Ecualyptus* hybrid compared to controls due to diffusion. However, the absorption of preservatives considerably decreased with the increase in the size of the wood samples. The increase in absorption in the ponded specimens is due to the development of bacteria which are reported to cause porosity in wood by disintegration of ray parenchyma. In general, specimens ponded for two and four months showed almost equal absorptions.

**Comments**

A good experimental study. Not clear if there was any follow up with non-leaching preservatives!

8. **Evaluation of wood quality parameters of plantation grown *Eucalyptus citriodora* hook. for different**

**Principal Investigator:** R. Vijendra Rao

**Duration:** 2006

**Significant Findings**

Radial variation showed the stabilization of the character after a distance from the pith which can be taken for determining the rotation period. Physical and mechanical properties studied indicate that the wood is suitable for construction and furniture. Potential for use of *Eucalyptus citriodora* as an alternative wood for lacquerware craft has been compared with *Wrighia tinctoria.*

**Comments**

This study needs to be followed up depending upon the distribution of *Eucalyptus citriodora* in India.

9. **Polymerization filled composites**

**Principal Investigator:** Ajay Karmarkar

**Duration:** 2006

**Significant Findings**

An efficient way to overcome problems of poor dispersion and interfacial adhesion when developing composites form polar wood fibers and non polar polymers is one-step synthesis of composites by using Polymerization-Filling Technique (PFT). Using this technique, ethylene was polymerized directly from the wood fiber surface which promoted good filler dispersion and improvement in mechanical properties of the resulting composites. A novel technique of *in situ* generation of co-catalyst from co-catalyst precursor resulted in higher rates of polymerization and very high catalyst activity. The study demonstrated that highly filled composites can be prepared by filler supported catalyst system using cellulosic materials as fillers in a slurry reactor. Slurry reactors which are used commonly in industries for manufacture of polyethylene can be conveniently used for production of cellulose filled high density polyethylene (HDPE) composites without any major modifications.

**Comments**

A highly useful study for the composite industries.

10. **Assessment of wood quality of *Simarouba glauca* DC for its timber value**

**Principal Investigator:**

**Duration:** 2006

**Significant Findings**

Studies on *Simarouba glauca* DC wood suggest that the timber is dimensionally stable due to low shrinkage values. The timber was classified as moderately heavy, weak, not tough, soft and very steady and can be used for furniture and light packing cases. The timber also has good potential as an alternate timber for handicrafts.

**Comments**

Needs follow up depending upon the availability of this timber.

11. **Wood-Fibre plastic composite foams with improved cell morphology by continuous process**

**Principal Investigator:** Pankaj Kumar Aggarwal

**Duration:** 2006

**Significant Findings**

Flexural modulus of the fiber filled Polystyrene increased upto 30% loading. Powder filled composites also showed increase in the flexural modulus and foamed WPC indicated increase in stiffness.

**Comments**

Useful study needs to be followed up.

12. **Performance and evaluation of selected bamboo species treated by modified boucherie process**

**Principal Investigator:** D Venmalar

**Duration:** 2006

**Significant Findings**

*Dendrocalamus strictus, Pseudooxytenanthera stocksii* and *Banbusa arudinacea* can be successfully treated by modified Boucherie method. Chemical analysis showed that even the top portions of the culms received sufficient amount of the preservatives. The distribution of preservatives was throughout the length of the culm making this method a very useful one.

**Comments**

A very useful study already being adopted by many

13. **Chemical induction of heartwood in Sandal**

**Principal Investigator:** K.H. Shankaranarayana

**Duration:** 2006

**Significant Findings**

*Dendrocalamus strictus, Pseudooxytenanthera stocksii* and *Banbusa arudinacea* can be successfully treated by modified Boucherie method. Chemical analysis showed that even the top portions of the culms received sufficient amount of the preservatives. The distribution of preservatives was throughout the length of the culm making this method a very useful one.

**Comments**

The work needs to be conducted on a large-scale basis looking at the interesting and encouraging results.

14. **Exploration of new eco-friendly wood preservative from neem leaves and seeds**

**Principal Investigator:** Swati Dhyani

**Duration:** 2007

**Significant Findings**

Extracts by different methods of neem seeds and leaves as possible natural preservatives were studied against wood decaying fungi and termites on poplar and chir pine. Neem seed oil performed best compared to other extracts of neem leaves, providing maximum protection to the test blocks of both poplar and chir to the blocks of both poplar and chir against the test in fungi in soil block assays. Methanol extract proved to be the second best treatment followed by ethanol and acetone extracts of neem leaves. Neem seed oil proved to be the best treatment followed by methanol extract of neem leaves in providing maximum protection to test blocks of chir and poplar in field shifting their durability class from non-durable to resistance one. Nine major fractions were separated and two pure compounds were isolated from neem leaves of which the major pure compound was a flavaniod - Quercetin. This compound at 0.05% and 0.005% concentrations is reported to completely check the growth of wood destroying brown and white rot fungi by malt-agar bioassay.

**Comments**

An extensive study on preparing wood preservatives from natural extractives. This study needs to be continued so that concrete alternatives to chemicals can be arrived at.

15. **Influence of pre-treatment technique on the treatability of hardwood from Karnataka**

**Principal Investigator:** P. Narayanappa

**Duration:** 2007

**Significant Findings**

Considerable increase in the retention of copper sulphate preservative in *Eucalyptus grandis* due to ponding with specimen-size being the limiting factor.

**Comments**

This is a follow up of an earlier project (at 220). Here only one preservative is used and *Eucalyptus grandis* is studied.

16. **Development of commercially viable technologies for extraction of fibers from unexplored forestry species of Uttarakhand**

**Principal Investigator:**

**Duration:** 2008

**Significant Findings**

It is reported that softening process by using boric acid, washing soda and bleaching took less time for making ropes, textiles and the carding and spinning machine was introduced on a pilot basis in Mangroli, Chamoli to commercialize fibre production from Industrial Hemp (Bhang) and *Gerardiana heterophylla* (Dans Kandali) . This work is expected to uplift the livelihood status of local people of Uttarakhand at least of the high attitude weaver communities.

**Comments**

This has very little research component. However, monitoring of its output at the places where the technique has been initiated/installed would be helpful in promoting such low-cost techniques.

17. **Anatomical approach to evaluate treatability of timbers**

**Principal Investigator:** D. Venmalar and M. Sujatha

**Duration:** 2008

**Significant Findings**

Nine species of plantation timbers were treated with silver nitrate and red oil stains to find out their treatability classes penetration indices. The treatability classes thus arrived at are:

1. *Grevillea robusta* and *Hevea brasiliensis* - **a**
2. *Melia dubia* and *populous deltoids* – **b**
3. *Acacia mangium* and *Ecalyptus eurograndis* - **c**
4. *Acacia auriculiformis, Ecalyptus tereticornis* and *Gmelina arborea* - **d**.

**Comments**

The tests need to be replicated on commercial sized lumber to confirm the findings and to modify current treatment practices wherever necessary.

18. **Investigation on the mechanisma of success of *Mytilopsis sallei* (recluz) in managing toxic load arising out of biodeterioration measures**

**Principal Investigator:** M. Balaji

**Duration:** 2008

**Significant Findings**

*Mytilopsis sallei* preferably settles in polluted zones of different ports in India as competition for space will be less because most of the sensitive fouling species try to avoid polluted conditions. It is found to adjust to the background levels of both copper and hydrocarbons as indicated by the function of pollutants during different months. *Mytilopsis sallei* accumulates copper from leachates of timber treated to different CCA loadings continuously. This trait is very important for the animal to thrive in stagnant waters, where heavy metals do not dissipate and recurring additions ultimately prove lethal. The animal is able to manage the toxic loads at lower concentrations either naturally or by binding the metal to mettallothioneins. At higher concentrations, it perhaps depends on gut microflora that bind/chelate the metal making it non-toxic to the animal.

**Comments**

A good study from the point of view of pollution control by aquatic mollusks. Such studies need to be continued.

19. **Investigations on the resistance of commercially available bamboo in Karnataka to borers, termites and fungi**

**Principal Investigator:** Raja Muthukrishnan

**Duration:** 2008

**Significant Findings**

Dealers of bamboos were ignorant of low cost bamboo preservation techniques and their advantages. The major bore identified was *Dinoderus minutes* Fabricius followed by *Lyctus africanus* Lense and *Heterobostrychus aequalis* Waterhouse. The annual revenue loss caused by borers in bamboo depots is around 25-40 %. The bottom portion of the culm was found on an average to be more durable against borers and fungal attack. Five morpho species of parasites could be collected from *Dinoderus minutes* in which, one species was identified as *Heydenia indica* belonging to the family: Pteromalide. The other species belonged to families Braconidae, Ichneumoniade and Eurytomide. *B. bambos* procured from wet zone were more durable than those procured from dry zone. *Dendrocalamus strictus* from dry zone were more durable compared to those from wet zone. *D. stictus* was found to be more durable against termites and fungi compared to *B. bambos*. Neem seed kernel extract (NSKE) and Nimbedicine and Cashew nut liquid based paints and coatings proved to be less effective against termites. Whereas, chemicals such as organophosphates, Imiadaclorpid and synthetic pyrethroids provided good protection for bamboo against termites for more than a year.

**Comments**

A very useful study. The results are of importance to all bamboo artisans and researchers working on bamboo preservation.

20. **Studies on enhancement of natural durability of bamboo and plantation grown species with conventional/eco-friendly preservatives**

**Principal Investigator:** Dr. Sadhna Tripathi

**Duration:** 2008

**Significant Findings**

A new and fixed composition of three salts was used to develop a preservative (ZiBOC) which is amorphous and water insoluble and dissolved with the help of co-solvents. This was tested and found efficient against *Trametes Versicolor* (White rot) and *Oligoporus placentus* (brown rot) in protecting poplar and chirpine.

In a separate study, CCA treated bamboos perfomaned in the order *D. strictus* > *D. giganteus* > *B. balcooa* > *B. arundinacea* > *B. nutans* in the field. However, the last two did not perform well in the field. The best treatment methods were in the order Boucherie > Diffusion > VAC-FRI > Wick process. CCB treated bamboos performed in the order *D. giganteus* > *D. strictus* > *B. nutans* > *B. arundinacea* > *B. balcooa* in the field. The best treatment methods were in the order Wick process > Diffusion > Boucherie > VAC-FRI.

**Comments**

CCA and CCB were assessed in bamboo field trials. A new preservative, ZiBOC studied against poplar and chir pine wood. Both studies need to be continued and concluded.

21. **Environmental impact of leachates from copper-chrome-arsenic (CCA) wood preservative under marine condition**

**Principal Investigator:** M. Venkateswara Rao

**Duration:** 2008

**Significant Findings**

The study revealed that no discernible levels of elemental accumulation (<mg.g$^{-1}$ of dry biomass) of CCA leachates could be detected in any of the 14 species of biota and one sea weed examined. It is inferred that leachates of CCA treated timber put to test under marine conditions at a harbor do not affect the biota growing on nearby port structures. On the other hand, the chemical leachates emanating out of the CCA treated timber panels exerted a definite bearing on wood borers and curtailed their entry into the timber thereby offering protection for pretty long time.

**Comments**

A good study showing that the threat by CCA leachates may be over-emphasized. Such studies need to be promoted further to assess the impact on various organisms. (This study is to be considered in the context of project at 233)

22. **Effect of particle size on properties of wood filled polypropylene composites**

**Principal Investigator:** Ajay Karmarkar

**Duration:** 2009

**Significant Findings**

A novel compatibilzer with isocyanate functional group was synthesized by grafting m- Isopropenyl –α-α-dimethylbenzyl-isocyanate (m-TMI) using reactive extrusion process. Addition of wood fibers in polypropylene composites resulted in more rigid and tenacious composites due to the effective reinforcement of low modulus polypropylene matrix with the high modulus wood filler. The study concluded that particles between 52 and 85 mesh size provide the best properties. Particles finer than 85 mesh have aspect ratios much below the critical value which reduces the composite's properties. Particles above 52 mesh (larger diameters) also exhibited relatively low properties. A model was developed to predict the Young's modulus of re-inforced composites. A significant improvement in density, dynamic MoE and shear modulus were observed in wood-filled polypropylene composites with the increasing wood content.

**Comments**

An extensive study on WPC very useful to the industries. More aspects may need to be addressed. The study needs to be extended on a long-time basis as a programme.

23. **Evaluation of wood quality of *Eucalyptus* clones and plantation grown *Grevillea robusta* A. cunn. based on spiral grain**

**Principal Investigator:** N.C.M. Rajan and
**Co Principal Investigator:** A.K. Sethy

**Duration:** 2009

**Significant Findings**

Five clones of 4-6 yrs. *Eucalyptus tereticornis* representing Kolar and Mandya and 4 clones of 6-7 years old from ITC, Bhadrachalam Paperboard Ltd and Five trees of *Grevillea robusta* were found to have significant permissible spiral grains for various applications like paper and pulp industries.

**Comments**

More studies required (if not already done) for confirmation in the proposed use.

24. **Studies on the durability of treated and untreated timbers of selected species**

**Principal Investigator:** D. Venmalar

**Duration:** 2009

**Significant Findings**

*Lagerstroemia lanceolata* is a highly durable timber whereas durability of *Lophapetalum wightianum* is very low; but both these species easy to treat. *Artocarpus heterophyllus* is very difficult to treat because of its interlocked grains. Coppiced *Eucalyptus* poles can be treated both by pressure and non- pressure methods with lower concentration of the preservative for lesser treatment time. The treatment of poles by Sap displacement and Boucherie methods are more effective when the moisture content of the pole is more than 70%. Mainly CCB was used in the study.

**Comments**

A very good study. However, for concluding the findings, follow-up projects containing more detailed investigations need to be carried out.

25. **Studies on performance of plantation grown species in cooling towers**

**Principal Investigator:** Ram Lal

**Duration:** 2009

**Significant Findings**

CCA, CCB and ZiBOC treated veneer specimens of four species were fixed species on untreated chir frames and installed in an Industrial cooling tower. After one and half years it was found that toon wood species was greatly affected in treated as well as untreated conditions. Preliminary observations on efficacy of ZiBOC, CCA and CCB exhibited no differences in their activity.

**Comments**

Needs to be followed up.

26. **Studies on the effect of design parameters and different adhesives on the performance of finger joints in commercial timbers**

**Principal Investigator:** Ram Lal

**Duration:** 2009

**Significant Findings**

Finger jointing technique was studied using mango and *Eucalyptus* samples. Urea Formaldehyde adhesive performs better than PVA in static bending and compression. The maximum crushing stress under compression parallel is lesser in jointed sections of *Eucalyptus* unlike in the case of mango. The role of design parameters was quite clear in the case of *Eucalyptus*.

**Comments**

First study on finger joints with modern machine, Needs follow up.

27. **Drying studies on timbers useful for handicrafts**

**Principal Investigator:** N. K. Upreti

**Duration:** 2009

**Significant Findings**

Bulking treatment with urea was found to be more effective in *Acacia nilotica* than in *Mangifera indica* in controlling emergence of surface cracks during gradual moisture.

**Comments**

Useful for handicrafts sector. More species may be tried.

28. **Eco-friendly preservatives and fire retardants combinations for protection of structural bamboos for low cost houses**

**Principal Investigator:** Dr. Sadhna Tripathi

**Duration:** 2009

**Significant Findings**

Different compositions of fire retardant chemicals along with ZiBOC were tested on 3 bamboo species. Composition1 [$(NH_4)_2SO_4$+ $(NH_4)_3PO_4$ + ZiBOC] performed best in fire retardance and the performance on bamboos can be arranged in the order *D. strictus* > *B. tulda* > *B. arundinaceae.* Composition 4 [$Mg_3(PO_4)_2$ + $Mg_2P_2O_7$+ ZiBOC] imparted maximum protection against both brown and white rot in *D. strictus*. Four separate combinations of ZiBOC with $(NH_4)_2SO_4$, $(NH_4)_3PO_4$, $Mg_3(PO_4)_2$and $Mg_2P_2O_7$separately protected *B. arundinaceae* and *D. strictus* against termite decay.

**Comments**

A very useful study from the point of view of preservation and protection against fire for bamboo structures. This study needs to be taken up for more bamboo species.

29. **Monitoring of biofouling at Visakhapatnam**

**Principal Investigator:**

**Significant Findings**

Of the three test stations studied, the highest richness In biofouling composition was in the order: Slipway Complex> Ore Berth> Marine Foreman Jetty. 19 species of fouling and 11 species of wood boring organisms were found to be new introductions to Visakhapatnam port. Of these, two fouling organisms are being reported for the first time from India.

**Comments**

To be compiled with other results on marine fouling organisms.

30. **Investigation on marine fouling and wood boring organisms at Machilipatnam and Nizampatnam ports, Andhra Pradesh**

**Principal Investigator:** M. Balaji and
**Co Principal Investigator:** M.V. Rao

**Duration:** 2010

**Significant Findings**

Nine species of fouling forms were identified as belonging to primary Fouling Assemblages (PFA) - that directly attach to the surface of the wooden test panels at Machilipatnam. 8 species of fouling forms were found to settle on different substrata. The virulence of marine wood borers was very heavy and the test panels were destroyed within a short duration of 2-3 months of their exposure at this site. Primary fouling assemblages of foulers belonging to six species were recorded from the wooden test panels at Nizampatnam. In all, 15 wood borer species belonging to teredinids, pholadids and sphaeromatids were recorded from the test panels at this port. The damage was very heavy in long term panels as the wood borers completely destroyed the material within a short duration of two to three months of their exposure.

**Comments**

A detailed study on marine fouling of timber at two ports. To be compiled with other similar studies which were carried out at other locations.

31. **Effect of moisture content and diameter on the treatability of canes by vacuum and pressure impregnation method**

**Principal Investigator:** D. Venmalar

**Duration:** 2011

**Significant Findings**

It was found that moisture content plays an important role on the absorption of preservatives in canes [*Calamus thwaitesii* (large), *C. dransfieldii* (medium) and *C. vattayila* (small)] with dried canes absorbing more preservatives (CCB and Boric acid) than green ones. However, there was no significant difference in the absorption of preservatives between the large, medium and small diameter species. The absorption of CCB and boric acid were almost same in vacuum-pressure methods but the absorption of CCB was slightly higher than boric acid in dipping treatment. The penetration tests showed complete penetration of both the preservatives through and through.

**Comments**

A good study carried out well. Needs to be continued for different methods and other species.

32. **Wood quality assessment of selected candidates of *Eucalyptus tereticornis* of Australian origin**

**Principal Investigator:** Vimal Kothiyal

**Duration:** 2011

**Significant Findings**

Models through NIR were developed for specific gravity, shrinkage, bending parameters and lignin & homocellulose contents for *Eucalyptus tereticornis*. Wide variations in properties of 47 phenotypes were observed through the study.

**Comments**

A very good study. This faster method needs to be a continuous programme so that ICFRE might come up with somewhat species-independent universal models for various wood properties.

33. **Studies on the gas permeability of selected imported timbers marketed in Karnataka**

**Principal Investigator:** P. Narayabappa

**Duration:** 2011

**Significant Findings**

The permeabilities of five imported species were found to be in the order of gurjan > pyinkado > merbau > red meranti > balau. The last one is highly refractory. However, except for gurjan, all other species exposed to termites were found to be in sound condition even after three years.

**Comments**

More studies required for drawing useful conclusions.

34. **Development of treatment technology for commercially important difficult to treat species**

**Principal Investigator:** Ajmal Samani

**Duration:** 2011

**Significant Findings**

*Eucalyptus tereticornis* and *Melia azedarach* samples were given different pretreatments like hot water dripping, steaming, incising and then were treated by diffusion and pressure methods with CCA, CCB, Borax-Boric and ZIBOC preservatives at 8% concentration. Pretreatment by dipping in hot water for 2 hours before pressure treatment, followed by diffusion treatment for 24 hours in preservative solution gave best retentions of all the preservatives and can be used for the treatment of refractory timbers.

**Comments**

A good study on pre-treatment to achieve high preservative penetration and retention in difficult to treat timbers. To be grouped with other preservative techniques developed.

35. **Study on morphology and properties of natural fiber filled polypropylene composites**

**Principal Investigator:** Pankaj Kumar Aggarwal

**Duration:** 2011

**Significant Findings**

Jute-Polypropylene (PP) composites with m-TMI-g-PP coupling agents improved mechanical properties at 50% filler content. Rubber wood composites and Bamboo-PP composites showed almost the same properties followed by Wheat straw-PP composites. Lantana-PP composites showed only marginal improvements. Composites with coupling agent m-TMI-g-PP EXHIBITED 20%-30% better properties than MAPP coupling agent in all the cases of bio-based fibers. Torque increased with the filler content. The apparent viscosity decreased significantly with increase in the shear rate. Moisture absorption in jute- PP composites was minimum. Dry leaf litter cannot be used for making natural fiber-thermoplastic composites.

**Comments**

Many studies on this aspect have been reported from IWST. Compilation of all such results is necessary.

36. **Synthesis and characterization of hybrid polypropylene-montmorillonite - wood fiber nanocomposites**

**Principal Investigator:** Ajay Karmarkar and Pankaj Aggarwal

**Duration:** 2012

**Significant Findings**

Nanoclay-polypropylene (PP) composites and hybrid nano-clay-wood fiber-polypropylene composites were developed. Use of coupling agent was not found to improve mechanical performance of nano-clay polypropylene composites. Addition of nanoclay at all levels increased tensile strength, flexural strength, modulus of elasticity of the composites. Impact strength exhibited steady decline with increase in filler content. Macromechnical and micromechanical finite element modeling was used to predicted stress strain behavior and stiffness. Mean value of stiffness obtained through simulation was in good agreement with experimental results. Stress-strain behaviour predicted through macromechanical finite element modeling was also in good agreement with experimental results. Nanoclay-PP composites exhibited superior performance over conventially used filled polypropylene composites as A-pillar trim panels under head form impact safety test conditions.

**Comments**

A very good work on nano-composites. Use of nano-technology as such needs to be a continuing programme in composites as well as in solid wood processing.

37. **Fabrication and performance study of Vacuum based wood dryer for fast and efficient drying of Indian timbers**

**Principal Investigator:** Dr. N.K. Upreti

**Duration:** 2012

**Significant Findings**

An indigenous vacuum dryer for wood seasoning has been developed. One inch thick chirpine (Class B - moderately refractory) which takes 5-7 days in steam-heated kiln could be seasoned in 50.1 hours in the new kiln. 1 inch thick Deodar (Class C -non refractory) wood which takes 8-10 days to season in steam heated kiln could be seasoned in 26.5 hours in the new kiln. 1inch thick toon (Class B - moderately refractory) which takes 13-16 days to season in steam heated klin could be seasoned in 57.8 hours in the new kiln. 1 inch thick Shisham (Class B - moderately refractory) wood which takes 12-15 days in steam heated kiln could be seasoned in 43.9 hours in the new kiln.

**Comments**

Very high drying rates achieved. Other species, especially the difficult to season ones, need to be studied and schedules evolved.

38. **Development of Commercial Timber Information System (CTIS) in Southern India**

**Principal Investigator:** V. Soundararajan

**Duration:** 2013

**Significant Findings**

A web database was developed based on timber market survey information, published literature and subject expert's opinion. This web database is accessible to the public through the institute website http://iwst.icfre.gov.in. This will serve as a platform to exchange the information available with others and to serve as an information center for timber manufacturers, traders and end users.

**Comments**

A very good effort in developing a database on timber for traders and users.

39. **Utilization of *Bambusa bambos* (L.) and *dendrocalamus strictus* (roxb.) as an alternative of wooden dunnage pallets**

**Principal Investigator:** S.K. Sharma

**Duration:** 2013

**Significant Findings**

The moisture content, specific gravity, shrinkage, culm wall thickness, culm diameter and inter-nodal distance and static bending and compressive strengths of *D. strictus* and *B. bambos* were studied. Based on these properties, the suitability indices of both bamboo species as dunnage pallets were evaluated and both the species were found Suitable for dunnage pallets. However, *B. bambos* is more preferred owing to its higher diameter.

**Comments**

Suitability of two bamboo species is reported. The result needs to be compiled with other bamboos' utilization results.

40. **Enhancing dimensional stability and durability of wood for flooring application by eco-friendly thermal processing**

**Principal Investigator:** Dr. S.R. Shukla

**Duration:** 2013

**Significant Findings**

Heat treatment of *Acacia auriculiformis, Ecualypts* spp., and *Hevea brasiliensis* (rubberwood) were carried out. A vacuum-pressure PID controlled heating oven was designed and got fabricated. One LVDT- based swell-o-meter instruments to monitor to monitor real-time swelling profiles for evaluating dimensional stability was designed and developed. Colour change was observed to be uniform thoughout the wood blocks and intensity of darker blown colour was found to increase with increasing heat treatment temperature. Average roughness parameters of surface along the grain were much lower (40%-50%0 compared to those across the gain at different temperatures. EMC, Specific gravity and MoR reduced due to heat treatment. Higher treatment temperature made the wood more water resistant and dimensionally stable with rate of swelling decreasing with increasing treatment temperature. Flexural MOE and compressive strengths were not affected by temperature. Heat treated wood showed excellent decay resistance against two different fungi.

**Comments**

A good and useful study. Needs to be compiled and compared with other wood modification studies by ICFRE.

41. **Strength properties of finger joints of *A. auriculaeformis* A. cunn. ex benth of different ages (6-7 and 10-11years old) for various end uses**

**Principal Investigator:** Dr. N.C.M. Rajan,

**Duration:** 2013

**Significant Findings**

Finger jointing was attempted with short fingers. The bending strength of the finger jointed *A. aurilculiformis* wood was found to be 40-50% lesser than its solid wood. PRF jointed wood samples exhibited highest values of MOR.

**Comments**

As suggested by the PI, more finger profiles need to be explored.

42. **Study of drying stresses in wood during seasoning through non-destructive method**

**Principal Investigator:** Sh. Shailendra Kumar

**Duration:** 2013

**Significant Findings**

The stress reversal in wood during drying may be predicated by merely measuring the intact shrinkage of the wood board, as rate of the shrinkage changes its phase after the stress reversal. Wood width is shown to be inversely proportional to the drying stresses in wood. The core layer is least and lately affected by stresses in wood compared to surface layer but is more important in terms of drying stresses in wood.

**Comments**

A very good scientific study. Needs to be continued and applied to evolve faster seasoning methods

43. **Heterogeneity Study between and within species using near infrared spectroscopy and assess wood quality**

**Principal Investigator:** Dr. Vimal Kothiyal

**Duration:** 2013

**Significant Findings**

Twelve clones of p. deltoids could easily be distinguished using two NIR spectral ranges. Four species of *Eucalyptus* were also identified which is otherwise difficult to be identified with anatomical features. All the species used in the present study could be easily separated from each other.

**Comments**

A good preliminary study using NIR spectroscopy for qualitative identification of wood. Being a very promising field, more projects in this field need to be encouraged so that wood identification might become simpler.

44. **Studies on the effect of fire retardant chemicals on glue shear strength of plywood**

**Principal Investigator:** Ajmal Samani, Scientist - D

**Duration:** 2013

**Significant Findings**

The study investigated the effect of seven different fire-retardant compositions of $(NH_4)_2SO_4$, $(NH_4)_3PO_4$, $ZnCl_2$, Borax, Boric acid, Silicic acid, Sodium silicate, Phosphoric acid etc. on fire-resistance of plywood made from poplar veneers. Plywood treated with seven different fire retardant compositions passed the fire retardant tests whereas plywood treated with four compositions passed the glue shear strength test. Plywood prepared from the veneers treated with four fire retardant compositions passed the glue shear strength test and samples made from veneers treated with three fire retardant compositions passed the fire retardant tests.,

**Comments**

An interesting and useful study for the plywood industries. The promising combinations need to be tried on other plywoods also. Follow up projects are essential.

45. **Studies on bamboo joints for structural purposes**

**Principal Investigator:** Sh. Rajesh Bhandari

**Duration:** 2013

**Significant Findings**

It is found that there is no effect of node on compression strength on bamboo joint. Large diameter culms resulted in higher strength than low diameter ones. MS-BOLT (10mm) is a very good alterative over the traditional tying and lashing practices for joining bamboo culmns. Coal tar is found to be good alternative over cement slurry as filler; but both can be used depending upon the availability and ease of workability. Effect of filler material may be overcome by using more number of MS-bolts. More emphasis should be given to the high tensile strength of bamboo by innovative designing of space frame of structural members and beam-coulmn joint with MS-bolt as fasteners.

**Comments**

A very useful study for users of bamboos as structural members.

46. **Natural fiber-PVC composites for light structural applications**

**Principal Investigator:** Dr. Pankaj K. Aggarwal

**Duration:** 2014

**Significant Findings**

Lignocellulose based Polyvinyl chloride (PVC) composites can be successfully prepared by modification and melt bending. The mechanical properties (tensile and flexural) were improved by treating with silane. Studies on such PVC composites indicated that the bamboo powder and wood fiber absorbed almost same amounts of moisture. Incomplete encapsulation of fillers (wood and bamboo) by the polyolefin matrix occurred in the composites with all the loadings (10-50%).

**Comments**

A good study on wood and bamboo as fillers in PVC. Results need to be compiled along with those from other projects on WPC.

47. **Furfurylation of wood to improve properties for various applications**

**Principal Investigator:** Sh. A.K. Sethy
**Duration:** 2014

**Significant Findings**

Modification by impregnation of furfuryl alcohol, a bio-based chemical, into wood with Maleic anhydride (2%) and citric acid (4%) was found to be optimum for higher resin yield in *Bombax ceiba* and *Maesopsis eminii*. Moisture absorption was reduced and dimensional stability in terms of anti-swelling efficiency was significantly improved due to furfurylation of wood. Stiffness of modified samples did not change significantly. *M. dubia* and *G. robusta* indicated that high density refractory timbers may lose strength due to furfurylation. However, the compressive strength of modified samples increased significantly. Modified samples showed improved resistance against fungal decay, termite and marine borer attack.

**Comments**

A good study on modification of four wood species. The results should be compiled with the results of other wood modification studies to assess the best modification process for overall wood utilization.

48. **Wood quality variability in sawn timber from three plantation grown species**

**Principal Investigator:** Dr. Shakthi Singh Chauhan,

**Duration:** 2014

**Significant Findings**

Wood quality variability in sawn timbers from three plantation species viz. Silver oak (*Grevillea robusta*), Acacia (*Acacia auriculiformis*) and *Eucalyptus* (*Eucalyptus* hybrid) are reported. This study revealed significant variations in the measured parameters in all the species. Silver oak and *Eucalyptus* boards exhibited severe warping, twisting and end cracking whereas acacia boards were relatively stable on natural drying. Acoustic velocity in dry condition and wood basic density were not inter-related. Drying degrades were not associated with nay of the measured wood quality parameters but had association with ring orientation. Pilodyn penetration exhibited a significant negative relationship with the wood density in all the species. This attribute makes it suitable for segregating timber according to density class. The significant variation in dynamic MoE and wood density in sawn boards warrants the segregation of timbers based on its inherent wood traits for efficient utilization. Acoustic velocity was negatively correlated with longitudinal shrinkage except in *Eucalyptus*. The rate of change of acoustic velocity with moisture content below FSP was nearly 2.5 times higher than the above FSP and was consistent in all three species. The resonance frequency of longitudinal vibrations was also found to be effective way to monitor the moisture loss in wood.

**Comments**

A very good scientific study. This should be continued and concluded with stress on utilization aspects of major plantation species in India.

49. **Studies on macro wood deteriogens at Kakinada port and Narsapur Greenfield port, Andhra Pradesh**

**Principal Investigator:** Dr. M. Balaji

**Duration:** 2014

**Significant Findings**

Exposure trials of chir pine and semul test panels conducted at three test sites revealed that fouling accumulations were almost similar in Kakinada port and Fishing Harbour sites. The fouling was represented by almost all common entities of fouling accumulations in Indian ports. The fouling at the test site at Narsapur was less and represented by euryhaline species. The fouling accumulations exhibited significant preferences to different surfaces exposed at all the test sites with copper, being toxic in nature, hosting the least or almost no fouling accumulations.

**Comments**

A good study. To be compiled along with the results of other such studies in Indian marine conditions.

50. **Nanoparticles based wood coatings for outdoor applications**

**Principal Investigator:** Dr. K.K. Pandey

**Duration:** 2014

**Significant Findings**

A method of dispersion of nanoparticles in polyurethane based on functionalization of the nanoparticles with 3-glycidoxypropyltrimethoxysilane (GPS) was developed. Surface modification of nano-particles with GPS was very effective in avoiding agglomeration of the particles. Dispersion of zinc oxide nanoparticles in polyurethane clear coating significantly restricted the colour changes and photo-degradation of wood polymers. UV resistance of rubber wood surfaces could be significantly improved by UV coating containing $T_iO_2$ nano-particles

**Comments**

A very good study on achieving UV resistance for top coats for wood surfaces. Without doubt, this should be a continuous programme for arriving at the best coats for outdoor uses.

51. **Evaluation of wood properties and growth performance of *Eucalyptus* hybrids raised in multi-location trials**

**Principal Investigator:** Dr. P.K. Pandey, Scientist - E

**Duration:** 2014

**Significant Findings**

Two hybrids developed by FRI were studied. FRI-14 showed higher values for growth parameter than of FRI-EH 001. Significant intra-ramet variations among most of the wood traits for both hybrids indicated that they do not have stability for the wood traits. Inter-ramet variations were significant for most of the wood traits showing that homogeneous wood properties could not be achieved from both hybrids. Population of FRI-EH001 showed more stability than of the FRI-14. Both the hybrids were different genotypes for growth and wood traits. FRI-14 showed better performance of growth and wood- traits than of FRI-EH001. Chemical nature of both the hybrids was similar.

**Comments**

A good detailed morphological and anatomical study on two hybrids of *Eucalyptus* developed by FRI. The findings need to be substantiated by physical and mechanical properties as well.

52. **Application of defects detection technique on standing trees**

**Principal Investigator:** Dr. Y.M. Dubey, Scientist - C

**Duration:** 2014

**Significant Findings**

The ultrasonic velocity along multi-transverse directions of tree trunk varies. Magnitude of hollowness in tree trunk is directly proportional to the degradation ratio of the ultrasonic velocity. Centre hollowness/cracks and its sizes were successfully detected in tress by ultrasonic technique. But hollowness and multiple cracks in timber may not be distinguished by this technique.

**Comments**

A very useful method for defect detection in standing trees. As the PI suggests, studies on larger girth trees need to be taken up. A long-term programme to find out the possibility of arriving at species-independent, location-independent method needs to be encouraged.

53. **Evaluation of *Sesbania grandiflora* and *Lannea coromandilica* for paper making**

**Principal Investigator:** Dr. S.P. Singh, Scientist - C

**Duration:** 2014

**Significant Findings**

The species *Sesbania grandiflora* can be recommended to Indian Pulp and Paper Industry for making strong kraft paper under optimized conditions as an alternative fibrous raw material. *Lannea coromandelica* can be recommended to Indian Pulp and Paper Industry for making bleached grade writing and printing paper with adequate strength properties after blending 5% long fiber of bleached bamboo.

**Comments**

A good study. The findings must be conveyed to the paper industries**.**

54. **Studies on the suitability of different combinations of plantation grown species for Laminated Veneer Lumber (LVL)**

**Principal Investigator:** Sh. D.P. Khali, Scientist - E

**Duration:** 2014

**Significant Findings**

LVL can be prepared at a specific pressure of 24.5kg/cm$^2$ with 2mm and 3mm thick poplar veneers. LVL can also be prepared at 21.0 kg/cm$^2$ and 24.5kg/cm2 specific pressure using 2 mm thick veneers of *Eucalyptus*. Combi LVL can be prepared meeting all physical and mechanical requirements using alternate veneers (both 2 mm and 3 mm thick) of poplar and *Eucalyptus*. The adhesive used was PF. The industrial trial also was successful.

**Comments**

A significantly important study on combi-LVL. It is a must that other combinations also need to be investigated without considering as duplication so that the industries and farmers who practice agroforestry are benefitted.

55. **Screening of oil of *Pongamia pinnata* linn., *Jatropha curcus* linn. and *Simarouba glauca* D.C. for developing eco-friendly wood preservatives**

**Principal Investigator:** Mrs. D. Venmalar

**Duration:** 2015

**Significant Findings**

Rubber wood without any treatment is highly susceptible to fungi, borer and termites and deteriorates within 12 months when put into use. Treatment of rubber wood with copperised oils of *Pongamia pinnata, Jatropha curcas* and *Simarouba gluaca* offered protection against decay fungi, borer and termites. Copperised oils show 'Resistant class II and pure oils show 'Moderately resistant class III against fungus. Both pure and copperised oils show complete protection against borers. Treatment with pure oils increased the life of specimens by 4-5 times and copperised oils by 7-8 times. All the three copperised oils work as eco-friendly alternative wood preservatives.

**Comments**

A very good study on eco-friendly preservatives. Results need to be combined with other such eco-friendly preservatives by ICFRE so that the best ones can be adopted across multiple timber species.

56. **Variability of growth stresses in *Melia composite* (under AICP)**

**Principal Investigator:** Dr. Pankaj Aggarwal

**Duration:** 2015

**Significant Findings**

The magnitude of longitudinal growth strain in 15 clones of *M. composita* trees studied was much lesser than 700 micro-strains and therefore is of not of any serious concern in wood processing. This was also evident from the sawing study. Log girth and taper were negatively associated with acoustic velocity signifying faster growth affects certain wood quality parameters. Wood basic density and acoustic velocity were not related to each other.

**Comments**

A very good study. This must be redone in other locations also. To be compiled with the results of other projects on this species.

57. **Chemical modification of wood for durability improvements**

**Principal Investigator:** Sh. Ajmal Samani, Scientist - D

**Duration:** 2015

**Significant Findings**

Woods of *Pinus roxburghii* and *Populus deltoides* were modified using different concentrations of citric acid (CA) using sodium hypophosphite (SHP) as catalyst and 140$^{o}$ C curing temperature. The modified samples treated with CA20.7%+SHP19.5% showed maximum (volumetric) ASE. In termite mound test also minimum weight loss percent of 9.4 % was observed in samples which underwent the above treatment.

**Comments**

A sound alternative method for classical preservation techniques. This should be continued and results must be compiled along with the other wood modification findings.

58. **Vacuum press drying studies of *Melia composita***

**Principal Investigator:** Sh. Shailendra Kumar

**Duration:** 2015

**Significant Findings**

The core of *Melia composita* ,a permeable wood, is equalized quickly with lower atmospheric pressure. However, preheating time should also be considered when drying above boiling point. Keeping the temperature constant, pressure intensity plays an important role in wood drying. It was found that longitudinal permeability does not contribute significantly in vacuum drying of *Melia composita* wood neither above FSP nor below it. Hence, there is no need to end seal thicker wood sections for vacuum press drying.

**Comments**

A very relevant study on VPD of Indians woods. Only one inch thick sections were studied. This faster technique needs to be explored for other species and varying thickness needs to be complied with the results of other works on this species.

59. **Refinement in vacuum timber dryer designed by FRI and its performance studies**

**Principal Investigator:** Sh. N.K. Upreti

**Duration:** 2015

**Significant Findings**

The wood dryer developed indigenously is capable of drying timber much faster than the traditional steam-heated kilns and hence it is a very useful tool for commercial drying of timbers. Drying time of Deodar could be halved after refinement. During application and sustenance of vacuum inside the kin, the temperature of wood surface does not increase.

**Comments**

Refinement of an existing dryer using which two species could be dried faster than traditional steam heated kilns**.**

60. **Nanocellulose filled starch based composites**

**Principal Investigator:** Dr. Shakti Chauhan

**Duration:** 2016

**Significant Findings**

Different plasticizers like glycol, glycerol, urea, formamide, poly vinyl alcohol (PVA), Poly Ethyelene Glycol (PEG), water and their combinations were studied to achieve optimum thermoplasticization. Torque and temperature behavior during thermoplaticization was found to depend on the type and content of the plasticizer. Disruption of granulated structure of starch is indicated after thermoplaticization. Glycerol-water and Urea-formamide combinations were found to be effective plasticizers in imparting thermoplasticity in starch. The storage modulus of the synthesized nano-cellulose film was found to be 96 GPa. Completely bio-degradable composites were developed by blending TPS with poly lactic acid (PLA) along with the fillers in different proportions. Increasing TPS proportion in the PLA-starch based composite resulted in reduction in strength properties but reinforcement with nano and micro cellulose increased the tensile and flexural strengths of the composites. Inclusion of grafted PLA resulted in significant improvement in the strength properties due to chemical coupling between PLA and TPS through the coupling agent.

**Comments**

A very good study. To be compiled with results on other green composites.

61. **Evaluation of wood properties of *Melia composita* of different ages from Southern India for finding suitability for various uses and development of value added products**

**Principal Investigator:** Dr. S.K. Sharma

**Duration:** 2016

**Significant Findings**

Various physical and mechanical properties of 5-6 and 9-10 years old trees under green and air-dry conditions are reported. Shrinkage for both age groups was found to be higher (around as 17-19%) compared to teak wood (7%). Fibre length and fibre length and fiber wall thickness were found to vary significantly between the two ages selected. Based on physical and mechanical properties, suitability indices of 9-10 year old *Melia composita* wood were found to be 10-12% higher than those of 5-6 year old. The suitability indices also indicate that timber of both the age groups is suitable for applications such as tool handles, construction, light packing cases and furniture.

**Comments**

A good study on the properties of *M. composita* wood. Needs to be compiled with other results on this species.

62. **Development of composites of lops and tops of *Melia composita.***

**Principal Investigator:** Sh. D.P. Khali

**Duration:** 2016

**Significant Findings**

Particle boards can be prepared with 21 Kg/cm$^2$ specific pressure and10 % UF resin. SBG II fibre boards (grade I) can be prepared with 21 Kg/cm$^2$ specific pressure and 8%-10% PF resin. SBG II fibre boards (grade II) can be prepared with 17.5 Kg/cm$^2$ and 21Kg/cm$^2$ specific pressures and 8%-10% PF resin.

**Comments**

The developed techniques are useful for the particle board and fiber board industries**.** Results may be compiled along with other results on *M. composita*.

63. **Studies on performance of ZIBOC treated imported wood in different agro climatic conditions**

**Principal Investigator:** Dr. Sadhna Tripathi

**Duration:** 2016

**Significant Findings**

White meranti exhibited treatability class 'a' while mottled penetration was observed in red and yellow meranti exhibiting class 'c'. For Douglas fir, which is non-durable in Indian climatic conditions and difficult to treat (Class'd'), a new vacuum-pressure treatment method has been developed which can completely treat the species and this technique may be transferred to industry. In field test of stakes, it is clearly demonstrated that average retention irrespective of preservative and concentration was in the order: D. fir > white mearnti > Red meranti > Yellow meranti. Study on stake test in field also revealed that at Dehradun and Jodhpur, all test species except red meranti without preservative treatment (control) are non durable while treatment by CCA and ZIBOC protected all test species**.**

**Comments**

Treatment method for Douglas fir standardized. ZiBOC efficacy estimated against CCA. Results to be compiled with other studies on wood preservation by ICFRE.

64. **Study on the performance of treated timbers (ZiBOC, CCB & CCA) and their natural durability in cooling tower**

**Principal Investigator:** Dr. Sadhna Tripathi

**Duration:** 2016

**Significant Findings**

CCA, CCB & ZiBOC were studied on a prototype & industrial cooling towers using two species: *Pinus radiate* and Duoglas fir with *Pinus roxbhurghii* as reference species. Veneer specimen placed on the industrial cooling tower clearly indicated that Chirpine proved the best where as the other two species performed comparatively similarly. The study indicated that treated stakes of *P. radiata* and Douglas fir in industrial cooling tower exhibited lesser weight loss compared to Chir pine. Among the preservatives, CCB performed best while ZiBOC and CCA were comparable.

**Comments**

A very useful study for the cooling tower industries.

65. **Studies on working quality and finishing aspects of *Melia composite***

**Principal Investigator:** Dr. Kishan Kumar V.S.

**Duration:** 2016

**Significant Findings**

*M. dubia* can be easily worked upon just like teak. The working quality index of this species was estimated to be 102 compared 100 of teak. This species shows good machining properties under planning, sanding and shaping operations.

Lacquer gives very high gloss on *M. dubia* wood substrate and Melamine provides the least. However, melamine coat illustrated best weather resistant properties by retaining almost 83 % of its initial gloss after 25 days' exposure to high humidity. Lacquers were found to be superior to PU and melamine in restricting moisture entry into *M. dubia* wood substrate.

**Comments**

To be compiled with other works on this species.

66. **Wood modification of *Melia composita* for improving its dimensional stability and durability**

**Principal Investigator:** Dr. K.K. Pandey

**Duration:** 2017

**Significant Findings**

Thermally modified *wood* of *M. dubia* showed colour darkening but with uniform colouration. The modification caused degradation of cell wall polymers resulting in generation of structures which are responsible for the colour darkening. The modified wood absorbed less water and exhibited better dimensional stability but had lesser strength than unmodified wood. Though the modified wood showed improvement in decay resistance against brown ort fungus, termite resistance was not good. Chemically modified wood showed good hydrophobicity and dimensional stability.

**Comments**

A very good study on wood modification. Follow up studies on how to retain strength and improve other properties like termite resistance are essential. Needs to be compiled with other studies on wood modification by ICFRE.

67. **Liquefaction of wood and value added products from the liquefied wood**

**Principal Investigator:** Smt. Shakti Singh Chauhan

**Duration:** 2017

**Significant Findings**

Liquefaction was easily achieved in cardanol which is derived from CNSL. In case of CNSL, addition of small proportion of phenol was essential to get satisfactory liquefaction. Microwave heating for liquefaction in glycerol and PEG was also found to be effective. Liquefaction using extrusion process and ultrasonication were not efficient. A wood based adhesives was synthesized using phenol liquefied and cardanol liquefied wood and were used for preparation of plywood. Water resistance, boiling water resistance and boiling water proof. The prepared adhesive was found to be effective in Water resistance, boiling water resistance and boiling water proof. Preliminary trials indicated that liquefied wood coated wood exhibited weather and decay resistance.

**Comments**

A very useful study. The multiple uses of liquefied wood deems it necessary to continue this work in large scale.

# Genetics & Biotechnology

1. **Screening, clonal propagation, ex-situ conservation and genetic improvement of *Pongamia pinnata***

   **Principal Investigator:** R. Nainamalai

   **Duration**: 2004-2007

   **Summary**

   - The *Pongamia* cuttings treated with IBA at 2500 ppm concentration was found to be the best in terms of root length, root fresh weight, root dry weight, no. of roots, number of sprouts and survival rate.
   - The seeds collected from plus tree number 14 of northern sivicultural division Dharwad was estimated to have the higher oil content as compared to other silivicultural zone.
   - The oil extracted from the seeds of all plus trees was analysed qualitatively in terms of Density Viscosity, Refractive index and specific gravity. The research revealed that there is no variation existing among the plus trees for such parameters.
   - The progeny trial and germplasm bank were established using seeds and grafts of plus trees from Karnataka and Andhra Pradesh at Nallal Field Research Station. The survival percentage was found to be 93%.
   - Iso-enzymes studies provided the basic information that there is variation among the plus trees populations this will be used as a base to initiate the advanced studies in tree improvement programme.

2. **Domestication, mass multiplication and popularization of *Moringa oleifera* genotypes with superior leaf nutritive cytokinin content and cytokinin content**

   **Principal Investigator:** Dr. Sanjay Singh, Scientist-E

   **Duration**: 2008-2012

   **Summary**

   - The research conducted under the project in the duration of 4 years resulted in number significant findings which have been enlisted below:
   - *Moringa oleifera* genotypes from all eastern Indian states viz., Jharkhand , west Bengal, Bihar and Orissa have been collected and maintained in germplasm garden. Clonal propagation procedures have been developed through different types of shoot cuttings (involving auxins and non-auxins treatments and their combinations).
   - 24 genotypes screened for leaf nutritive value including endogenous sugar, starch, protein, Ca and Mg, vitamins while HPLC method was employed for estimation of leaf cytokinin in 12 in promising genotypes.
   - Protein content was generally high and varied between of 3.0 mg/100g (JRD) and 81 mg/ 100g (JEK) with average content 38.41mg/100g among the all accession.
   - Average soluble sugar content was found to be 55.87 mg /100 mg among the accession with lower content of 43mg/ 100g in OCB and WHP and higher value 71mg/100g in BPG.

- Endogenous level of Proline exhibited significant difference in different accessions. Average Proline content was found to be 2.37 mg/100g among the 24 accession with lower content of 1.0mg/ 100g in JRK and higher value 4.4 mg/100g in ORB.
- Changes in the Phenol concentration in the leaves of different accessions were significant. Average Phenol content was found to be 24.13 mg/ 100 g with low content value of 14.22mg/100g in JWJ and higher value 33.35mg/ 100g in JRB and JLK
- Significant differences were also recorded in endogenous Beta carotene content was found to be 2.91 mg/ 100g with lower content of 1.32 mg/100g in JSC and higher value 5.44 mg/ 100g in OSH.
- Average Retinol content was found to be 0.48mg / 100g among the 24 accession with lower content of 0.22mg/ 100g in JSC and higher value of 0.90mg/100g in OSH.
- Moringa leaves can provide the needed minerals for undernourished and malnourished people with high endogenous calcium (80 mg/ 100g), iron (20 mg/ 100g) and magnesium (200mg/ 100g).
- Cytokinin content in twelve best accessions varies from 121.97 to 797.04 pg/g FW which is very high. Accessions with high leaf cytokinin may be utilized for clonal development for industrial applications in crop productivity enhancement. This finding supports the use of M. oleifera leaf extract as a foliar application in large scale.
- Trial of leaf extract as bio stimulant for crop growth demonstrate that M.oleifera leaf extract promotes fruit yield and quality of tested crop. We recommend that M. oleifera leaf extracts (12.5 leaf extract + 87.5 water) as suitable for the vegetables growth and thus, for the fruit yield.
- Overall, exceptionally high level of nutrition (eg. Protein as high as 81 mg/100g; vitamin C 90mg/ 100g; iron 20mg/ 100g) and cytokinin (as high as 797.04 pg/g FW ) has been recorded in some of the genotypes which can be transferred to farmers and industries as clones.

3. **Study of salt tolerance through gene expression pattern analysis**

**Principal Investigator:** Dr. Tarun Kant, Scientist-E

**Duration:** 2010-2015

**Summary**

- The hydroponics system developed and perfected under the present investigation can be used to grow other halophytes as well as it is easily reproducible low cost system.
- *Lepidium sativum* is a good halophytic system for carrying out salt stress studies because it grew well on a hydroponic system at salinity levels as high as 200 Mm NaCl.
- In *Lepidium sativum* the genes LsNHX-1, LsSOS -1 and LsCLC –c were having a high baseline constitutions indicating that genes are hyperactive even without salt stress.
- The expression levels of LsHKT-1 gene do not undergo a remarkable change even at highest salinity levels of 200 Mm NaCl treatment . It appears that this gene which primarily is responsible for K+ ion uptake probably does not lose its primary function even under high salinity levels as is the case with it glycophytes, where it also starts transporting Na+ ion under NaCl rich environment.
- In leaf tissue of *L. sativum* grown at high salinity levels, LsNHX-1 gene attains a 4 fold up-regulation state by 6 hours, while in root tissue; the same level is achieved much early, that is at 3 hours.
- It was observed that the LsSOS – 1 gene in root tissue is expressed at a higher level compared to that in the leaves.
- While in case of LsSOS -1 gene, the expression level differences between the leaf and root tissue is not remarkable.
- Using this unique in silico cascade approach, a total of nine putative genes with role in salt stress management have so far been predicted.

4. **Genetic improvement of Khasi Pine (*Pinus kesiya*)**

**Principal Investigator:** Dr. Ombir Singh, Scientist-F

**Duration:** 2003-2008

**Summary**

- A total of 33 plus trees have been selected in East and West Khasi hills of Meghalaya.
- Variations were observed among the progenies raised from these plus trees in respect of growth performance at nursery level and the same progenies will also be evaluated in seed orchard cum progeny trial.
- Seedling seed orchard cum progeny a trials of selected plus trees was established at Umiam Barapani.
- Seed maturity indices for *Pinus kesiya* was determined by considering specific gravity as parmeter.
- Occurance of cones in *Pinus kesiya* four, five and even six in some of the plus trees was observed.

5. **Clonal test trials on *Casuarinas equisetifolia* L. in north coastal Andhra Pradesh**

**Principal Investigator:** Dr. N. Rama Rao, Scientist-F

**Duration:** 2003-2008

**Summary**

Best suitable clones of *Casuarina equisetifolia* L. for plantation along the coastal area of north Andhra Pradesh have been identified. The clone CP4202 – M has desirable attributes of 50.66% survival, average height of 14.00 m and average basal stem diameter of 46.67 cm while the clone APVSYM - 5M had the values of 46.66%, 14.46 m and 45.67 cm, respectively. Thus, these two clones may be rated as superior performers among the ten clones tried for plantation in a coastal area.

6. **Genetic improvement of *Dalbergia latifolia* Rox through selection and evaluation of germplasm in central India**

**Principal Investigator:** Dr. Fatima Shirin, Scientist F

**Duration:** 2013-2017

**Summary**

- Surveys were carried out in the potential pockets of *Dalbergia latifolia* in different Forest Division of Madhya Pradesh, Maharashtra, Odisha and Chhattisgarh. Candidate plus trees of *Dalbergia latifolia* were located and selected. A total of 197 CPTs were selected in the four central India states.
- Half – sib seeds were collected from the CPTs selected from Madhya Pradesh, Maharashtra, Odisha and Chhattisgarh. From selected seeds seedlings were raised and germination data was collected and the progeny trail was established at TFRI Jabalpur.
- Shoot organogenesis was achieved by conducting two- factorial experiment to study the effect of different concentrations of TDZ and auxins.

7. **Conservation of sandal (*Santalum album L.*) germplasm production of quality planting stock and promotion of SANDAL cultivation**

**Principal Investigator:** Dr. Syam Viswanath, Scientist F

**Duration:** 2006

**Summary**

- Germplasm bank cum Clonal Seed Orchards of elite material of Santalum album L. been established.
- Cultivation of sandal wood in farm land has been promoted by incorporating herbaceous medicinal plant as intercrops.
- Progeny trail of Sandal has been established.

8. **Developing clonal technology for raising clonal plantation of indigenous species *Ailanthus excelsa* and *Ailanthus triphysa* in Tamil Nadu and Kerala**

**Principal Investigator:** Dr. D. Rajasugunasekar

**Co Principal Investigator:** Dr. V.K.W. Bachpai

**Duration:** 2010-2015

**Summary**

The study stressed relevance of Juvenile coppice shoots for rooting success in propagation of *A. triphysa*. The interesting consequences from the point of nursery business where the related species. *A. triphysa* was not possible to propagate by vegetative means can be overcome by usage of juvenile coppice shoots , 2000 ppm IBA and cost effective polytunnel technique, to tap immediate gains of tree improvement gains of tree improvement programme. Therefore, improved quality planting stock of *A. triphysa* can be produced using the juvenile shoots derived selections and can be deployed in clonal plantations for productivity enhancement. The clonal technology of Ailanthus excels and A. triphysa has been standardized about 40 clones of Ailanthus excelsa have been assembled in a VMG from different districts such as Coimbatore (11˚01' 64 N:76˚57'21" E) Salem (11˚ 39' 10 N:78˚11'27"E), Thuraiyur, Trichy district (11˚08' 37 N:78˚36'59 E) mass multiplication and large scale plantation. Considering the marketing potential of this species, this technique has tremendous scope for easy adoption by farmers, propagators , wood based industries has tremendous scope for easy adoption by farmers, propagators, wood based industries and has significant value in conservation and sustainable utilization in safety matches industry.

9. **Conservation of sandal (*Santalum album L.*) Germplasm production of quality planting stock and promotion of SANDAL cultivation**

**Principal Investigator:** Dr. Ashutosh Srivastava, Scientist-C

**Duration:** 2003-2006

**Summary**

A Clonal Germplasm has been established using rooted cuttings from all the 24 provanance under study at Institutes Field Station at Nallal.

10. **Identification of superior growth promoting strains of *Frankia* in *Casuarina equisetifolia* and *Casuarina junghuhniana***

**Principal Investigator:** Dr. A. Karthikeyan, Scientist-D

**Duration:** 2009-2013

**Summary**

Casuarinas are being cultivated in Pondicherry and Tamil Nadu day by day due to its popularization as fuel wood species, nitrogen fixing capacity and potential for adaptation to diversified soil and climatic conditions. *Casuarinas equisetifolia* and *Casuarinas junghuhniana* seedlings were raised usually under inert material (vermiculate) of *C. equisetifolia* and *C. junghuhniana*. The roots of *C. equisetifolia* and *C. junghuhniana* produce root nodules where the Actinomyeete bacteria, *Frankia* fix atmospheric N2which is essential nutrient for all plant metabolism activities. To enhance the use of *Frankia* under this project 10 different strain of *Frankia* isolated from different places of *C. equisetifolia* and *C. junghuhniana* plantations. The strains were characterized and identified as Frankia through morphological characteristics. *Frankia* colonies are differentiated in to 3 different cell types 'vise (1) hyphae (2) spores and (3) vesicles. *Frankia* strains were cultured in artificial liquid P media and applied in this study. Nitrogenase activity of *Frankia* stains was determined using acetylene reduction assay for identifying superior strains of Frankie. These clones were planted in the field and growth assessments were taken. The inoculation of *Frankia* resulted increased growth than non inoculated trees. Soil nutrients were increased after planted *Frankia* inoculated *C. equisetifolia* and *C. junghuhniana* rooted stem cuttings. A product called N fixer was developed and released for the benefit of Casuarinas growers.

11. **Studies on variability in rooting proficiency in selected genotypes of *Pongamia pinnata* (L) Pierre**

**Principal Investigator:** Dr. Animesh Sinha

**Duration:** 2010-2012

**Summary**

*Pongamia pinnata* plantations established by vegetative propagation (stem cuttings / grafting) can be considerably more profitable than those using conventional seed propagation techniques. The profitability of cuttings in terms of economic gains can be raised further if the cuttings /scions are obtained from an elite genotype due to its inherent positive characteristics. The rooting ability of *P. pinnata* is linked to its genotype, in addition to the seasonal effects and other contributing factors. Among four different auxins studied, IBA was found best for rooting from stem cuttings. IBA 1000 ppm showed maximum rooting (58.3%) of stem cutting collected from 4-5 old trees during March. However, the highest rooting among the CPTs studied was observed in DIRCHT (41.6%) in IBA 1000 ppm, followed by DIDCPD (35%) in three component mixture i.e. IBA 1000 ppm + IAA 250 ppm +NNA 250 ppm. January to march season was found the best for rooting of stem cutting as well as for grafting in Kanranj. The highest Grafting success was observed in DIRCPD (80%) followed by DIRCCP (75%). It was also observed that softwood grafting of CPTs studied produced higher succeed than hardwood grafting.

12. **Comparative study of clones of *Eucalypts* and *Acacia* hybrid for handicraft sector**

**Principal Investigator:** Dr. S. K. Sharma, Scientist-G

**Co Principal Investigator:** Dr. S. R. Shukla, Scientist-E

**Duration:** 2010-2013

**Summary**

The wood of *Eucalyptus eurograndis* and *Acaia* Hybrid (*Acacia auriculiformis, Acacia mangium*) clones were procured and studied for their various anatomical, physical and mechanical properties and also the wood working qualities. Only few properties (specific gravity, shrinkage and heartwood percentage) were evaluated as most of the work has been done in the division except finding its suitability for handicrafts based on wood working qualities. The clone GR3 showed better results as compared to GR8.

Two clones of *Eucalypt eurograndis* grown near Tumkur, Karnataka (India) of 5-6 year old were selected to study physical (specific gravity, shrinkage and heartwood percentage), mechanical (static bending, compressive strength, hardness) and anatomical properties (fibre and vessel morphology). Clone GR283 has shown very less amount of heartwood compared to clone GR330. Fibre lengthy, fibre diameter, wall thickness, vessel diameter and vessel element length showed significant differences in both the clones. Average basic density was found to be 552 kg/m3 and 441 kg/$m^3$ and bark density was 402 kg/$m^3$ and 354 kg/$m^3$ for the clone GR283 and GR330 respectively. Clone GR330 was found more suitable for handicrafts and light weight material applications due to higher amount of heartwood and lower wood density whereas clone GR283 can be utilized for paper and pulp applications.

Three clones of 8 year old Acacia hybrid (*Acacia mangium* x *Acacia auriculiformis*) grown in Bhadravati, Karnataka were studied for physical (specific gravity, shrinkage and heartwood percentage), mechanical (static bending, compressive strength, hardness) and anatomical properties (fibre and vessel morphology). The fibre morphology, vessel morphology and specific gravity were studied from pith to periphery and radial variations were analyzed statistically between the clones. Various properties were also compared with pure form of *A. mangium* as well as *A. auriculiformis* of similar age. Compared to pure form of *A. mangium* and *A. auriculiformis,* Acacia hybrid clones showed longer fibres. The wood working qualities were also observed for all the three clones but there was no significant difference among these clones. However, clone H4 and AK47 showed better results.

13. **Genetic Variability and Selection in Natural Populations of *Artocarpus* Species**

**Principal Investigator:** Dr. Maheshwar Hegde, Scientist-C

**Co Principal Investigator:** Dr. K Palanisamy, Scientist-E

**Duration:** 2000-2006

**Summary**

Natural populations of *Artocarpus integrifolia*, *A. hirsute* and *A. lakoocha* have Bennp identified in Tamil Nadu and Kerala. A. Integrifolia has been found naturally at 900 to 1300 M elevation in evergreen forests at Kolli hills, Anamalai hills and Nilgiri hills in Tamil Nadu and at Silent valley in Kerala. A. hirsute is found to occur throughout Kerala from sea level to 600M altitude in evergreen forests. Occurrence of *A. Lakoocha* is found to be rare. A good population of this species found in Topslip area in Tamil Nadu. Variation in tree morphology, fruit bearing habit, fruit size, pulp taste, pulp colour, pulp consistency, seed morphology, seed weight, seed germination and seedling growth characteristics in nursery have been recorded and analyzed in *A. intergrifolia*. Within population variation was more compared to between populations.

A Progeny trial (2 ha) of selected trees in different populations of *A. Integrifolia* was raised in Kolli hills. A seed Production Area (10 ha) of *A. hirsuta* has been established at Palode (Kerala). This SPA will be a good ex situ conservation stand because it is endemic and threatened species in Western Ghats. Isozyme standardisation was done for two enzymes namely, Aspartate Amino Transferase (AAT) and Acid Phosphatase (ACP). Isozyme (AAT) analysis showed that expected heterozygosity is slightly less than the observed heterozygosity in *A. intergrifolia*. Genetic distance was calculated between identified populations of *A. intergrifolia*. It was found that genetic distance was less between Panruti, Kpthagiri, Valparaiso and Barliar. The Kolli hills population was distinct cluster and genetic distance between this population and others ware more. The natural regeneration status of all three Artocarpus species was studied at Topslip area. It was found to be totally absent for *A. lakoocha*, *A. hirsuta* and *A. intergrifolia*. All these species have very high ecological importance since they are major food source for many wild animals in the sanctuary.

Occurrence of Alternaria blight disease on seedlings of Artocarpus species in the nursery was reported. Different treatments like application of fungicides, and applications, and application of the biocontrol agents such as *Trichoderma viridae* and pseudomonas fluorescence was also attempted to effectively control the disease problem. This disease found to cause up to 100 per cent mortality in the nursery.

During 2006 reconnaissance survey was carried out to identify the natural populations in Kanyakumari, Gudulur and Kalvarayan hill area in Tamil Nadu and Wayanaad area in Kerala. Seeds of Artocarpus heterophyllus were collected from identified populations in Kanyakumari and Kalvarayan hill area in Tamil Nadu and Wayanaad area in Kerala and seeds of Artocarpus hirsute were collected from natural forests in Kanyakumari and Gudulur in Tamil Nadu and Wayannad and Mukkali area in Kerala. Seedlings were raised in nursery. To understand the genetic variation between and within population isozyme analysis was done with three enzymes naely, esterase, Aspartate Amino Transferase (AAT) and Peroxidase. The isozyme bands showed considerable variation between and within population.

14. **Screening of high oil and *Azadirachtin* in Neem**

**Principal Investigator:** Dr. U.K. Tomar, Scientist-F

**Co Principal Investigator:** Dr. N. Ravi

**Duration:** 2003-2015

**Summary**

Progeny trial is well maintained at Jaipur in collaboration SFD Rajasthan. Overall survival (92%) of this trial was highly satisfactory. 100% survival of progeny of CPTs number 7 followed by 98% survival of CPT 17 family. Family number 4,7,11 and 12 was superior by 20-30% in height and 10-20% in girth from rest, Progenies of CPT No. 3,4,5,6 and 7 was not at affected by frost. It is interesting to note that CPT number 4 and 7's progenies have shown better performance in height and girth parameters. Unfortunately, CPT Number 12, which was one of good performer in girth and height parameters is maximally affect by frost (41.2%). Overall fruiting and flowering was very poor (Total 9.7% trees flowered in 2010-11). Maximum trees in flowering stage were observed in family P07, which was also better in growth and not at all affected by frost also.

Seed samples (50 Nos.) were collected, depulped and processed for estimation of chemical constituents (Aza and Oil). Variation in different families cannot be compared due insufficient seed samples from each family. All 33 samples were having oil range from 40 to 52%. Average oil content of 31 trees was 45% which is a good indicator of quality plant material. Oil content was maximum in P09 progeny, which was 48% followed by P08 (47.1%), P02 (47.0%) and Po1 (46.7%). None of the tree yielded less than 40% oil content. Azadirachtin content could not be estimated this year due poor seed yield per tree in year 2011-12.

Seeds collected in the month of August 2012 from 50 trees were sent to TER for Azadirachtin and oil content estimation revealed average oil content 45% and four families P04, P07, P09 and P17 gave more than 50% oil content. Unfortunately, average azadirachtin content of 45 samples was very (1427.5ppm). This was expected due almost seven months delay in estimating azadirachtin concentration. However, only about 5% plants are producing seeds in sufficient quantity is not enough to evaluate trial scientific standards. Hence this project was concluded and once about 200 trees started giving sufficient seeds this trail will be evaluated again for two or three years successively to get better picture and deliverables.

15. **Standardization of Propagation Method and Germplasm Conservation of *Machilus villosa* (Roxb.) & *Quercus lineate*: Promising Timber & Fuel Wood of North West Bengal**

**Principal Investigator:** Sanjeev Kumar Bhatia, Scientist-C

**Co Principal Investigator:** P.K. Biswas, Range Officer

**Duration:** 2011-2014

**Summary**

Both Species, *Machilus villosa* as well as of *Quercus lineataare* untouched by the researchers. No work in direction of its propagation and planting stock improvement has been done till date. The research conducted under the Project in the duration of 3 years resulted in number significant finding which have been enlisted below:

- Having great variability in seed traits between all the selected candidate plus trees of Machilus villosa as well as of Quercus lineate offers ample scope of improvement. MV4, MV3, Mv20, MV14, MV7, MV1 and MV13 in case of M. Villosa and Q16, Q3, Q10, Q15, Q9 and Q20 of *Q. Lineata* showed high values for different seed traits, showing their importance for selection by seed origin in the plantation programme.
- Similarly, significant variability was found among growth characters in both species, which is a good sign for future breeding, hybridization and improvement programme.
- On the basis of growth traits, germplasm of six plus trees of Machilus villosa namely MV4, MV6, MV7, MV8, MV14 and MV20 and plants of nine plus trees of *Quercus lineate* namely Q1, Q, Q5, Q9, Q10, Q12, Q15, Q16, and Q20 were selected and planted in conservation plots which can be used as improved material for future plantation and research works.
- Being significant correlation of nursery germination percentage with the seed length, seed width and hundred seed weight proves their improvement at the preliminary stage of selection for large plantations through sexual reproduction.
- New methods like grafting, budding or air layering has to be tried in both species as propagation through cutting is not successful. As small success was found in case of *M. villosa*, some more experiments can be carried out to standardize the same.
- Viability studies showed that the seeds of *Machilus villosa* are orthodox and can be stored up to 2 year by simple storage. Acorns of *Q. Lineate* were recalcitrant and cannot be stored more than 3-4 months by simple means. New technology of storage can be utilized to prolong its viability.

16. **Interspecies hybridization between *Eucalyptus Pellita* and *E. Urophylla* and development of F1 hybrids**

**Principal Investigator:** Dr. Parveen

**Co Principal Investigator:** Dr. Ashok Kumar

**Duration:** 2010-2014

**Summary**

A breeding arboretum of eucalypts was established in the year 2006 in open-pollinated mating design for production of inter and intra-specific hybrids. The species of same sun-genus planted side by side at 3x3 spacing for creating more chances of natural crossing and to make it easy for controlled crossing. *E. pellita* is frost resistant and moderately resistant to stem cankers *Cryphonectria cubensis* and has faster rate of growth. *E. urophylla* has the potential for higher productivity and adaptability characteristics but it susceptible to the stem canker disease. In this project, success has been achieved to produce hybrids of *E. grandis* x *E. pellita*, *E. pellita* x *E. tereticornis*, *E. pellita* x (*E. urophylla* x *E. grandis*), (*E. urophylla* x *E. grandis*) x *E. pellita*, *E. pellita* x *E. urophylla* and *E. urophylla* x *E. pellita* through controlled pollination. These hybrids have been planted in the field.

The inter-specific hybrids *E. pellita* x *E. uropyhylla, E. pellita* x (*E. urophylla* x *E. grandis*) have been planted in field at Raiwala, Dehradun in July 2012. The growth data were recorded in respect of height and diameter at breast height and analyzed at the age of 1.7 year. The mean standing volume production was calculated by formula 'd2h' used to compare relative growth performance where d is diameter at breast height and h is total height. The mean volume production 616.44 $cm^3$ was recorded for *E. Pellita*, 716.99 cm3 recorded for *E. urophylla*, 5124.46 $cm^3$ recorded for *E. pellita* x (*E. urophylla* x *E. grandis*) and 7906.86 $cm^3$ was recorded for *E. pellita* x *E. urophylla*.

The superiority per cent 1182.65 was recorded for the hybrid *E. pellita* x *E. urophylla* over mean population of *E. pellita* and 1002.78 over mean population of *E. urophylla*. The superiority per cent 731.29 was recorded for three-way-cross hybrid of *E. pellita* x (*E. urophylla* x *E. grandis*) over means population of *E. Pellita* and 614.71 per cent recorded for *E. urophylla*. These hybrids need to be evaluated at the later stage to see whether they maintain their superiority in growth performance or not.

17. **Genetic Variation for in vitro morphogenetic potential of *Dalbergia sisoo* Roxb. Clones and evaluation of their field performance**

**Principal Investigator:** Dr. Yogeshwar Mishra

**Duration:** 2007-2012

**Summary**

In vitro clonal variations were observed amongst 5 clones of *Dalbergia sisoo* belonging to Gonda, Faizabad, Jabalpur and Raibarely in respect of in vitro responses. Regional variations were exhibited in the in vitro multiple bud induction ability (Percentage of cultures forming multiple buds and mean number of buds induced) on nodal explants excised from cuttings. The MS medium variously supplemented with NAA and BA showed various responses in aseptic culture establishment and bud break. Out of five clones (GBW 4, JB 1, FZB 1 and FZK 1, RSk 1), Faizabad (FZK 1) resulted in maximum aseptic culture establishment (90%) and sprouting response (54%). The combination of 1.35 µM NAA + 2.5 µM BA was found most suitable for maximum aseptic culture establishment of 0.53 µM NAA + 5.0 µM BA resulted in maximum sprouting response. The maximum of 3.23 fold shoot multiplication was obtained in FZB 1 clone. Clonal variations were recorded in the shoot proliferation efficiency as well as rootability of microshoots of these clones as well as their optimal plant growth regulator requirement. The effect of culture status (liquid and semi solid), two explants types (single and double nodal segment) and three basal media (MS, WPM and Nitsch & Nitsch) were also evaluated in five clones, which revealed significant effect of liquid status of medium on shoot multiplication in all clones as compared to semi soild medium. Various doses of GA3 noticed to have pronounced effect on callus free shoot formation in different clones. Five basal media viz., MS, B5 WPM, N&N and SH media were used in combination with 1.0 mg/1 IBA for in vitro rooting in five clones. Different growth regulators and their doses also played significant role in inducing roots and the maximum of 45% rooting was obtained in the medium supplemented with 1.5 mg/1 IBA in GBW 4 clone, which was significantly higher than other clones. The effect of strength of two basal media i.e., ½ MS and ½ WPM were evaluated on rooting percent, root length and root number were scored in five clones. Between these two media tested ½ MS medium emerged as the best medium to produce 57.33% rooting whereas ½ WP medium produced 38.59% rooting. Among different clones, FZB 1 and FZK 1 clones were produced at par rooting response (58.33%), which was significantly higher than other clones. FZB 1 clone produced 73.33% rooting on ½ MS medium, which was at par with FZK 1 clone (70%)

The hardening technique for in vitro raised plantlets was perfected. Using the hardened plantlets one successful field trial was laid out. Using the information generated by this work in vitro production of elite planting material can be maximum by ameliorating plant growth regulator requirement in the medium.

18. **Investigations on Genetic Variation and Inheritance of Western Indian Teak (*Tectona grandis*)**

**Principal Investigator:** Pravin H. Chawhaan, Scientist-G

**Co Principal Investigator:** Dr. D.K. Mishra and Dr. Abha Rani

**Duration:** 2009-2015

**Summary**

The present investigation revealed highly significant variation for the fruit and seed parameters in teak, studied using a group of selected trees of Fulwadi and March seed orchards CPTs from Dang area. In case Fulwadi and March seed orchard clones differences between clones were significant for all the morphological traits, except for No. of locules and No. of filled locules. In case of dang material all the traits exhibited highly significant variation amongst CPTs except for No of locules. However, maximum value of coefficient of variation was observed for filled locules (29.86) in both the group of trees.

In seed orchard clones stone width exhibited positive and significant positive association with filled locules and seed weight respectively. Similarly, stone weights parameters displayed positive and significant correlations with filled locules. The association of these traits with filled locules was even stronger at genotypic levels. Stone weights also showed high heritability and high genetic gain estimates. In Dang material however, stone length and width exhibited positive and significant correlation with filled locules with strong association at genotypic level. In both the materials stone width traits are highly heritable and showed significant relation in the desired direction with most of the characters, hence it proves its usefulness as single character for selection to effect indirect improvement in seed-fullness and reduction in emptiness in fruits.

19. **Developing vegetative propagation techniques for *Bambusa vulgaris* var. Yellow and *Dendrocalamus strictus***

**Principal Investigator:** Dr. S. A. Ansari

**Duration:** 1995-1997

**Summary**

Adventitious rhizogenesis in Culm branch cutting of *Bambusa vulgaris* var. Striata and *Dendrocalamus strictus* was influenced by seasonal variation, size of cuttings, IAA treatment and their all possible interactions. Adventitious rhizogenesis in both species was found to be season specific and the cutting size and IAA treatment helped in optimizing rooting behavior during responsive warm season of the year. April x 100 ppm IAA x double / triple nodal cuttings and February x 100 ppm IAA x double cuttings are recommended for large scale vegetative propagation of *B. vulgaris* var. Striata and *D. Strictus*, respectively.

20. **Selection and Evaluation of high yielding Clones of *Pongamia pinnata***

**Principal Investigator:** Dr. K. Palanisamy, Scientist-F

**Duration:** 2011-2016

**Summary**

Ninety one high fruit yielding trees were selected in Southern India, multiplied clonally and assembled in the clone bank. The branch cuttings of pongamia treated with IBA shown good rooting. The pod yield, more than 100kg was recorded in 7 trees, viz IFGTBPP-19 (250 kg), IFGTBPP-66 (202.56 kg). IFGTBPP-14 (130.71 kg), IFGTBPP-63 (116.19 kg), IFGTBPP-13 (107.39 kg), IFGTBPP-9 (106.85 kg) and IFGTBPP-44 (103.51 kg). It was found that the tree No IFGTBPP-19 of Dharmapuri showed high fruit yield of 250 kg/tree and high oil content of 30.5% and tree No IFGTBPP 63 of Erode with 116 kg fruit/tree and 24.2% oil content and identified these clones as potential for clonal plantation. In addition the tree No IFGTBPP-44 of Nagapattinam from coastal area exhibited maximum pod weight (402 g), pod area (12.6 cm2), pod length (6.25 cm) and pod breadth (2.90 cm) with pod yield of 130 kg and oil content 21.6% was also found to be the best clone for clonal plantation and breeding programme. The maximum seed weight was recorded in IGFTBPP-13 of Krishnagiri (275g) but oil yield was less (18.93%). It was found that out of 91 trees, 15 trees showed high yield of above 75-250 kg/tree and 20 tree with high oil content of 25 to 33%. These 35 clones have to used for clonal plantation programme by state forest departments of southern India. The present investigation revealed that the dry areas like krishnagiri and Dharmapuri and coastal areas are found to be good for high fruit yield. In India the private Industries have established Pongamia plantation whereas forest departments and farmers have not taken up the planting programme in large scale.

The clones were multiplied through wedge grafting from the clone bank and established clonal trial at Neyveli, Tamil Nadu and being evaluated. The clones showed flowering and fruiting within a year, whereas *Pongamia* tree takes 8 to 10 years for flowering. The state forest departments can effectively use these clones for planting programme. The seeds collected from 91 selected trees showed good germination. The morphological and physiological characteristics and biomass of the seedlings of 91 selected trees have been studied. A germplasm bank with 91 selected tree seedlings was also established in Neyveli, Tamil Nadu. It was found that 1100 high fruit yielding trees of *Pongamia* were selected across the country. The clonal plantation of *Pongamia* can be established in different states with high yielding clones and thereby improve productivity and biodiesel production.

21. **Evolving Clonal propagation Technology for Teak to Improve Productivity**

**Principal Investigator:** Dr. K. Palanisamy

**Duration:** 2000-2006

**Summary**

Clonal propagation plays an indispensable role in forestry by means of large scale production of superior genotypes, establish clonal plantation and thereby improve productivity. In Brazil, China and India significant enhancement of productivity has been reported in clonal forestry of Eucalyptus. Vegetative propagation of teak through rooting of branch cuttings, grafting and micro propagation have been attempted form the last five decades. However, clonal plantation of teak is not in operation in India. Clonal propagation technology for multiplication of superior teak trees through juvenile coppice shoots has been developed. Cuttings from coppice shoots of mature trees showed good rooting (>74%) in different seasons. IBA was found to be a suitable treatment for adventitious rooting in teak and coir pith as best rooting media. Mature coppice shoots showed high rooting potential of 91 % probably due to high carbohydrate and nutrient contents in the mature shoots. Adventitious root formation and root system of coppice shoots of 63 year-old mature trees were similar to the cuttings of one year-old stumps suggesting the juvenility of coppice shoots in rooting. In teak, rooting depends upon the physiological status of the cutting, and season is no longer a major barrier in rhizogenesis. Through this technique superior trees teak can be mass multiplied throughout the year for clonal forestry programme. In addition a technique for mass multiplication for clonal seed orchards (CSO) seedlings has also been developed. About 1000 ha of CSO of teak has been established in different teak growing states to produce quality seeds for plantation programme. However most of CSO showed low seed production and not meeting the planting target. Young sprouts collected from 1 to 2 year old CSO stumps showed 79 to 100% rooting in IBA treatment throughout the year. Though the seed production is low in CSO the CSO seedlings can be multiplied to meet the planting target with quality planting materials.

Superior teak trees with good stem form, height and girth were selected in different locations of Kerala, multiplied clonally and assembled in the vegetative multiplication garden for genetic improvement. It was found that the volume of the selected trees was significantly higher than the average volume of the trees in the plantations indicating the possibility of enhancing the productivity of teak through clonal plantation. The rooting performance of different teak clones has been studied. Field trials were established with improved planting stock of teak in Kerala and Tamil Nadu and evaluated. The growth performance of propagules raised through coppice shoots of mature trees (63 year old tree) were similar to those of seedlings in field condition further confirming the juvenility of coppice shoot plants. A clonal trial of teak established at Nilambur (Kerala) was evaluated and compared with the plantation raised with seedlings. The height and collar girth of the clones varies from 4.8 to 6.5 m and 19.3 to 24.2 cm respectively, whereas the height and girth of the seedlings ranges from 4.6m and 17.9 cm respectively 3 years after planting. In addition to clonal forestry, clonal technology is also useful for conserving the valuable germplasm which is otherwise lost permanently after the rotation period. The clonal technology of teak has been transferred to the Kerala Forest Development Corporation under a consultancy programme.

22. **Genetic evaluation of teak of Orissa origin**

**Principal Investigator:** Dr. A. K. Mandal

**Duration:** 1997-2000

**Summary**

Availability of direct information on the magnitude and type of gene actions, heritability, genetic gains and genetic interrelationships among traits of economic importance is of paramount in formulating a meaningful breeding strategy in any species. Teak is the most important timber species of India, receiving substantial international attention of the workers and genetic improvement work being taken up to various levels.

Genetic analysis of four different half-sib progeny tests of different age groups, established in different locations of Orissa, indicated highly significant difference among families (clones). Family x replication interaction variation was non0significant in all cases. Height, diameter at breast height and basal area recorded low to high heritability values, and genetic gains were similar. The characters studies were controlled by both additive and non-additive gene actions. Highly significant and positive correlations were observed among height, diameter and basal area. Of the 44 parents tested, 14 were found to have high and positive combining ability values.

23. **Selection and Genetic Evaluation of *Melia composita* Wild.**

**Principal Investigator:** Dr. Ashok Kumar, Scientist-E

**Co Principal Investigator:** Ms. Parveen, Scientist-C, Dr. K.P. Singh, Scientist-C, Dr. Tara Chand, Scientist-B and Dr. Amit Pandey, Scientist-

**Duration:** 2009-2012

**Summary**

A series of plus trees were selected from the natural range of the species. The plus trees were also selected from plantation regions of Uttarakhand, Haryana and Punjab. Individual progenies were raised and established at ten geographical locations in the states of Haryana, Punjab Uttar Pradesh and Uttarakhand. The index method of selection was adopted for selecting plus trees for genetic evaluation. During selection it was ensured that the experimental material represents maximum distribution range and the wider genetic diversity is maintained. The early trend showed greater variability among the selected genotypes for various morphological characteristics. The seed harvesting and processing protocols were standardized. The seed germination and rising of the seedlings was a serious issue which has completely been resolved. It is because of Tackling of the issue of seed germination that thousands of the seedlings could be propagated and planted across the locations. The insect and disease incidences were also studied, and found that insects attack is progeny specific and needs further investigation. The detailed studies were carried out to control the storing pests for the seeds. However, no major disease was recorded in the species.

The multi-location progeny trials were established with the objective of identification of superior and stable genotypes that are resistant to disease and insect-pests. The initial adaptability was reported. The physiological and morphological characterization of different progenies has also been carried out over the locations.

At two locations Kharkhan and Punjab Agriculture University, Ludhiana) after two years (2012)

came out as the stable and productive over the location. This was also notice that out these progenies how many of them also resistant to insect pest. A total of 8 progenies performed well and maintained their position in best performing clones on the basis of measured growth traits 159, 195, 234, 237, J-12, J-20, J06 and J-9. Two progenies (195 and 237) were not attacked by insect borer and found resistant to insect attack.

In another multilocational trial studies, it was found that after one year, among 21 progenies established at three locations (Raipurrani, Panchkula, Nolta Pinjore and Chutmalpur, Uttar Pradesh) the above average performing for recorded growth traits are a follow, progenies 241, 256, J-02, J-03, J-04, J-06, J-07, J-10, J-11, J-12, J-13 and J-15. Out of these progenies 241 and 256 had shown minor incidences. At the age of one year observation recorded from two trials at Raipurrani and Nolta showed that out of twenty one progenies, 9 progenies viz. 20, 24, 32, 59, 75, 114, 234, 238 and 239 were found to be productive over the locations. Two progenies (75 and 237) were found completely resistant to the disease incidences.

24. **Collection of germplasm of *Madhuca indica* J.F. Gmel for identification of best sources in Chhattisgarh through phytochemical evaluation**

**Principal Investigator:** Dr. Fatima Shirin, Scientist-F

**Co Principal Investigator:** Dr. Yogeshwar Mishra, Scientist-F and Mrs. Neelu Singh, Scientist-F

**Duration:** 2012-2016

**Summary**

Field surveys were carried out in the three agroclimatic Zones of Chhattisgarh. Phenotypically superior trees of *Madhuca indica* were selected in five girth classes, viz, 61-90 cm, 121-150, 151-180 cm and over 181 cm. The selection of trees was done based on fruit yield, girth of trees, height, clean bole height and crown diameter. Two localities in each agroclimatic zone were taken up for survey. These locations were Sarguja and Jashpur in North Hills Zone, Bilaspur and Balod in Chhattisgarh Plain Zone and Jagdalpur and Bhanupratapur in the Bastar Plateau Zone. Flowers and fruits were collected from these trees in appropriate months, viz, March-April for flowers and June-July for fruits. It was found that significant variation existed in the morphological characters of flowers; fruits and seeds collected from different localities, Fresh weight and dry weight of mahua flowers were maximum in Sarguja and Jashpur locality. Moisture content was found to be maximum in flowers of Jagdalpur. The length of dry flowers was found to be significantly more in Sarguja.. The effect of localities was found to be statistically significant on seed weight. Maximum seed weight was obtained in Bhanupratapur and Jagdalpur locality. Biochemical analysis was carried out and sugar was estimated in flowers. The sugar content of flowers obtained in different localities was significantly different from each other. The sugar content of flowers was significantly affected by the location from where they were collected. Maximum sugar (79.53%) was observed in flowers of Sarguja locality followed by flowers of Jagdalpur locality (77.08%). The girth class of also significantly affected for sugar content of flowers.

The two localities of Sarguja and Jagdalpur yielding more sugar in their flowers can be utilized for a number of uses in food industry and pharmaceutical industry. Similarly, localities yielding more oil content in seeds, viz, Jashpur and Sarguja can be edible oil. The study provided valuable input for identification of morphological variability in mahua flowers, fruits and seeds which can be used in Existence of substantial variation could be utilized for genetic resource conservation and further tree improvement programmes of the species.

25. **Population genetic analysis of Himalayan Banj Oak (*Quercus leucotrichophora*) forests and its pertinence to genetic conservation**

**Principal Investigator:** Dr. H. S. Ginwal, Scientist-F and Dr. Maneesh Singh Bhandari, Scientist-C

**Duration:** 2011-2015

**Summary**

Twenty-nine large Banj Oak populations from Uttarakhand and Himachal Pradesh were investigated for Genetic Diversity using RAPD-DNA markers. Results revealed that majority of the oak forests of Himalayan landscape depicted low level of genetic diversity, and revealed that it had undergone considerable genetic change in response to fragmentation, drift, and/or barriers to gene flow. Study has revealed that most of the variation in Banj Oak forests lies within populations than between the populations. Banj forests with low gene diversity need special attention for their scientific management for increasing diversity level. Also these forests will be more susceptible to environmental variations. Results of the project will go in long way for conservation, management of oak forests and initiating genetic resource improvement programs in this species.

26. **Studies on variability in rooting proficiency in selected genotypes of *Pongamia pinnata* (L.) Pierre**

**Principal Investigator:** Dr. Animesh Sinha

**Duration:** 2010-2012

**Summary**

*Pongamia pinnata* plantations established by vegetative propagation (stem cuttings/grafting) can be considerably more profitable than those using conventional seed propagation techniques. The profitability of cuttings in terms of economic gains can be raised further if the cuttings/scions are obtained from an elite genotype due to its inherent positive characteristics.

The rooting ability of *P. pinnata* is linked to its genotype, in addition to the seasonal effects and other contributing factors. Among four different auxins studied, IBA was found best for rooting from stem cuttings. IBA 1000 ppm showed maximum rooting (58.3%) of stem cutting collected from 4-5 year-old trees during March. However, the highest rooting among the CPTs studied was observed in DIRCHT (41.6%) in IBA 1000 ppm, followed by DIRCPD (35%) in three component mixture i.e., IBA 1000 ppm, + IAA 250 ppm +NAA 250 ppm. January to March season was found the best rooting of stem cutting as well as for grafting in Karanj. The highest grafting success was observed in DIRCPD (80%) followed by DIRCCP (75%). It was also observed that softwood grafting of CPTs studied produced higher success than hardwood grafting.

27. **Genetic Evaluation of *Aquilaria malaccensis* Lamk. In North Eastern India and Establishment of Gene Bank**

**Principal Investigator:** Dr. N. Ravi, Scientist-B

**Co Principal Investigator:** Dr. Tara Chand, Scientist-B and Sh. N. P. Mahadevan, Scientist-B

**Duration:** 2010-2013

**Summary**

The high market demand for the oleoresin (agar wood) produced by the agar tree lead to unsustainable and indiscriminate harvest from the agar growing regions of the world, including the north eastern region of India. This caused the fast disappearance of the species from wild and also led to increased planting of trees outside the forest. Due to continue felling of the trees, only very few young trees or plantations were found. These trees will also be felled for its economical value and to meet the demands of people who were associated with it. The species with available genetic diversity must be conserved for future tree improvement programme and for its own evolution for its adaptation.

The agar trees were limited in its natural habitat and they were also under threat in spite of all protective measures. Survey was carried out and 56 trees were selected from different states of North East India. These trees were selected from home gardens, old plantations, old government establishments where they were planted as wildings and from naturally regenerated in preservation plots by public in their own land. Trees grown in a very distant location were expected to have differences in their genetic nature. The progenies of these 56 trees were raised and established in conservation plots, germplasm banks. The performance of the progenies would give information on genetic variations existing among them. These materials could also be used as base population for future improvement programme.

Molecular approaches using RAPD technique was used to understand the genetic diversity existing among the selected trees at the early. Twenty eight trees from the selection, grouped into eight groups based on their geographical location, were used for this study. The results revealed that considerable genetic distance exists between the groups and some of the groups from far off regions showed less genetic distance. Few groups showed more genetic distance than other groups. Further research in needed to study the effect of exploitation on genetic structure of the tree species in its nativity and in plantations and man-made forests. The preliminary observations clearly indicated that genetic variation exists among the selected trees and more genotypes needs to be added for ex-situ conservation to increase genetic diversity in the preservation plots.

28. **Development breeding populations of teak with broad genetic base for long term genetic improvement**

**Principal Investigator:** Dr. A. Nicodemus, Scientist-F and Shri. A. Mayavel, Scientist-C

**Duration:** 2012-2015

**Summary**

Large variation exists within teak populations which can profitably be exploited to increase productivity of plantations. Significant family variation for growth traits in two contrasting test locations indicates differences in the genetic merit of parent trees and the breeding efficiency of the populations (SPA/CSO). Seedlots from the walayar CSO and SPAs in Arienkavu and Topslip showed better growth than other seed sources. Clones selected based on seedling vigour have shown fast growth and straight and cylindrical stem in farm land. Fifty such outstanding seedlings accessions have been identified for clonal propagation, field testing and supply stakeholders.

29. **Genetic Improvement of *Casuarina* Species through second Generation Orchards**

**Principal Investigator:** Dr. A. Nicodemus, Scientist-F

**Co Principal Investigator:** Dr. John Prasanth Jacob and Dr. A. Karthikeyan

**Duration:** 2008-2015

**Summary**

This Project is a continuation of the ongoing *Casuarina* breeding programme initiated in the year 1998. The overall aim of the project is to capture additional genetic gain in terms of growth, from and wood traits over and above what has been obtained in the first generation breeding. The first generation orchards located in the states/UT of Andhra Pradesh, Tamil Nadu and Puducherry have been assessed and outstanding trees selected. Using open-pollinated seeds collected from the selected trees 14 ha of second generation progeny tests cum second generation SSOs have been established in the states/UT of Andhra Pradesh, Tamil Nadu and Puducherry. Maintenance of all field trials plots and periodic assessment for survival growth is progressing. Progeny tests that have reached the age of 4 and more years have been marked for thinning of inferior families and individuals. Thinning of inferior trees completed in two trial plots and converted the progeny trial second generation seedling seed orchards. Open-pollinated families from the Karunya orchard of *C. Equisetifolia* and *Panampalli* orchard of c. *Junghuhniana* performed better in all test locations. In general heritability values ranged from 0.1 to 0.2 for growth traits and stem straightness. No adverse correlation was found between growth and stem straightness providing scope for simultaneous selection for traits. Strong genotype-environment interaction was found among families.

30. **Genetics evaluation of bamboo germplasm in RFRI germplasm bank**

**Principal Investigator:** Dr. Tara Chand

**Co Principal Investigator:** Dr. S. Pattanaik and Dr. N Ravi

**Duration:** 2009-2012

**Summary**

*Bambusa tulda*, *Bambusa nutans* and *Bambusa balcooa* are the three most important species preferred by the farmers in the northeast. Under the World Bank aided planting stock improvement programme FRFI, Jorhat has assembled superior genotypes of these three cultivated species in its germplasm bank for conservation purpose as a safeguard against any natural calamities. These accessions e from different geographic locations of northeast India assessed for the amount of genetic diversity. In the present investigation, the primer-screening step resulted in 12 decamer primers which detected polymorphisms and 32 other random primers, which did not give amplification products. The reproducibility was tested on template DNA from three independent extractions of three initial clumps, using leaf samples collected in different seasons. The amplification profiles of total genomic DNA from three bamboo species with twelve random primers produced a total of one hundred five fragments ranging in size from 0.4-3.5 kb, out of which all were polymorphic. The similarity matrix was obtained using Nei and Li's coefficient similarity coefficients ranged from 0.02-1.0 in three species of bamboo tested in the present investigation. These similarity coefficients were used to generate a tree for cluster analysis using UPGMA method. Two types of comparisons were carried out to evaluate the degree of genetic diversity and relationship in the bamboo germplasm collection i.e. among groups (which represent mostly of accessions), as well as between three bamboo species. The results from this study stipulate that the RAPD technique is a useful tool for the identification of germplasm analysis and genetic relationship between and within the bamboo species. The comparatively large number of polymorphisms obtained seems due to large phylogenetic distance among these taxa. It would allow a more quantitative assessment of genetic distances between species. Such an analysis, together with data from other molecular Further, such advancement could be supportive in identifying taxa of potential value in genetic improvement programmes.

31. **Genetic improvement of *Gmelina arborea* Roxb. throuch Selection and Clonal Evaluation**

**Principal Investigator:** Shri. A. Mayavel, Scientist-C

**Co Principal Investigator:** Dr. V. Sivakumar, Scientist-E

**Duration:** 2011-2016

**Summary**

The intensive survey was carried out in natural forest and farmers plantation of Tamil Nadu, Kerala and Andhra Pradesh. Selected 90 CPTs based on growth superiority, clear bole and pest and disease resistance. The CPTs were marked with GPS. The data on bio-metric, phenology and reproductive character have been recorded from selected CPTs. Wood sample (core) collected from selected CPTs and analyzed wood density, fiber length and lumen diameter and fiber angle. The reproductive characters like time and mode of a thesis, pollen fertility, no of stamen, no of pollen, pollen ovule ratio and visitor for pollination have been observed. Seeds were collected from selected CPTs and studied seeds variation of different open pollinated families through image analyzer. Standardized nursery techniques for large scale multiplication and studied variation in seedlings characters of different population. Established progeny trail of Gmelina arborea at Salem and Thuvarankurichi with 44 open pollinated families planted randomized block design in a spacing of 4x4. Morphological data has been recorded for evaluating performance of progenies. Silivicultural techniques were standardized for commercial cultivation of *Gmelina* in farm land.

32. **Studies on reproductive biology and propagation techniques of *Schleichera oleosa* (Lour.) oken an oil bearing tree and important Lac host plant**

**Principal Investigator:** Dr. Animesh Sinha

**Duration:** 2006-2009

**Summary**

The extensive exploration was carried out for the collection of superior *S. oleosa* trees from the whole lac producing region in eastern part of the country, represented by three states, West Bengal, Jharkhand and Orissa. Around 30 trees were selected. Point Grading Method for tree selection is *S. oleosa* was followed. Very good information has been generated by identifying the hormonal treatment combinations for rooting after a thorough testing by stem cutting trial. Based on the results of grafting, the method of cleft grafting followed in experiment 2 was more dependable for clonal propagation of young trees in Kusum. These cheap and reliable methods of macro propagation such as air layering, grafting and stem cutting of *Schleichera oleosa* will provide a valuable tool for tree breeding within the species. Desirable trees can be preserved as clones, controlled pollination made easier and seed orchards can be established for future seed supply.

In present investigation work on rooting and acclimatization of in vitro proliferated shoots was initiated. However, In spite of several efforts, no rooting was observed in micro-propagation experiments. Attempts were taken for in vitro seed germination to get cotyledonary nodes for using it as explants. Attempts were also taken for multiplication and elongation of shoots in culture. A good account of data has been generated in these aspects. DNA extraction method from juvenile leaves of clones has been standardized with the aim to test the clonal fidelity.

The extensive survey was carried out throughout the Kusum growing areas in Jharkhand and Orissa

for data collection on flowering and fruiting of this species. Very good information has been generated on time of flower initiation in different places. The quantum of flowering was inconsistent, abundant in some years and meager in others. The extensive tour was also carried out for collection fresh seed of this species in each year. Different methods were applied for enhancement of seed germination percentage viz. Mechanical scarification, soaking of seed in cold/hot water, acid or Gibberellic acid or other chemicals, etc. The highest seed germination was observed when the fresh seeds were pretreated with $KNO_3$ for 1 hour.

33. **Population structure, regeneration status and pollination ecology of *Dalbergia latifolia* and *D. sissoides***

**Principal Investigator:** Dr. K. R. Sasidharan, Scientist-E

**Co Principal Investigator:** Dr. B. Nagarajan, Scientist-F, Dr. C. Kunhikannan, Scientist-F and Dr. Maheshwar Hegde, Scientist-E

**Duration:** 2011-2017

**Summary**

*Dalbergia latifolia* and *D. sissoides* are considered as two precious timber species of India. *D. Latifollia* is naturally distributed in the Indo-Malaysian region. In India, it occurs in the sub-Himalayan tract from Oudh eastwards to Sikkim, Bihar, Orissa, Central, Western and Southern India. *D. sissoides* is a closely allied species of *D. latifolia* and is Kerala. Of late, the population of these species has been dwindling considerably in the forest areas.

There are many factors, which are intervening in the reproduction and establishment of tree species in the natural habitats, which could be either biotic or abiotic or both. Further, the habitat destruction and depriving of the required ecological conditions for the species to continue their life cycle often leads to their population decline. Therefore, it is essential that, the population of the tree species like *D. latifolia* and *D. sissoides* are monitored in the natural habitats, so that some management interventions could be possible to conserve of both of these valuable timber species. The regeneration status of both of these species in most of the forest areas are still not known and therefore, understanding of the natural regeneration and the factors influencing the regeneration will help the Forest Management to take adequate measures to ensure preservation of the species in the natural forest areas. Field observation and experimentation on diverse aspects of pollination ecology are a must in order to understand various intricacies involved in different plant- pollinator systems and framing measures for effective conservation of the genetic resource of these species, both in-situ and ex-situ.

The population of *Dalbergia latifolia* and *D. sissoides* were identified by referring to herbarium data, floras and vegetation maps in 7 Forest Divisions of Tamil Nadu 14 Forest Division of Kerala. Data was collected on population structure and regeneration from the specific locations in these forest divisions. In most of the locations situated in the Western Ghats, both *D. latifolia* and *D. sissoides* were found to occur together, in varying proportions. In the Eastern Ghats, only *D. latifolia* was recorded. In general, the density of trees of higher girth classes (mature trees) were more, compared to that of lower girth classes, with very less number of pole stage and saplings, in most of the locations studied. The natural regeneration was found to be scanty and generally it was seen in the open areas, away from the mother trees.

Invasion of exotic weeds like *Lantana camara*, *Mikania micrantha*, *Chromolaena odorata* and

*Cassia spectabilis* were noticed in most of the locations studied and it could have influence on the natural regeneration of the Dalbergias. The moist deciduous forest areas, where the Dalbergias occur were also found to be fire prone and the occurrence of fire was an annual phenomenon. Grazing by cattle is another menace encountered by these seedlings coming up might have been killed during the seasonal fire incidence; eaten away or trampled by cattle during grazing. Predation of flowers and flower buds by some of the insects and birds was found to affect the fruit setting rate in *D. Latifolia*.

Phenological studies were made on selected population of both the species and various events like leaf fall, leaf flutings, flowering and fruiting recorded. The flowering phenology of both the species was found to be totally different. Various floral structural and functional characteristics were also studied, is adapted for insect pollination, especially by bees and butterflies. Crossing experiments were carried out to understand the breeding behaviour in *D. latifolia* and *D. sissoides* which brought to light that both of them are cross-pollinated and they also exhibit self-incompatibility even though very few fruits are produced as a result of self pollination, the fruits fall off prematurely.

34. **Genetic Improvement of *Buchnania lanzan***

**Principal Investigator:** Har Prasad

**Duration:** 2007-2010

**Summary**

- Survey and identification of 33 candidate plus trees.
- Collection of seeds (half sib progenies) from identified 25 CPTs.
- Nursery preparation.
- Establishment of progeny trial and data collection.

35. **Studies on Inheritance pattern in Teak of south Indian origin**

**Principal Investigator:** Dr. A. K. Mandal

**Duration:** 1996-1997

**Summary**

The genetic analysis of quantitative characters in teak (*Tectona grandis*) was done using growth data of age five from a progeny test material established with 18 half-sib families and one control. The results indicated the presence of considerable genetic variation for height, diameter and basal area. Preponderance of additive gene was noticed for height as evidenced by both high heritability and genetic gain values. Diameter and basal area were found under the control of non additive gene action. Highly significant and positive correlations were found among all the characters. Clones KLN-2, 4, TNT- 11, 15, 16, 20 and 21 were found to be general combiners for all traits studied. Results have been discussed in the light of breeding strategies to be followed in teak.

36. **Evaluation of different genotypes of Eucalypts**

**Principal Investigator:** Dr. Parveen

**Co Principal Investigator:** Dr. Ashok Kumar

**Duration:** 2014-2015

**Summary**

There is urgent need to improve the productivity of eucalyptus in India. The Forest Research Institute is working on genetic improvement of different species of eucalyptus through hybrids production, selection and progeny trails. The field trials of *E. citriodora*, *E. Torelliana* and their reciprocal hybrids have been laid out at different locations to evaluate for their growth performance. The maximum estimated MAI of individual outperforming genotypes was recorded at different locations. The maximum value 50.4 m3 /ha/yr was recorded for inter-specific hybrid of *E. torelliana* x *E. citriodora* at the trial established at Dehradun at the age of six years.

The maximum MAI of individual outstanding plants in populations raised from seedlings 50.44 m3/ha/yr was recorded for E2 at Dehradun followed by 42.40 m3 /ha/yr for E3 at Hoshiyarpur at six year age.

The pooled mean annual increment (MAI) was also calculated for all the treatments over the locations established in the year 2007. The maximum pooled mean annual increment value 6.56 m3 /ha/yr was observed in the treatments E2 followed by 4.96 m3 /ha/yr in E1 from the populations raised through seedlings. The mean value 11.55 m3 /ha/yr was recorded for the treatment E6 (clone 2070). In the trial laid out in the year 2008, the maximum mean value 8.68 m3 /ha/yr was observed in the treatment E3 followed by 5.23 m3 /ha/yr for E1. The mean value 11.97 m3 /ha/yr was recorded for the treatment E6.

Intra-clonal variation in respect of MAI at different locations was calculated. The values varied from 37.32 to 0.26 m3 /ha/yr at Moga, 7.97 to 1.55 m3 /ha/yr at Amritsar, 23.59 to 1.09 m3 /ha/yr at Bithmeda, 12.54 to 0.43 m3 /ha/yr at Dehradun, 47.42 to 4.52 m3 /ha/yr at Hoshiyarpur, 30.22 to 12.56 m3 /ha/yr at Pantnagar, 28.81 to 1.06 m3 /ha/yr at Patiala and 29.36 to 2.18 m3 /ha/yr at Yamuna nagar. A wide range of intra-clonal variation was recorded in this clone.

The growth parameters have been analyzed for one year old progeny trials established in March 2013 at four locations viz. Pipal Padav, Haldwani (Uttarakhand), Kharkhan, Hoshiyarpur (Punjab), Chaksarkar, Firozpur (Punjab) and Tapri, Saharanpur (Uttar Pradesh) Just to compare the growth performance at early age. The progenies number 33 and 17 have shown better performance at all locations, though there is a wide range of stand volume production which is due to Genotype x Environment (G x E) interaction. The progenies number 30 and 35 also performed better in Haldwani and Hoshiyarpur. Some progenies are performing better at particular site (site specific). The progeny No. 14 performed better at Haldwani but not in other locations.

The maximum average stands volume 2801.81 cm3 for the progeny No. at Haldwani, 913.24 cm3 for progeny No. 33 at Hoshiyarpur, 338.49 cm3 for the progeny No. 13 at Firozpur and 1708 cm3 for progeny No. 17 at Saharanpur. The superiority per cent over population mean in terms of volume was recorded 64.14 at Haldwani, 99.13 at Hoshiyarpur, 125.62 at Firozpur and 79.77 at Saharanpur respectively.

Since the performance of the progenies show change in their ranking position, the reliable estimates

could be made since they complete atleast half rotation age. A comparison was made on growth performance of selected mean. The pooled mean of height, collar diameter and volume production of selected one-year-old progeny trails have been compared with pooled mean of height, collar diameter and volume production of unselected one-year-old trials established in the year 2007 under the project 'Deployment of promising F1 hybrids of E. Citriodora and E. Torelliana for establishment of vegetative multiplication garden and their field trials". The superiority per cent over population mean in respect of height, collar diameter and stand volume was recorded for 54.65, 60.28 and 296.63 respectively.

37. **Estimation of gene diversity and enhancing seed production in seed orchard of Eucalyptus, Casuarinas, Acacia and Teak**

**Principal Investigator:** Dr. Mohan Varghese

**Duration:** 2003-2007

**Summary**

The fertility was registered for each tree at age eight and nine years in seedling seed orchards of Eucalyptus tereticornis (N=192 & 525) and E. camaldulensis (N=182 & 505) established at two sites (one moist one dry) in southern India .E. camaldulensis on the moist location (Panampally) had 73% fertile trees and low fertility difference. Only 23% trees were fertile in the E. tereticornis orchard at the same site and the fertility variation was high. In the dry location (Pudukkottai), fertility was almost the same in both species at nine years, with 45 & 51% fertile trees in *E. camaldulensis* and tereticornis respectively. Gene diversity values of the seed crop estimated for two consecutive years are fairly high except for the E. tereticornis orchard located in the moist site. The effect of different treatments on tree growth and fertility was studied in one unpedigreed seedling seed orchard (sso) each of Eucalyptus camaldulensis and *E. tereticornis* in an arid location (Pudukkottai) in southern India. Four treatments namely application of (1)high dose of nitrogen (two doses of 217 g N / tree), (2) Nitrogen with phosphorus (two dose of 10 g sodium borate and 25g zinc sulphate ), (3) pollarding trees at 5m height with application of N,P,K and trace elements were given. Compared to untreated control, only hormone application showed significant increase in proportion of fertile trees in both species for four successive years. The number of fruits produced per tree also significantly increased with hormone application, through the difference was comparatively less in the fourth year.

Two seedling seed orchards each of *C. junghuhniana* established by thinning provenance trails in coastal (Pondicherry) and inland locations (Karunya and Panampally ) in south India were evaluated for sex expression and fertility variation . More than 80% of the trees in *C. equisetifolia* orchards were fertile in both sites with a similar pattern of more (almost 2 times) female trees and equal proportion of monoecious and none flowering trees. In c, Junghuhniana, the coastal orchard had twice the proportion of fertile trees as that of the inland. Orchards established in coastal environment had less fertility variation and hence maintained higher diversity in both species. Coastal site had more trees contributing effectively to seed production than inland locations. Measures like constrained seed collection from large number of trees promoting representation of superior provenances with low fertility would be useful in checking diversity loss during domestication.

Fertility differences between clones were estimated in a 25 year old clonal seed orchard (CSO) of teak at walayar in Kerala state. The CSO has 20n clones selected from Karulai (KLK), Nilambur

(KLN), Sungam (KLS) and Thunakadavu (TNT) regions in Western Ghats and Bhadrachalam (SBL 1) in Andhra Pradesh. In the CSO only 20% ramets of 14 clones were fertile. Fruit set the in CSO was 947 fruits per tree. There were great differences in fertility variation between two seedling seed orchards of *Acacia auriculiformis* established in two locations. The fertility variation in the Karunya orchard was much lower in 2005 compared to the previous year. Thus fertility variation is directly correlated with the location and the climatic conditions each year.

38. **Chemo typing of sapindus emarginated – a potential NTFP of Tamil Nadu for saponins**

**Principal Investigator:** DR. R. Anandalakshmi, Scintist-E

**Duration:** 2010-2015

**Summary**

Populations of soap nut were identified in areas such as Mettupalayam, Sarkarpathy Palani, Thirmoorthy hills, Thalavadi, Pillur, Dhimbham, Thengumarada, Aliyar, Pachamalai, Hoggenakkal, Srivilliputtur, and Rajapalaym in Tamil Nadu. The number of fruits per meter length of branch was taken as selection criteria. Identified 132 CPTs of soap nut. Collected seeds processed and assessed tree wise, germination capacity. Recorded seedling parameters and standardized nursery practices. Standardized separation of Saponins by differential solvent extraction process from fruit rind and carried out estimation of Saponins by gravimetry. HPTLC profiling of Saponins was done to compare populations. Tree wise saponin content was estimated and threshold value of Saponins for short listing high saponin yielding CPTs was identified to be 13%. Management of nursery pests and diseases of soap nut was carried out and hardened seedlings for out planting. Established germplasm bank of soap nut at Panampally. Raised seedlings of the 30 shortlisted high saponin yielding accessions and established four multilocational trails, at Gudalpur (1 ha), Salem (1 ha), Neyveli (1 ha) and Thuvarankurichi (1 ha). Provided drip irrigation facilities. Completed field maintenance operations and recorded growth and survival data at regular intervals of six months. Interim results of the trial evaluation reveals that significant variability exists among the accessions which could be exploited in future tree improvement programs. Extension programs through farmers mela have been undertaken to popularize the species for cultivation by farmers and planting by forest departments. Through this project assembled a wide genetic base of high yielding Sapindus emarginated for tree improvement and simultaneously the valuables bio resource of soaput has been conserved.

39. **Selection and screening of germplasm of *Thespesia populnea* for improving productivity**

**Principal Investigator:** Dr. Kannan C.S. Warrier

**Duration:** 2011-2016

**Summary**

*Thespesia populnea* (L.) Soland ex correa is a valued multipurpose tree species. The species has been planted throughout the tropics and is naturalized in tropical climates throughout the world. The timber is of great local utility, being suitable for furniture agricultural implements, carts and carriages, musical instruments, wheel- spokes, boat building and also for turnery. It is tough, durable and resists termites. The wood is highly preferred because it does not spilt. The available information indicates that the research programmes on this species are limited to medical uses/therapeutic values. The major problem with *T. populnea* is that the stem is often crooked. The trees grow in short twists and turns with numerous limbs, therefore lumber is generally found in short lengths. No systematic tree improvement programmes have been put for identification of superior germplasm through variability studies. Germplasm assemblage and evaluation of different provenances or seed sources to understand the variability is fundamental to any tree improvement research. The current project envisaged to understand the variability of *Thespesia populnea* with reference to growth and tree form in Kerala, Tamil Nadu and Puducherry and assembling the germplasm in the form of clones. The project also envisaged screening the germplasm in the form of clones. The project also envisaged screening for key insect pests of this species.

Extensive field surveys were undertaken in the western, north western Cauvery, Delta, North Eastern, southern and high rainfall zones of Tamil Nadu, Puducherry, North central and south regions and tree form. Total height varied from 5.6 to 16m where as the clean bole height ranged between 1.5 and 6m. The GBH varied from 66 to 267m.

Cuttings from the selected trees were collected and kept for rooting in the vegetative propagation complex of IFGTB. Bud sprout could be observed in all the cuttings and the rooting percentage was 60. A clonal multiplication area was established at Panampally Research centre of IFGTB near Palatka, Kerala with 86 rooted clones. No pest attack was observed till September 2012. However, 3 clones were affected by Mealy bug later. Control measures and prophylactic measures have been adopted. No pest attack was noticed in the CMA since April 2013.

40. **Clonal test trials on *Casuarinas equisetifolia* L. in north coastal Andhra Pradesh**

**Principal Investigator:** Dr. N. Rama Rao, Scientist-F

**Duration:** 2003-2008

**Summary**

The clone CP4202 – M has desirable attributes of 50.66% survival, average height of 14.00 m and average basal stem diameter of 46.67 cm while the clone APVSYM - 5M had the values of 46.66%, 14.46 m and 45.67 cm, respectively. Thus, these two clones may be rated as superior performers among the ten clones tried for plantation in a coastal area.

41. **Establishment of molecular taxonomy facilities and molecular characterization of selected bamboo species (494/Bot-71)**

**Principal Investigator:** Dr. Anup Chandra, Scientist - D

**Co Principal Investigator:** Dr. Santan Barthwal Scientist – D and Dr. Ajay Thakur Scientist - D

**Duration:** 2010 –2013

**Summary**

Traditional taxonomy is based on morphological feature and need sample in flowering stage, sometimes it is difficult to distinguish closely related species hence molecular taxonomy as tool required for identification. Necessary infrastructure for molecular taxonomy was established Systematic Botany Discipline at Forest Research Institute Dehradun. For DNA isolation leaf samples were collected from 15 bamboo species (*Bambusa vulgaris, Dendrocalamus longispathus, Dendrocalamus membraneous, Bambusa nutans, Bambusa tulda, Gigentochloa albociata, Bambusa balcooa, Bambusa wamin, Dendrocalamus giganteous, Bambusa striata, Dendrocalamus asper, Melocanna baccifera, Bambusa polymorpha and Melocanna baccifera*) from different locations (FRI Dehradun, Lalkuan, Pant Nagar, RFRI, Jorhat). 11 RAPD and 25 ISSR markers were screened for molecular characterization and suitable markers were identified. Study reflected variability at intra species level. However these markers were not able to detect variability at inter species level.

**Scientific findings**

- Basic infrastructure for molecular taxonomy studies were established
- Suitable molecular markers identified for molecular characterization
- With few molecular markers some species of Bamboo were characterized

42. **Molecular Variability in *Cylindrocladium quinqueseptatum* causing leaf and seedling blight in Eucalyptus**

**Principal Investigator:** Dr. Amit Pandey, Scientist – E

**Duration:** 2007 –2010

**Summary**

*Cylindrocladium quinqueseptatum* causes large-scale mortality in nurseries and and aafects plantations of Eucalyptus. Using DNA fingerprinting of different isolates of this pathogen 14 population lines were identified across three populations growing state viz. Uttarakhand, Panjab and Haryana. In addition to this by sequencing ITS region of nrDNA the identity of the pathogen was authenticated and species specific primer was designed. Sequences were deposited in GenBank, USA.

**Scientific findings**

- Molecular diagnostic kit for Cylindrocladium quinqueseptatum was developed
- Potential biocontrol micro-organisms were screened

43. **Genetic improvement of Acacia auriculiformis through half-SIB progeny selection**

**Principal Investigator:** Dr. Maheshwar Hegde, Scientist - D

**Duration:** 2005 –2010

**Summary**

This project work was carried out at Institute of Forest Genetics and Tree Breeding Coimbatore during 2005 to 2010. The main objective of this project was to improve the stem form and reduce the occurrence of multiple stems in *Accasia auriculiformis* plantation through selections, progeny testing and establishing second generation seedling seed orchards. For this work first generation seed orchards of *Acacia* were used for selection of trees and the seeds were collected from the selected tree and seedling were raised in nursery of Silviculture Division IFGTB. Progeny trials were established in 4 diverse locations. The effect of location on stem forms and growth was noticed.

**Scientific findings**

- 132 trees were selected based phenotypic trait
- Two progeny trials were raised and established
- Significant variations were observed for different growth parameters among families and seed sources
- Second generation seed orchard were raised from established progeny trials

44. **Web enabled database and analysis of gene sequences implicated in abiotic stress tolerance for screening gene homologues in salt tolerant tree species**

**Principal Investigator:** Dr. Mathish Nambiar-Veetil, Scientist - E

**Co Principal Investigator:** Shri. R. Vivekanandan, Scientist – E and Dr. B. Nagarajan, Scientist – F

**Duration:** 2009 –2013

**Summary**

A back end database structure was developed using MySQL. Front pages with graphical user interface were design using HTML, CSS and JavaScript. The MySQL database was connected with PHP coding for user queries and display outputs. The database was initially hosted in a free hosting site www.igbaas.site90.com and security audit of website was carried out by third party. The website was finaly hosted in the ICFRE server http://igbaas/ifgtb.icfre.gov.in for public use. The key features of this database was (a) contains 2500 gene sequences related to abiotic stresses from different species, (b) It is editable and updatable by users, (c) user-friendly, (d) searchable for degenerate primers, nucleotide and primer sequences of genes and related information from wikigenes and pubmed, (e) facilitates bioinformatic analysis. Probes were developed to identify salt tolerance gene viz. *NHX1, HKT1, AKT1, SOS1*and *HAK.* 84 clones of casuarina equisitifolia were screened and highly salt tolerant (TNIPT-4, TNKBM-407) and susceptible (PYN, TNPB2) clones were selected. the progressive increase in proline content in the branchlets were observed with increasing NaCl concentration upto 450 mM, after which there was a decline. The tolerant clone, TNIPT-4, showed the maximum accumulation of proline at 450mM (25.26moles/gram tissue). RNA isolation and cDNA synthesis protocol were optimized for *Casuarina equisitifolia, Eucalyptus camedulensis, Eucalyptus tereticornis, Pongamia pinnata, Prosopis juliflora and Acasia nilotica.* The sodium hydrogen transporter gene (NHX) from *Casuarina equisetifolia* (330

bp), *E. camendulensis* (494 bp), *E. tereticornis* (614 bp), *P. pnnata* (385 bp), *A. nilotica* (348 bp), *P. juliflora* (371 bp), *K. candel* (725 bp), *Bruguiera gemnorhiza* (355 bp), B. *cylendrica* (445 bp), *B. sexangula* (351 bp), HKT1 gene from *E. tereticornis* (638 bp), *P. juliflora* (220 bp), AKT-1 gene from *C. equisetifolia* (236 bp), *E. camendulensis* (280 bp), *P. juliflora* (300 bp), *b. sexangula* (325 bp), *B cylendrica* (230 bp), *K candel* (310 bp) and *A. nilotica* (361 bp) and Actin genes from *B. cylendrica* (293 bp), *B. gymnorhiza* (265 bp), *B. sexangula* (255 bp), *K.candel* (234), *A. nilotica* (201bp), *P. pinnata* (213 bp), *E. cameldulensi* (311 bp) and *C. equisitifolia* (204 bp) were sequenced and published with accession numbers at the genebank databe of NCBI, Nation library of medicin and NIH, USA.

**Scientific findings**

- Web enabled database was developed for abiotic stress tolerance related genes
- Gene specific primers were designed for isolation of salt tolerant genes
- Significantly tested gene specific primers for their utility in identification of important gene homologues

45. **Allelic diversity of cinnomoyl coa reductase (CCR) gene in Casuarinas equisetifolia**

**Principal Investigator:** Dr. A. Shanthi, Scientist - B

**Duration:** 2008 – 2012

**Summary**

This study was carried out in Forest Genetics and Tree Breeding, Coimbatore. In this study 25 selected clones of *Casuarinas equisetifolia* were taken for wood proximate and molecular variation. The result obtained from proximate study showed consistent variation in wood traits which are useful in paper and pulp industry. The study identified four clones having higher hemicelluloses content. For molecular variation the DNA was isolated from different clones calculated the molecular variation using RAPD primers and significant variation was obtained.

**Scientific findings**

- New CCR gene sequence of *Casuarinas equisitifolia* were developed and deposited to gene bank library
- High cellulose content clones were short listed and identified

46. **Identification of secondary xylem specific cellulose synthase genes from eucalyptus tereticornis**

**Principal Investigator:** Dr. Modhumita Dasgupta, Scientist - E

**Duration:** 2008 –2012

**Summary**

The project work was carried out at Institute of Forest Genetics and Tree Breeding Coimbatore during 2008 to 2012. The main objective of this project was to identify secondary xylem specific cellulose synthase genes from *Eucalyptus tereticornis*. In this study seven reference genes were selected to assess their suitability towards normalization of real time PCR data across *E. tereticornis* tissues and EtAct2 was evaluated as the most suitable candidate for gene expression studies in the species and three cellulose synthase gene involved in the development of secondary xylem were isolated and characterized from *Eucalyptus tereticornis* and the expression of these genes in both developing xylem and the mature xylem was confirmed through reverse north and RT- qPCR analysis.

**Scientific findings**

- Gene specific markers for cellulose content were developed
- Cellulose synthase gene was isolated
- Seven reference genes identified which was used for normalization RT-PCR data

47. **Determination of the target genes in *Leptocybe invasa* for engineering resistance in eucalyptus through gene-silencing approaches**

**Principal Investigator:** Dr. Mathish Nambiar – Veetil, Scientist -E

**Duration:** 2010 –2014

**Summary**

Project work was carried out at Institute of Genetics and Tree Breeding, Coimbatore. The main aim of this project was to identify the gene involved in the growth and development of *Leptocybe invasa* and to test the potential of identified genes in growth inhibition of *L. invasa*. For this the gene involved in growth and development of *L. invasa was isolated and sequenced.*

**Significant finding**

- Growth and development related genes were sequenced and analyzed
- A PCR amplification method directly from insect grub was developed
- An accessory was developed and patent was filed for delivery of nucleic acid into galls in plant
- Potential Target genes for RNAi based incorporation of resistance were determined

48. **Differential analysis of transcript expression in *casuarinas- Trichosporium* interaction to isolate defense- Related genes**

**Principal Investigator:** Dr. Modhumita Dasgupta, Scientist - E

**Co Principal Investigator:** Dr. R. Yasodha, Scientist – E and Dr. V. Mohan, Scientist - E

**Duration:** 2006 –2010

**Summary**

The project focused on elucidated the molecular pathways involved during interaction of woody perennial *Casuarina equisetifolia* when challenged by its wilt pathogen *Trichosporium vesiculosum* and also aimed at isolating pathogen defense–related genes from *C. equisetifolia.*Transcript profiling revealed over expression of 14% pathogen defense –related; 6% other abiotic stress related; 2% symbiotic; 2% cell wall related transcripts and 2% regulatory genes while 70% of transcripts were known. Transcripts like nodulin which are expressed during early nodulation in *Casuarina* was also found to be over expressed when challenged during pathogen elicitation.qRT-PCR analysis revealed 28 fold increase in expression of the glucanase; 13.6 fold increase in expression of chitinase ; 16 fold increase of gene coding for cytochrome oxidase; 9 fold increase of gene encoding nodulin and 2.7 fold increase in expression for gene having a heavy metal domain was observed. Transcript coding for signal recognition particle showed 1- fold increase in expression after 48 hrs of pathogen elicitation.

**Scientific Findings**

- Some defence related genes over expressed revealed by Transcriptome profiling validated by qRT-PCR
- 52 EST sequence submitted to NCBI
- Two genes Class I chitinase and glucanase were isolated and characterized
- A patent on Low cost high recovery protocol for RNA isolation was filed

49. **Studies on assessment of genetic diversity and structure of Boswellia serrata Roxb. Populations through RAPD and ISSR molecular markers**

**Principal Investigator:** Dr. Pramod Kumar, Scientist - B

**Co Principal Investigator:** Dr. S.A. Ansari, Scientist – G and Dr. Parvez Jalil, Scientist - C

**Duration:** 2011 –2015

**Summary**

This study was carried out in Tropical Forest Research Institute, Jabalpur in year 2011-2015. The study was based on the concept that the species is threatened due to declining no of natural population and their sizes, poor natural regeneration with inverted pyramid shaped age structure.12 natural population from MP 03 from chhattisgarh were surveyed and leaf and wood samples were collected for the study. Study reveals that the fruit set/ seed set is low due to self-incompatibility and post fertilization abortiveness. Fiber analysis shows 3 groups on the basis of fiber length. However no relationship exists between fiber length and GBH of trees. Khandwa MP and Sarguja in Chhattisgarh show highest fiber length. Molecular studies reveals the moderate amount of genetic diversity in MP using RAPD and ISSR combined primers, therefore indicating dividing /fragmented population.

**Scientific Findings**

- Phenology and reproductive biology have been studied
- Genetic Diversity estimated with molecular marker between and within the population
- Population structure and gene flow were studied

50. **Assessment of variability and genetic fingerprinting in pongamia pinnata (L.) pierre using microsatellite markers**

**Principal Investigator:** Dr. Sanjay Singh, Scientist - F

**Duration:** 2010 –2015

**Summary**

This study was carried out in Institute of Forest Productivity, Ranchi in year 2010-2015.in this study the variability and genetic analysis of 24 Pongamia genotypes selected from various locations in Jharkhand were assessed for seed oil traits as a scope for further breeding program. The result showed that the various biochemical characters linked to molecular data recorded significant variation among the different genotypes. The highest oil content was found in K19 followed by K27 and K22. Genetic variation statistics revealed the number of polymorphic loci ranged from 6-12 in full sib,19-22in half sib and 21-23 in combined. Among the genotypes, the genotype K21 and K15 showed 100% polymorphism. Private alleles were also found in this study.

**Scientific Findings**

- Superior genotypes were selected and screened on the basis of morphmetric and biochemical parameters
- Genetic variability was assessed with microsatellite markers
- Morphological, oil yield and quality traits associated microsatellite markers were identified

51. **Genetic improvement of eucalyptus through mapping and tagging of QTLs/Genes**

**Principal Investigator:** Dr. B. Nagarajan, Scientist - F

**Duration:** 2010 – 2015

**Summary**

This study was done in Forest Genetics and Tree Breeding, Coimbatore. In this study two full length genes (EtCesA3 and EtHBI) were isolated and sequenced. SNP discovery was conducted in subset of population with extreme phynotype.94 genes involved in development were selected for target capture and deep sequencing across three parents used for developing mapping population. Finally with control pollination and hybridization, 6 mapping population were developed targeting pulp and rooting properties

**Scientific Findings**

- With controlled pollination and hybridization, 6 mapping population were developed targeting pulp and rooting properties
- Multilocation Hybrid Clonal Trials (MLHCT) were established for multienvironmental phenotyping to determine QE effect
- Tagging of QTL/genes not found in the report

52. **Quantitative trait loci (QTL) mapping in eucalypts for salinity tolerance**

**Principal Investigator:** Dr. R. Yasodha

**Duration:** 2008 –2013

**Summary**

This study was carried out in Institute of Forest Genetics and Tree Breeding, Coimbatore in year 2008-2013. In this study Salt tolerant *E. camaldulensis* clones and hybrid individuals identified through hydroponic experiments. The project developed a mapping population for the inter-specific cross between *E. tereticornis and E. camaldulensis*. Genetic linkage map developed for the cross *E. camaldulensis x E. teretocornis* was developed and the total length of paternal and maternal map was 1422.28 cM and 1845.8 cM respectively. SSR markers were used to validate hybrid purity. Hybrid purity values for 25 SSR loci were > 85.0% which is acceptable in controlled hybridization through conventional methods. One significant QTL was detected in the chromosome 6 explaining 64% variation.in this project field trial were conducted to evaluate the performance of hybrids in comparison with open pollinated trees, self-pollinated trees and commercials clones and found few individuals perform better than commercials clones. Immortal mapping population was established in the field as vegetative multiplication garden.

**Scientific Findings**

- Mapping population for *E. tereticornis* and *E. camaldulencis* were developed
- QTL map for salinity tolerant trait were developed
- With SSR marker, genotypic of mapping population were completed

53. **Molecular assessment of breeding patterns in clonal seed orchards of teak in Andhra Pradesh**

**Principal Investigator:** Dr. S. Pattanaik

**Co Principal Investigator:** Dr. G.R.S. Reddy and Dr. A. Srivastava

**Duration:** 2011 – 2014

**Summary**

This study was carried out in Institute of Forest Biodiversity in year 2014-15. This study was taken up to study the gene flow in clonal seed orchard of *Tectona grandis* and to find out whether the Teak CSO was established to produced genetically superior seeds. For these purpose 4 polymorphic microsattelite markers was selected to carry out paternity test of 105 individuals. The noof alleles observed for the 5 micro satellite markers varied from 26 to 33. From the 5 seed bearers , located at different parts of the orchard, and their offspring's it is clear that the available pollinators effectively moving pollens to different parts of orchards.

**Scientific Findings**

- Molecular assessment not achieved.

54. **Molecular analysis for population differentiation and mating system studies in *Acacia auriculiformis* using dominant and codominant markers**

**Principal Investigator:** Dr. A. Shanthi, Scientist - C

**Co Principal Investigator:** Dr. Maheswar Hegde, Scientist – D and Dr. V.K.W. Bachpai, Scientist - C

**Duration:** 2010 –2014

**Summary**

The study was carried out in Forest Genetics and Tree Breeding institute, Coimbatore in year 2010-2014. In this study the genetic diversity of *Acacia auriculiformis* was estimated with the data generated from dominant marker eg. ISSR in the orchards population. The different ISSR marker primers were subjected to the *Acacia auriculiformis* orchard population and level of polymorphism were studied. The seed orchard diversity analysis expressed significant variation in the first and second generation orchard seeds. Five micro satellite markers studies revealed the high out crossing rate estimated in both generation orchards.

**Scientific Findings**

- Molecular data generated and high genetic diversity reported
- Seed area, length, breadth and perimeters were significantly high in second generation seed orchard than first generation
- High out crossing rate were reported for matting system

55. **Development of tree DNA fingerprint database**

**Principal Investigator:** Shri. R. Vivekanandan, Scientist - E

**Duration:** 2010 –2013

**Summary**

This study was carried out in Institute of Forest Genetics and Tree Breeding, Coimbatore in year 2010-2013.This study involved in collecting information related to molecular marker studies conducted at IFGTB. DNA marker systems like RAPD, ISSR, FISSR, AFLP, SSR and SNPs were used in different species viz. *Eucalyptus, Casuarinas Acacia* and *Teak.* This study will help in Conservation of Biodiversity,Tree improvement and Species Improvement as a better Genetic resources.

**Scientific Findings**

- Tree DNA fingerprint database developed

56. **Biotechnological approaches for improvement of plant species with special reference to pulp and paper**

**Principal Investigator:** Dr. Vimal Kothiyal

**Co Principal Investigator:** Dr. Sanjay Naithani and Dr. P.K. Pande, Scientist – D

**Duration:** 2004 –2008

**Summary**

165 samples of *Leucaena leucocephala* including wood, twins, branches, seeds and soil were collected from various regions of Uttarakhand and Rajasthan and deposited with NBRI, Lucknow. All wood samples were evaluated for chemical, physical and anatomical characterization. Lignin and extractive content variation between branch wood and main bole studied. FT-NIR protocols developed for specific gravity, lignin, holocellulose and extractives.

**Scientific Findings**

- 52 Elites short listed on the basis of higher fibre length and low lignin content
- FT-NIR protocols were developed for specific gravity lignin and holocellulose estimation

57. **Molecular analysis of high resin yielding genotypes of *Pinus roxburghii***

**Principal Investigator:** Dr. Santan Barthwal, Scientist - D

**Duration:** 2007 –2010

**Summary**

This project work was carried out at Genetics and Tree Propagation Division of Forest Research Institute, Dehradun. The main purpose of this study was to identify the high resin Yielding genotypes *Pinus roxburghii* of and their molecular analysis. It is difficult to identify high resin yielder at early stage of growth and development. Molecular marker technologies provide hope for an early identification of high resin yielding genotypes. Total of 72 genotypes of *P. roxburghii* from (Uttarakhand, Himachal Pradesh and Jammu) were characterized using RAPD and ISSR markers. The number of polymorphic loci was 120 (82.76%). The total gene diversity was 0.289 and Shannon's Information index was 0.432 for the analyzed genotypes. Within population gene diversity (Hs) and proportion of total genetic diversity between populations (Gst) was 0.273 and 0.053 respectively. Three RAPD loci (M-186-48, M- 186-49 and OPA-6-76) and one ISSR locus (ISSR – 7-108) have shown significant association with resin yield. Of which OPA-6-76 have shown high occurrence (80.64%) in high resin yielders (resin yield higher than 2.5kg/ annum using bore hole tapping method) and lower occurrence (38.09%) in low resin yielding (less than 1kg/ annum) genotypes of *P. roxburghii.* The results indicate possibility of using these loci for development of molecular markers for high resin production.

**Scientific Findings**

- ISSR and RAPD loci were identified associated with resin yield
- Individuals of P. roxburghii have shown high resin yield and genetic diversity
- Upto some extent, they were able to link the association between high resin yield loci and identified molecular markers

58. **Characterization of *Pinus roxburghii* for resin yield using association studies and spiral grain formation in wood using molecular markers**

**Principal Investigator:** Dr. Santan Barthwal, Scientist - E

**Co Principal Investigator:** Dr. H.S. Ginwal, Scientist – F, Dr. Kulwant Rai Sharma, Dr. Y.S. Parmar and Shri. B.P. Tamta, Scientist – D

**Duration:** 2011–2014

**Summary**

Project work was carried out at Genetics and Tree Propagation Division of Forest Research institute, Dehradun. Thirty four loci were identified to be associated with the resin trait and 51 loci were identified when population structure was taken into consideration while doing the association analysis of the molecular marker and resin yield data of selected genotypes. 16 loci have shown association with resin yield.

Genomic fingerprinting in 100 samples twisted and normal genotype of Chir pine was carried out using ISSR markers. The dendrogram were constructed and total genetic diversity reported which was found to be 0.269±0.017. The numbers of polymorphic loci were found to be 162 and the

observed percentage of polymorphism is 98.18. Cluster analysis has shown that the twisted populations are genetically closer to each other. The genotypes of normal population have grouped together and these groups separated from the groups of spiral grain formation.

**Scientific Findings**

- 16 loci associated with resin yield
- Genotypes of twisted population grouped together and separated from normal populations

59. **Development of methods for functional analysis of genes involved in salt tolerance in eucalyptus**

**Principal Investigator:** Dr. Mathish Nambiar- Veetil, Scientist - F

**Co Principal Investigator:** Dr. Modhumita Dasgupta, Scientist – F
Dr. V.K.W. Bachpai, Scientist - D
Dr. V. Sivakumar, Scientist - F
Dr. B. Nagarajan, Scientist - F

**Duration:** 2009 – 2016

**Summary**

Three different *Agrobacterium rhizozenes* strains (*A4, A4RS and R1000*) harbouring GFP based binary vector pHKN29 were used to evaluate their efficiency on hairy root induction in *Eukalyptus*. Highest transformation efficiency was reported in *A4RS.* Methods were developed for hardening of composite plants. Hoagland's media was found to be suitable for hardening of rooted plants both in laboratory and transgenic greenhouse environment. The *EtHKT1* partial genome sequence was submitted to NCBI gene bank. Unique RNAi target region of *EcHKT1* was identified, PCR amplified and sequenced. The RNAi target was cloned into the RNAi vector pHELLSGATE12. The constructs were introduced into *A. rhizozenes* and *A. tumefacience* respectively by electroporation. 108 Eucalypts composite plants with *EcHKT1* silencing construct were generated using *A. rhizozenes.* 30% of Eucalypts composite plants generated using the *EcHKT1* silencing construct were able to tolerate up to 400mM NaCl stress when compared to 0% survival in the pHKN29 controls. qRT-PCR was performed to find out gene expression of *EcHKT1* silencing construct. The study demonstrated for the first time the utility of composite transgenic strategy for screening genes conferring salt tolerance. Agrobacterium mediated transformation was found to be more responsive than biolistic method.

**Scientific Findings**

- New technique was developed for functional analysis of salt tolerance gene in root
- Three transformation construct as new product were developed for HKT1 gene silencing
- Genetic Transformation lab for gene function analysis established
- ICFRE's first transgenic green house facility at IFGTB established

60. **Study of Salt tolerance through gene expression pattern analysis**

**Principal Investigator:** Dr. Tarun Kant, Scientist - E

**Co Principal Investigator:** Dr. I.D. Aryan, Scientist – G and Dr. T.S. Rathore, Scientist - G

**Duration:** 2010–2015

**Summary**

This is the first ever report of use of *Lepidium sativum* as a halophytic close relative of *Arabidopsis thaliana* in understanding the expression pattern of key genes involved in salt tolerance mechanism using a comparative genomics approach. A low cost, efficient and a scalable hydroponic system was developed for the first time for growing *L. sativum*, which permitted easy salt manipulations, and convenient tissue collection for nucleic acid extraction. RNA extraction, purification, quantification and cDNA synthesis was successfully carried out for *L. sativum*. Gene specific primers were successfully designed for 4 genes namely *NHX-1*, *HKT-1*, *SOS-1* and *CLC-c* and successfully amplified intended amplicon which was further used to see similarity with the sequence of *A. thaliana* after sequencing. Genes *LsNHX-1*, *LsSOS-1* and *LsCLC-c* were shown constitutive gene expression under normal non saline condition. *LsHKT-1* genes do not undergo remarkable change. In the present study, a total of 9 putative genes with probable role in salt stress management have also been predicted.

**Scientific Findings**

- Easily reproducible low cost hydroponic system were developed
- Gene expression patterns of some salt tolerance genes under different treatment and time interval were reported


**Indian Council of Forestry Research and Education**
(An autonomous body of Ministry of Environment, Forest and Climate Change, Government of India)
P.O. New Forest, Dehradun, Uttarakhand, India