

Vol. III

Forestry Research

Essence for Outreach
(1986-2018)



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

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सत्यमेव जयते

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 116 PCRs classified in 6 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

पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार की एक स्वायत्त परिषद्
An Autonomous Body of Ministry of Environment, Forest & Climate Change, Government of India

दूरभाष / Phone : 135-2759382 (O)
EPABX : 0135-2224855, 2224333 (O)

ई-मेल / e-mail : dg@icfre.org
फैक्स / Fax : 0091-135-2755353

श्रीमती कंचन देवी, भा.व.से.
उप महानिदेशक (विस्तार)
विस्तार निदेशालय

Mrs. Kanchan Devi, IFS
Deputy Director General (Extension)
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 : 0135-2224830 (का.) (O)
फैक्स नं./Fax.No. 0135-2750693
ई.मेल/E-mail. ddg_extn@icfre.org

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 116 research projects presented under 6 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



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P.O. New Forest, Dehradun - 248 006 (Uttarakhand)

दूरभाष : 0135-2224830 (का.) (O)

फैक्स नं./Fax.No. 0135-2750693

ई.मेल/E-mail. ddg_extn@icfre.org

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 116 projects covering 6 themes i.e. Biofuel & Bioenergy, Chemistry, Ecology, Soil & Land Reclamation, Extension, Non-Wood and Protection. 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



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

भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद्
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P.O. New Forest, Dehradun - 248 006 (Uttarakhand)

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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.

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. Vineet Kumar, Scientist-G, FRI, Dehradun, Dr. V.K. Varshney, Scientist-G, FRI, Dehradun, Dr. A.K. Pandey, Scientist-G, FRI, Dehradun, Dr. Mohd. Yusuf, Scientist-G, FRI, Dehradun, Dr. Ranjeet Singh, Scientist-G, FRI, Dehradun, , Dr. Sudhir Singh, Scientist-G, FRI, Dehradun, Dr. Arun Pratap Singh, Scientist-F, FRI, Dehradun, Dr. Charan Singh, Scientist-E, FRI, Dehradun, Dr. Arvind Kumar, Scientist-E, FRI, Dehradun, Dr. R.S. Bhandari, Scientist (Retd.), FRI, Dehradun, Dr. H.B. Vashistha, Scientist (Retd.), FRI, Dehradun, Dr. A.K. Sharma, 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

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Biofuel and Bioenergy





1. Study the effect of microwave assisted heating and seed storage conditions on quality of *Pongomaia pinnata* seed oil for cost effective production of biodiesel

Duration: 2014

Principal Investigator: Dr. Ritesh Kumar

Critical analysis of the research theme & summary of the study

The study was conducted to carry out microwave assisted heating and seed storage conditions on quality of *Pongomaia pinnata* seed oil for cost effective production of biodiesel. On microwave heating there was an increase in the acid value of oil in microwave pretreated seeds as compared to untreated seeds. Therefore, pretreatment may be used for rapid oil extraction; however, it can't be used for long term seed storage. Study on effect of seed storage temperature on acid value was also investigated. Seeds stored at 5°C and 15°C retained their quality and germination percentage for longer time. The effect of microwave irradiation on production of biodiesel from high acid value *P. pinnata* seed oil was investigated. A two step process viz. acid esterification followed by alkali catalysed transesterification was adopted for production of biodiesel. The acid value from its initial values of 12 and 22 mg KOH/g to 4.0 mg KOH/g, respectively by utilizing 3 min microwave irradiation time using 1.5% H₂SO₄ concentration and 1:6 oil methanol molar ratio. Microwave assisted alkali catalyzed transesterification of pretreated *P. pinnata* seeds oil resulted in biodiesel yield of 99.3% with 98.8% purity. Reaction was completed in considerable less time under microwave heating. Fuel properties of biodiesel were found to be in line with ASTM and Indian biodiesel standards. Electric energy consumed during transesterification reaction was found to be 29.9 kJ. The energy saving during microwave heating is mainly due to rapid heating and reduced reaction time.

Critical analysis of the research theme & summary of the study

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Scientific findings & contents

The effect of microwave assisted heating and seed storage conditions on quality of *Pongomaia pinnata* seed oil for cost effective production of biodiesel was studied. Under microwave heating,





the acid formation is more. Microwave assisted alkali catalyzed transesterification of pretreated *P. pinnata* seeds oil resulted in biodiesel yield of 99.3% with 98.8% purity. The results indicate that the process may be helpful towards transesterification due to reduced time using microwaves. Findings of the study may be disseminated in the form of research papers. Developed methods may be useful for upscaling on pilot scale; however, exorbitant cost of microwave may limit the same due to economic reasons.

2. Production of Synthetic Biodiesel from Wood

Duration: 2014

Principal Investigator: Dr. Ezhumalai

Critical analysis of the research theme & summary of the study

The study was conducted to prepare synthetic biodiesel from wood. During the studies gasification was done by using various chemicals with variable quantities. Considerable changes could not be observed when Olevin sand was used as gasifier. Interestingly, maximum amount of CO was produced when 500 g of CaCO₃ introduced at the reduction zone (41.1%). Further, it was observed that CaCO₃ is the suitable reagent that can be used in the gasification. It was observed that by introducing 500 g of CaCO₃ in the reduction zone of gasifier, maximum amount of CO (41.1%), H₂ (21%) and reduction in CO₂ (reduced to 21.5%) with highest CO/CO₂ (76.5%) and almost maximum amount of heating value (27.4%) was produced. The experimental studies carried out by employing producer gas to liquid or biodiesel using iron-nickel catalyst of different quantities did not lead to appreciable yield probably due to more concentration of CO₂.

Scientific findings & contents

A study has been carried out to produce biodiesel from wood. The gasification was performed by using various chemicals in different quantities. Using Olevin sand as gasifier, significant changes were not observed. However, maximum amount of CO was obtained using 500 g of CaCO₃ at the reduction zone (41.1%). It was concluded that CaCO₃ is the suitable chemical that can be used in the gasification at maximum amount of CO (41.1%). H₂(21%) and reduction in CO₂(reduced to 21.5%) with highest CO/CO₂ (76.5%) and almost maximum amount of heating value (27.4%) was obtained. However, the experimental studies carried out using producer gas to liquid or biodiesel using iron-nickel catalyst of different quantities did not lead to appreciable yield probably due to more concentration of CO₂.

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

The PI may carry out experiments using synthetic gas having carbon monoxide and hydrogen in 1:2 ratio for production of synthetic biodiesel as per discussion with experts reported in PCR. Further, findings of the study may be disseminated in the form of research papers. Developed methods may be useful for upscaling on pilot scale, however, excessive cost of reactants required to produce biodiesel may limit the same due to economic reasons.



Chemistry





1. Selection and improvement of natural dye yielding plants

Principal Investigator: H.C Sindhuveerendra

Duration: 2013

Critical analysis of the research theme & summary of the study

Natural dyes are colorants derived from plants parts like roots, berries, bark, leaves and wood. Common dye stuffs are yellow dye and green pigments which are obtained from *Mallotus philippensis* and *Wrightia tinctoria*, respectively. *M. philippensis* is a shrub species and distributed throughout India. Tree improvement was initiated to obtain uniform quality dye powder, and to assess variation in the populations of Jharkhand and West Bengal and to select superior dye yielding trees. The species is unisexual and female plants bear dye yielding fruits. Hence superior trees with large crown, profuse fruiting, consistent colour of fruits, amount of dye powder yield/fruit were considered while selecting candidate plus trees. Analysis of biometric traits such as fruit width, fruit length and fruit weight was also carried out to assess potential variation pattern in the provenances. All the fruit traits exhibited good amount of variation suggesting potential for further selection. The germplasm of selected trees were collected through shoot cuttings and seeds. 19 CPTs of *M. philippensis* with large crown and high dye yields were selected. The selected population exhibited good variation and consistent quality of dye powder. The fruit also exhibited good variation in all fruit traits. Similarly, in *W. tinctoria*, 7 CPTs were selected based on good foliage after similar survey in Jharkhand and West Bengal. Leaves are used to extract green pigments. *W. tinctoria* populations are confined entirely to forest areas hence variations are of continuous type. Germplasm of all CPTs was collected. Laboratory protocols and improved dyeing techniques were developed to enhance color intensity and consistent dyeing. It appeared that making paste was easy method to prepare dye solution. There is further scope for research in the area of breeding systems of both the species and application of these dyes into food stuffs. Further improvement of these two plants is required to obtain dye pigments with consistent quality.

Scientific findings & contents

Both *M. philippensis* and *W. tinctoria* possess fairly good amount of natural variability in the present populations as well as in selected genotypes. 19 CPTs of *M. philippensis* were selected based on good crown size, higher fruiting capacity, high dye yield and good color intensity of dye powder. The dye yielding fruits in *M. philippensis* highly varied with dye content. The biometric characters such as fruit length, fruit breadth and fruit weight was also varied suggesting potential for improvement through selection. Sexes are separate and male plants occur rarely, thus creating physical barriers like large distance, requirement of high energy, long distance travelling pollinators for pollination. However, in spite of this, female plants were profuse seed bearer and exhibited good amount of variation, indicating existence of alternate breeding mechanisms. Similarly in *W. tinctoria*, most of the populations were confined to forests and that species did not acclimatized to agricultural or wastelands. A total of 7 CPTs of *W. tinctoria* were selected based on higher clear bole and good foliage. Leaves were source of green dye and some genotypes possess anthocyanin pigments in the leaves indicating premature nature of genotypes and non-domestication. Developed laboratory protocols and improved dyeing techniques led to enhance color intensity and consistent dyeing. Making paste was easy method to prepare dye solution. Germplasm was collected from all the CPTs in the form of shoot cuttings and seeds and seedlings were raised in the nursery and planted in open field.



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

Progeny trials are integral part of tree improvement. They are required to be tested for the fidelity of the parents for the heritability of the desired traits. This project resulted in improvement of seeds for increased dye content with consistent dye quality. These traits are to be tested further for their heritability through progeny trials.

2. Studies on variations with respect to in vitro azadirachtin production in selected high yielding populations of *Azadirachta indica* A. Juss

Principal Investigator: Fatima Shirin

Duration: 2014

Critical analysis of the research theme & summary of the study

Azadirachta indica has been declared the “Tree of the 21st Century” by the United Nations. With the isolation and characterization of azadirachtin, the neem tree has received global attention. The anti-feedant and repellent properties of azadirachtin has been established and it has become an important bio-pesticide for integrated pest management. The project was undertaken to study the extent of variability in azadirachtin content in 10 different selected populations of *A. indica*. and in their *in vitro* cultures, and to select population(s) of neem yielding high azadirachtin in *in vitro* conditions. The *in vitro* approach was adopted because under controlled and uniform culture conditions, the variation in azadirachtin production could be attributed to genetic factors. During the project period the variation in azadirachtin content (%) in the seeds, *in vitro* shoot cultures and callus cultures of the trees collected from 10 different populations, viz., Chhatarpur, Katni, Khandwa, Bargi (Jabalpur), Shahdol, Chhindwara, Gwalior, Raigarh and Bilaspur was determined. Wide genetic variability was found in the studied neem populations with respect to amount of azadirachtin in their seeds and in *in vitro* cultures.

Scientific findings & contents

The variation among the populations was more than within the population in seeds and in *in vitro* shoots. Maximum azadirachtin was produced in the seeds of Gwalior which was at par with Chhatarpur, Katni, Sihore, Shahdol and Chhindwara. Maximum azadirachtin in cultured shoots was produced in the Gwalior population which was statistically at par with that of Sihore. In callus cultures, significant variation was observed among the populations and azadirachtin was maximum in Gwalior population which was statistically at par with that of Sihore. Significant positive correlation was obtained between azadirachtin content of seeds, cultured shoots and callus cultures.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

The outcome of the study can be utilized towards following:

- (i) Selection and improvement of neem trees
- (ii) Mass multiplication of the Gwalior and Sihore populations through clonal propagation and raising of field plantations.
- (iii) Optimization of culture conditions for increased azadirachtin production and selecting high azadirachtin yielding cell line(s).



3. Prospecting fungal resources for development of natural dye

Principal Investigator: Dr. Rakesh Kumar

Duration: 2018

Critical analysis of the research theme & summary of the study

The project was initiated with the objective to develop natural dyes of varied range of shades from targeted fungal species which can produce bright hues of people's choice with good colour-fastness properties on different textile materials like silk, wool and cotton. It is worth mentioning here that so far the production of natural dyes has been limited to the development of natural colour from phytoresources. However, with expanding consumer's choice, diverse application of natural dyes, consequent demand coupled with dwindling forest resources the attempt was made for development of bright and attractive shades from alternatives bio resource was realized through this project. In recent years colours of natural origin have gained world-wide attention on account of their non-toxic, non-pollutant and less hazardous nature as compared to their synthetic counterparts. However, limitation of colours shades and diminishing resources of major source plants are considered to be major constraints. In order to practicably tackle the raw material constraints and to explore feasible alternative source of natural dyes, an innovative approach was attempted to develop attractive shades out of fungal resources suitable for textile dyeing. With this aspire, development of natural dyes was carried out from fungal resources (*Fusarium spp.*, *Penicilium spp.*, *Pycnoporoussanguineous* and *Xylariapolymorpha* under different conditions to produce dyes capable of imparting intense shades with better fastness properties and consuming less amount of dyestuff at the same time. The outcome of the research project led to the development of range of bright and fast shades of natural dyes for textile applications. Fungal resources were shown to have a significant potential for eco friendly dyestuffs that would provide useful and viable alternative to toxic synthetic dyes.

Scientific findings & contents

Extraction of natural dyes was carried out from fungus (*Fusarium spp.*, *Xylariapolymorpha*, *Pycnoporoussanguineous* and *Penicilium spp.*). Protocols for the artificial cultivations of the fungal species were developed in laboratory. Culture of *Pycnoporoussanguineous*, *Xylariapolymorpha*, *Fusarium spp.* and *Penicilium spp.* were prepared in laboratory under different conditions to produce natural dyes capable of imparting intense shades with better fastness properties, consuming less amount of dyestuff at the same time. Dyes were extracted under varying pH conditions and then extracted dyes were applied on various fabrics such as silk, wool and cotton. Apart from cultivation in laboratory the sporophores of *P.sanguineous* and *X. polymorpha* were collected from Dehradun campus and dyes were extracted under pH conditions to obtain high concentration solution of dye. The extracted dyes were applied on silk, wool and cotton fabrics and then dyed fabrics were mordanted using post mordanting method. The intensity of shades or depth of the chroma and the hue in silk and wool fabrics was found more thus appeared darker in shades in comparison to cotton. The shades produced on silk and wool fabrics were darker because the bonding of dye molecules with silk and wool fabrics (protein fibre) is stronger than cotton fabrics (cellulosic fibre). Also on mordanting of dyed silk, wool and cotton fabrics with different metallic salts the bonding of ions and molecules of dye and fabrics to metal ions were stronger in silk and wool fabrics than cotton fabrics. It involved the formation of two or more separate coordinate bonds between a polydentate (multiple bonded) ligand and a single central atom. Therefore, the fastness of dyed silk and wool fabrics were





also better than cotton fabrics. Testing on dyed and mordanted samples in respect of light fastness (method: IS-2454: 1985) and washing fastness (Method: IS-687:1979), rubbing fastness (Method: IS-766 : 1988), and perspiration fastness (Method: IS-971:1983) were carried out. All the silk and wool samples of fabrics exhibited very good to excellent colour fastness properties in case of cotton the fastness were relatively less but to the acceptable limits. In order to quantify the shade produced on the dyed and mordanted sample of silk, wool and cotton fabrics, they were subjected to determination of L*(Lightness and darkness), a* (redness and greenness), b* (yellowness and blueness), Chroma and K/S values by reference bench top spectrophotometer. The outcome of the project work amply demonstrated the fungal biomaterial as potential source of natural dye. Production of natural dye from fungi has added advantage not only in terms of their ease and feasibility in large-scale production at required magnitude and scale through laboratory culture under controlled environment but also the fungi-derived dyestuff qualify all standard of commercial natural dyes thus can fulfill the expectation of consumers and industries.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

- Patenting of the intellectual property generated.
- Publication of research papers and presentation of research results at various forum
- Awareness generation among local people about the benefits of using natural dyes through awareness campaigns.
- Extension of findings among dyers/NGOs engaged in natural dyes/local entrepreneurs to acquaint them about the investigated fungal species as economically viable source of natural dyes.
- Training programmes for VLCs, NGOs and entrepreneurs on extraction and preparation of dye products of various shades from the fungal species.
- Compilation and publication of brochures, pamphlets etc. for popularization of fungi as promising source of natural dyes and extension of related technical know-how.
- A follow up project directed towards upscaling of the processes for cultivation of the fungi and production of dyes thereof may be undertaken.



4. Phytochemical screening of Selected wild edible plants for exploration of new sources of luteolin

Principal Investigator: Dr. Y.C. Tripathi

Duration: 2017

Critical analysis of the research theme & summary of the study

Luteolin out of a wild edible flora of northwestern Himalayan region and to evaluate health-promoting antioxidant activity of selected wild edible plants. In recent years, there has been rising interest in the use of plant products as nutraceuticals in healthcare. In this context, wild food plants hold immense promise as high-value nutraceuticals and source of bioactive compounds for dietary supplements or functional foods. Luteolin, a flavonoid constituent of plants having widespread biological activities holds imperious role in prevention of several chronic diseases and health care. The Himalaya region, one amongst the biodiversity rich area, supports over 675 species of wild edible plants. The diversity of wild edible plants in the region has traditionally been known to play significant role in meeting nutritional, minerals and healthcare needs of indigenous communities. Among others, several wild fruits are traditionally acclaimed for their nutritional and antioxidant potential of the wild edibles in the region are meager. In this context, wild edible fruits need to be revitalized and brought back into the mainstream diet so that they can play their role in nutrition and nutraceuticals development. The objective of the project was to explore natural sources of bioactive compounds. Selected wild edible plants named *Callicarpamacrophylla*, *Prunusarmeniaca*, *Hippophaerhamnoides*, *Pueraria tuberosa* and *Myricaesculenta* were screened for their luteolin content and nutritional bioactive constituents, and to evaluate health-promoting and diseases-preventing antioxidant activity through *in vitro assays*, as well as to access the relationship between chemical composition and antioxidant activity. Research conducted under the project evolved species specific chromatography protocol for isolation of bioactive compounds luteolin from the selected wild edible plants. The work also resulted in standardization of physicochemical and Phytochemical parameters useful for authentication and quality control. Evaluation of the total phenolic content and antioxidant activity of the plants studied may be useful in promoting these species for their use in production of health drink, functional foods, nutraceuticals etc. The outcome of the project may be beneficial for rural communities, farmers, SFDs, NGOS and entrepreneurs.

Scientific findings & contents

The study led to the development of species-wise column chromatography method for isolation of luteolin from *Callicarpamacrophylla* leaves, *Prunusarmeniaca* fruits, *Hippophaerhamnolides* berries, *Pueraria tuberosa* rhizomes and *Myricaesculenta* fruits. The characterization of luteolin isolated was done by classical chemical methods as well as by spectroscopic analysis. The quantity of luteolin in the edible parts of the five species varied in the range of 66.2-20.9 mg/100 g of dried plant material. Highest luteolin content was recorded in fruits of *M.esculenta*(66.2 mg/100g) followed by *H.rhamnoides* berries (58.5 mg/100g) and *P.armeniaca* fruits (52.7 mg/100g). *C. macrophylla* leaves showed the lowest luteolin content. In the conclusion all the five species investigated contain good amount of luteolin, thus can be taken as potential natural source of the compound. Physicochemical and nutritional values of the edible parts of the target plant species and their diverse bioactive chemical composition through qualitative phytochemical screening was also determined. The physicochemical values like moisture content, ash value, extractive value, and phytochemical screening of the plants were established to substantiate the standardization data on





the plants. The various parameters determined will provide useful information for their botanical identification and may help in their quality control. Evaluation of the total phenolic content of the edible parts *C. macrophylla* leaves, *P. armeniaca* fruits, *H. rhamnoides* berries, *P. tuberosa* rhizomes and *M. esculenta* fruits suggested the presence of significant amounts of phenolic compounds in all the species. However, different extracts of the species found to contain varying amount of TPC. The antioxidant activities of different extracts of *C. macrophylla* leaves, *P. armeniaca* fruits, *H. rhamnoides* berries, *P. tuberosa* rhizomes and *M. esculenta* fruits examined by DPPH radical scavenging method showed that all the extracts of the five target wild edible plants at the used concentrations exhibited promising DPPH radical scavenging activity. The activity however found to vary according to the total phenolic content and a direct correlation between total phenolic content and radical scavenging efficacy was recorded.

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

Findings emanated from the project may be disseminated through paper publications and presentations in various scientific meetings; extended to farmers, NGOs, local entrepreneurs and other stake holders for awareness generation about the nutritional and biological significance of the locally available wild edible plant species through various extension programmes. Extension material such as brochures, pamphlets etc. on nutritional and health protective properties of wild edible plants investigated may be prepared for distribution in the extension programmes.

5. Chemical derivatization of α - cellulose Into value added products

Principal Investigator:

Duration:

Critical analysis of the research theme & summary of the study

Chemical modifications play a dominant role in improving the overall utilization of cellulose polymers. The derivatization of cellulose provides abundant scope for scientific curiosity as well as possibilities for industrial applications. The project entitled “Chemical derivatization of α - cellulose into value added products” was aimed to explore the new routes for chemical modification of α -cellulose Into value added Products with respect to better degree of substitution and homogeneous modification. New routes for synthesis of carboxymethylcellulose (CMC) and hydroxypropylcellulose (HPC), widely used biopolymers for various applications, were developed. CMC was further used for synthesis of hydrogels. Cellulose was first converted into cellulose triacetate (CTA), which was then transformed to CMC and HPC by in-situ de-protection followed by different etherification reactions. Reaction parameters were optimized to obtain a maximum degree of substitution (DS) and molecular substitution (MS) for synthesis of CMC and HPC, respectively. The reaction products (CTA, HPC, CMC and hydrogel) were characterized by FTIR and NMR spectroscopy.

Scientific findings & contents

Cellulose was converted into CTA, which was then converted to CMC by in-situ deprotection followed by etherification using NaOH and sodium chloroacetate in tetrahydrofuran-water (THF-H₂O) solvent system. The synthesized CMC was further transformed into a hydrogel using cross linking agent pyromellitic dianhydride. HPC was synthesized via CTA using propylene oxide in water at 50°C. Optimization of process by varying the reaction conditions and examining their



influence on DS / MS led to synthesize the CMC and HPC with industrially usable DS/ MS. FT-IR and NMR analysis of the optimized product confirmed the derivatization.

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

Findings of the study should be disseminated to the industry. Optimized processes could be patented. Evaluation of the functional properties of the derivatives could be taken up with the industry. Developed methods could further be scaled up under industrial collaboration.

6. Comparative studies on optimum treatment time and durability test of commercially important bamboo species in selected sites of north-eastern region

Principal Investigator: Dhruba Gurung, Scientist-B

Duration: 2015

Critical analysis of the research theme & summary of the study

The post harvest utilization of bamboos for diverse purposes is vitiated by various bio-degrading agents resulting into its short durability, thus incurring losses to local communities. To overcome this problem, traditional as well as scientific methods have been tried. Boucherie Apparatus (Jagriti) developed by RFRI, Jorhat) was found to be useful in preservation of green bamboos and being inexpensive could be used by the rural people. Study conducted was directed towards the optimization of process for preservation of *Bambusapallida* (Assamese: Bijuli bah) and *Dendrocalamushamiltonii* (Assamese: Kako bah) at Jorhat, Assam and Aizwal, Mizoram, respectively, using Jagriti by varying the concentration of preservative chemicals (Copper, Chrome: Boron) and pneumatic pressure. The treated bamboo samples were tested as per the standard procedure. Quantity of chemical preservative loaded on bamboo samples was chemically analyzed and percentage of chemical loaded was worked out. Results indicated that a fresh bamboo can be treated completely in about 15 minutes to 1 hour. Comparison of chemically treated and untreated control bamboos demonstrated the efficacy of preservative treatment.

Scientific findings & contents

Maximum incidence and intensity of *Schizophyllum commune* was recorded in the present study as far as the destruction of bamboo is concerned. Bamboos with the average age of 4 years could effectively be treated within 15-50 minutes. The water used in preparation of preservative solutions should be free of any particulate matter and hence should be filtered so that the particulate matters do not cause blockage during the treatment process. Harvested bamboos should be treated on the same day for optimum loading of chemical preservative (CCB). Delay in treatment process would result in inordinate delay due to physiological changes in bamboo. Loading of low concentration (8-12%) of preservative chemical (CCB) in water in the amount less than a gram/100 gram of bamboo sample was effective in enhancing the durability of bamboo samples in comparison to untreated bamboos when used in contact with ground.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

Standardized practice of preservation should be disseminated to the bamboo growers and users and training programmes should be organized for their capacity building. Preservation method should also be extended to other bamboo species and customized.





7. Screening and evaluation of selected members of Rutaceae from Southern India for anti-malarial activity

Principal Investigator: B.S. Chandrashehar.

Duration: 2017

Critical analysis of the research theme & summary of the study

Vector control is an important element of strategies to control major vector-borne diseases, in which chemical control remains the most widely, used approach. But many vector species have developed resistance to synthetic chemicals making their control extremely difficult and expensive. Also their extensive use have raised concern over the adverse effects on environment and human health. This necessitated to develop safe, effective, and low cost method for vector control. The study was designed to explore the larvicidal potential of *Rutagraveolens*, *Zanthoxylumrhesta* and *Toddaliaasiatica* extracts and also examine the oviposition deterrent effect of *R.graveolens* and *Zanthoxylumrhesta* against the targeted mosquito species. Potentiality of *Rutagraveolens* and *Zanthoxylum. rhesta* extracts as a larvicidal and oviposition deterrent agent towards two medically important vectors *Aedesaegypti* and *A. stephensi* was shown. Disrupting the oviposition sensory detection of mosquitoes by introducing deterrent of plant origin, which are cheap resources, might add value to integrated vector control.

Mosquitocidal potential of *toddaliaasiatica* against mosquito species of public health importance was also demonstrated.

Scientific findings & contents

Highest larvicidal activity was observed in petroleum ether extract of *Z. rhesta* stem bark, followed by chloroform, ethyl acetate and methanol extracts of seed coat. Out of several extracts of *T. asiatica* examined for larvicidal activity, the root and stem extracts showed moderate bioactivity. The root-chloroform extract was most effective on *A.aegypti*. Impact of larvicidal activity with selected extracts of *R. graveolens* and *Z. rhesta* on total protein content of mosquito larvae was found. The extracts displayed significant reduction in total protein content of the larval batches of *A. aegypti* and *A. Stephensi* compared to untreated control. Oviposition deterrent activity of the studied plant species against *A.aegypti* and *A..stephensi* adults was also observed. Preliminary phytochemical analysis of *Z.rhetsa* extracts study revealed the presence of different secondary metabolites.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

Follow up studies towards isolation and identification of bioactive constituents responsible for anti-larval property and their efficacy, mode of action and toxicity should be carried out for active implementation in vector control programs.



8. **Process refinement for extraction of quality fibre and optimal isolation of bioactive constituents from *Agave sisalana***

Principal Investigator: Dr. Y.C. Tripathi, Scientist-F

Duration: 2017

Critical analysis of the research theme & summary of the study

The objective of the project was to explore an ecofriendly method for optimal extraction of good quality fibre and to find out an improved and efficient procedure for isolation and quantification of pharmacologically important sapogenin from *A. sisalana* (sisal). Recently, there has been a growing interest in the use of plant fibers as reinforcing components owing to adverse environmental impact of synthetic fibres. *Agave sisalana* is one of the major fibre yielding plants with potential for diverse industrial applications. Conventional mechanical process of sisal fibre extraction leads to low yield and poor quality due to deformation on the fibre surface. Also, fibre extraction by chemical retting of sisal leaves is time consuming, water intensive, unhygienic and eco-unfriendly. Further, *A. sisalana* is an important source of steroidal sapogenins including hecogenin and tigogenin having commercial significance as sources of medically useful steroids. Separation of hecogenin-tigogenin mixtures remained a challenge due to exceedingly close relationship of these two compounds. Due to the reason, there has been lack of effective and feasible technique for separation and quantification of individual steroidal compounds. Research work under the project has evolved an ecofriendly and efficient method for extraction of fibre from *A. sisalana* through biological pretreatment of leaves. Fibre derived through biological pretreatment found to have better anatomical and microstructural traits thus excellent strength properties. The work also resulted in process development for isolation of bioactive steroidal constituents and a facile HPTLC method for quantitative estimation of hecogenin in *A. sisalana* leaf juice which is specific and accurate and can be used for quantification of hecogenin in the plant and other *Agave* species as well. The outcome of the project may be beneficial for farmers, SFDs, NGOs and entrepreneurs concerned with production and marketing of fibres and bioactive compounds

Scientific findings & contents

It was found that biological pre-treatment of sisal leaves facilitated smooth and efficient extraction of good quality fibre with better anatomical and microstructural traits thus revealing the excellent strength properties of fibre. Also developed a process for isolation of biologically active steroidal sapogenin from *A. sisalana* leaf juice, and a simple, rapid, accurate and specific HPTLC method for quantitative estimation of hecogenin in the *Agave sisalana* leaf. The method was found to be specific and accurate and could be used for quantification of hecogenin in *A. sisalana* and other *Agave* species as well. It was also be used in fingerprinting, high throughout analysis and routine quality control of herbal materials as well as formulations containing this compound.

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

Outcome of the research is useful and field usable. Training programmes for farmers, NGOs, local entrepreneurs and others engaged in sisal fibre extraction to acquaint them about the ecofriendly and cost-effective process of fibre extraction should be organized. Brochures, and pamphlets for popularization of the eco-friendly fibre extraction method and extension of related technical know-how should also be prepared and published.





9. Production and value addition by chemical derivatization of alpha cellulose of *Lantana camara* for its useful application

Principal Investigator: Dr. P.K. Gupta, Scientist-E

Duration: 2009

Critical analysis of the research theme & summary of the study

Chemical functionalization of cellulose aims to adjust the properties of macromolecule for different purposes, particularly, as a chemical feedstock for production of cellulose derivatives for a variety of applications. The conventional sources of cellulose include cotton linters and wood pulp which now-a-days are discouraged on account of the cost of the former and environment conservative regulations associated with the latter. Further, renewable raw materials are gaining considerable importance because of the limited existing quantities of fossil supplies. In this regard, cellulose-rich biomass derived from the nonconventional sources such as weeds, fibers, bamboos, and wastes from agriculture and forests, etc. acquires enormous significance, as alternative chemical feedstock, since it consists of cellulose, hemicellulose, and lignin, which contain many functional groups suitable to chemical functionalization. Etherification of cellulose through methylation, carboxymethylation, cyanoethylation, hydroxypropylation, single or mixed, is one of the most important routes of cellulose functionalization. Chemical composition and rheological characteristics make possible the selection of the modified cellulose to serve special applications. *Lantana camara* (LC), a noxious weed is a serious threat to the ecology. Mechanical, chemical and biological methods have been applied for its management but due to in built limitations could not be implemented in the field. Its luxuriant growth, vigorous survival and chemical composition make this weed a source of potential economic value for utilization of its abundantly available biomass into value added products offering thereby an efficient and effective method for its management. The study was, therefore, aimed at the possible utilization of cellulose rich biomass derived from LC through chemical derivatization. The alpha cellulose from LC was prepared by using conditions already optimized under PI's earlier project and was subsequently derivatized into cyanoethylcellulose,???? Reaction conditions were standardized for maximum degree of substitution for all the derivatives prepared. The derivatives were characterized by IR, SEM, TGA/DTA and WAXD studies. The study demonstrated a chemical approach for management of the noxious weed LC through its utilization into products, such as cellulose derivatives, of varied industrial uses.

Scientific findings & contents

Processing of the lignocellulosic biomass of LC using an already optimized procedure in the PIs laboratory yielded alpha cellulose. The percent yield, Av. DP, and the percentage of α -cellulose content of the obtained cellulose were found to be 38.76%, 430, 94.8, respectively. Conditions for carrying out etherification of the alpha cellulose were standardized and??? of derivatives (DS,????) - ---- were prepared. Comparative evaluation of the IR spectra and SEM studies of the alpha cellulose with that of the derivatives confirmed the derivatization. TGA/DTA and WAXD studies indicated their?????. The finding suggested that the lignocellulosic biomass from LC can also be utilized at par with woody biomass for production of alpha cellulose and cellulose derivatives. Thus, a new feedstock alternative to woody biomass for cellulose industry was found.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

The bench scale processes for isolation of alpha cellulose and its derivatives could be scaled up in collaboration with the chemical industry.



10. Studies on co-polymerization kinetics using filler supported catalyst system.

Principal Investigator: Ajay Karmakar

Duration: 2012

Critical analysis of the research theme & summary of the study

Conventional method of melt blending for preparing bio-fibre filled composites have limitations during compounding of these products such as large power requirements for mixing machinery, degradation of the polymer to filler, even when 'coupling agents' are employed. This necessitates a process wherein the polymerization and composite formation takes place simultaneously. The project was, therefore, aimed at synthesis of propylene/ethylene copolymer over cellulose supported catalyst and study the polymerization kinetics. The process involved immobilizing the cocatalyst into the cellulosic filler surface followed by addition of metallocene catalyst and then polymerization and composite formation took place simultaneously. All the polymerization reactions were carried out in a high-pressure stirred autoclave. Effect of temperature, ethylene pressure, and cocatalyst to catalyst ratio (Al/TM ratios) were also examined. Studies on kinetics of polymerization showed that, higher Al/Zr ratio and higher temperature led to higher polymerization rates but lowered the molecular weight. A model incorporating effect of reaction parameters on polymerization rates was also developed. It was successfully demonstrated that cellulose filled HDPE and HDPE-co-PP composites can be prepared using this technique

Scientific findings & contents

A new technique to prepare composites was developed. Cellulose filled HDPE and PP-co-PE composites could be prepared by using this one step synthesis technique.

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

Outcome of the research is novel and can be patented. Up scaling of the method developed could be taken up in collaboration with a wood based industry in a follow up project.





11. Studies on the seasonal variation in active chemical constituents of hadjor, *cissusquadrangularis* Linn.

Principal Investigator: Dr. Vishakha Kumbhare

Duration: 2011

Critical analysis of the research theme & summary of the study

Cissusquadrangularis (CQ) Linn. (Hadjor), known as asthisamharaka in Sanskrit is used in folklore medicine for healing bone fractures. The plant has also several pharmacological properties including analgesic, anti-inflammatory, anti-hemorrhoid activity, anti-bacterial, and anti-ulcer activity etc. The studies proposed in the project were directed towards (i) extraction and quantitative estimation of active chemical constituents of CQ, (ii) assessment of the best period for harvesting its active constituents, and (iii) dissemination of the results to the user target groups. The experiments were laid out according to factorial RBD and random sampling was done. Analysis of variance appropriate for the design was carried out. Standard methods were followed for estimation of active constituents. Surveys were conducted for availability of the species and its use by the tribal and herbal healers. Samples were also collected from available sources. The active chemical constituents including total phytosterols, ascorbic acid, macro-elements (calcium, magnesium, sodium and potassium), and micro-elements (selenium, and iron) were extracted and estimated and their monthly variation was studied to assess best harvesting period which found to be December to March. Radio frequency drying followed by the shade drying found to be suitable for the herb. However, for drying of the herb at large scale, shade drying was recommended. Studies for value addition of CQ stem conducted in collaboration with the Department of Food Technology, Laxminarayan Institute of Technology, and Rashtrasant Tukdoji Maharaj, Nagpur University, Nagpur led to develop processes for making six food products which conformed the FSSAI requirements. Four training programmes were conducted wherein demonstration of processes for value addition of CQ stems was given to the women officials of the SFD, women self help group and farmers. Two brochures were published in Hindi and English languages for extension activities. Six research papers emanated from the project work were presented in various scientific meetings.

Scientific findings & contents

Monthly variation in the content of the total phytosterols, ascorbic acid, macro-elements and micro-elements in the plant samples collected from different sources was found. The samples collected from Chhindwara was found to be the best in total phytosterols content followed by Akola. The samples obtained from Piparia was best followed by Raigarh in terms of the ascorbic acid content. The best harvesting time of the plant was found to be December to March. CQ stems (peel and core) were analyzed separately for their moisture, yield, and contents of the ash, phytosterols, ascorbic acid and phenols. These contents in the peel were higher than those of the pulp. Dehydration studies of stem were carried out. Radio frequency drying method was found to be the best followed by shade drying in retaining maximum amount of the active constituents. Shade drying was recommended for large scale drying of the herb from economic point of view. Assorted food products such as biscuits, cookies, jelly, squash, chutney were developed as per FPO and PFA specifications. Chemical and sensory evaluation of the finished products led to consumer acceptance.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

Outcome of the research should be published and more popularized amongst the stakeholders. Demonstration cum training programmes for value addition practices developed in the project can be included in the activities of the VVKs for advancing the capacity of the target stakeholders.



12. Phytochemical examination for utilization of leaves, barks, fruits and roots of Indian forest plants.

Sub project Title: Screening of *Cephalotaxusharringtonia* var. *harringtonia* for bioactive principles

Principal Investigator: Dr. Rameshwar Dayal

Duration: 1997

Critical analysis of the research theme & summary of the study

Genus *Cephalotaxus* is a potential source of bioactive compounds due to the anticancer activity of the alkaloids present in it. Literature survey revealed that very little work on the chemistry of *Cephalotaxusharringtonia* (CH) var. *harringtonia* growing in India was done. The project was, therefore, aimed to isolate and characterize bioactive compounds from its needles. An essential oil was isolated from the needles and its chemical composition established using GC-MS technique showed to be of good medicinal value. Altogether eleven compounds in different extractive of the needles were isolated and characterized with the aid of UV, IR, NMR and MS data. Compound ginkgetin displayed good hepatoprotective activity in rats. The study conducted generated significant new knowledge for further utilization.

Scientific findings & contents

The chemical examination of different extractives of needles of CH led to the isolation of eleven compounds of which two, apigenin-5-*O*- β -D-glucopyranosyl-(2 \rightarrow 1)- α -L-rhamnopyranoside (CH-F) and apigenin-5-*O*- β -D-(6''-acetylglucopyranosyl)-(2 \rightarrow 1)- α -L-rhamnopyranoside (CH-G) were reported for the first time in nature. 7,4',7''-tri-*O*-methylamentoflavone (CH-B) was a rare biflavonoid and along with 2-(3-methoxy-4-hydroxyphenyl)-propane-1,3-diol (CH-H) reported for the first time from a *Cephalotaxus* species. The latter compound could be an intermediate precursor in the alkaloid biosynthesis. Ginkgetin (CH-C) showed good hepatoprotective activity in rats. The essential oils of the needles and twigs were analyzed by GC-MS and GC-FID also for the first time with the β -caryophyllene as chief constituent in both the oils. The essential oil may be of very good medicinal value as their eight constituents namely terpinen-4-ol, α -terpineol, β -caryophyllene, germacrene-D, γ -cadinene, caryophyllene oxide, T-cadinol and β -eudesmol amounting to 54.8% in the needles oil and 54.9% in the twigs oil have been reported to have therapeutic and other bioactivities.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

Compound ginkgetin which showed good hepatoprotective activity in rats could also be investigated further for possible development into a hepatoprotective drug. Having studied the chemical profile of the essential oils derived from the needles and twigs, there is enough scope to research these oils further for their odoriferous and therapeutic value. Significant IP is expected from these researches.





13. Phytochemical examination for utilization of leaves, barks, fruits and roots of Indian forest plants

Sub project Title: Development of pest control agents and other bioactive compounds from *Vitexnegundo*

Principal Investigator: Dr. Rameshwar Dayal

Duration: 1997

Critical analysis of the research theme & summary of the study

Vitexnegundo, a large aromatic shrub commonly known as 'Nirgundi' is distributed throughout the greater parts of India ascending to an altitude of 1500 in outer Himalayas. This is also one of the common plants used in Indian System of Medicines. All parts of this plant are reported to possess medicinal properties. The leaves and roots are sold as drugs. The leaves are also reported to possess pesticidal properties. The objective of the project was to isolate and characterize chemical constituents occurring in the leaves of Nirgundi. Leaves and flowering twigs on hydrodistillation yielded an essential oil, composition of which was determined by GC-MS. The essential oil displayed pesticidal activity against *Sitotrogacereallela*. Viridiflorol, the main constituent of the oil, was isolated, characterized and found to possess significant antifeedant activity against rice weevil, *Sitophilusoryzae*. Altogether 12 compounds were isolated from different extractives of the leaves and characterized with the aid of UV, IR, NMR and MS data. Different extractives and pure compounds displayed dose dependent antifeedant activity against store grain insect *Sitophilusoryzae* and larvicidal activity against third star larvae of *Closterafulgurita* and thus could be of use in controlling them. New knowledge of very high significance was generated in the project which has high potential for utilization of the leaves into industrially usable products.

Scientific findings & contents

The essential oils of the leaves and flowering twigs of *Vitexnegundo* were analyzed by GC-MS for the first time. Viridiflorol was found to be chief constituent in both the oils. Chemical examination of different extractives led to isolation and characterization of twelve compounds from the leaves and seven from flowering twigs. Agnuside was found to be major chemical constituent in the leaves. The essential oil was found to be active against *Sitotrogacereallela* and different extractives and pure compounds showed a dose dependent antifeedant activity against store grain insect *Sitophilusoryzae* and larvicidal activity against third star larvae of *Closterafulgurita* and thus could be of use in controlling them. Viridiflorol also exhibited significant antifeedant activity against rice weevil, *Sitophilusoryzae*.

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

Having studied the chemical profile of the essential oils derived from the leaves and flowering twigs, there is enough scope to research these oils further for their odoriferous and biological properties. Significant IP is expected from these researches.



14. Integrated development of tree borne oilseeds of forest origin (Compact Plantations)

Principal Investigator: Dr. S.S. Bisen

Duration: 2002

Critical analysis of the research theme & summary of the study

India is rich in traditional oil seed production but is not able to meet the country's oil seed demand. This demand is partly met by non-traditional oil seeds of forestry origin commonly called tree borne oil seeds (TBOs). Despite of the vast potential of these TBOs, a small quantity of these seeds are collected. Besides utilizing existing potential of the TBOs by designing a suitable strategy for enhancing seed collection, new plantations of these species in degraded areas need to be promoted. This would not only increase the availability of vegetable oil resource but also produce green cover on degraded lands and generate rural employment. In view of the prospects of the TBOs, the objective of the project was to utilize degraded and problematic forest lands productivity and to raise compact plantations of oilseed bearing forest trees for economic benefit of local people. A total of a little over 1,00,000 seedlings of karanj, mahua, neem, and jatropa were planted in 8 divisions of M.P. Forest Department and their growth performance was reported. Training for the subordinate staff of the forest department, farmers and members of forest communities was organized to generate awareness about the TBOs of forest origin, their propagation methods, harvesting techniques and storage of seeds. Extension material of the species planted in form of pamphlets in Hindi and English were published and distributed among the villagers to motivate them for large scale adoption of TBOs on their farm lands. Need of elite natural stock of the above species and their nursery techniques to raise quality planting stock and standardization of storage practices of their seeds was realized.

Scientific findings & contents

Mahua, Neem, Karanj and Jatropa thrive well on degraded land. More initial care is needed for Neem, Mahua and Karanj as compared to Jatropa and Mahua being most sensitive to frost in winters. Survival for all the plantations put together ranged between 60-90%, least being for Mahua and highest for Jatropa. The plantation sites were found to respond in a positive manner, as some local grass species, viz. Doob (*Cynodondactylon*) and Laptua (*Cenchrusciliaris*) were seem to have come up, thereby indicating improvement in edaphic conditions. In a few plants of Jatropa, flowering and fruiting were observed during the second year of planting. People were found enthusiastic about planting these oilseeds bearing plants on their fields and in the vicinity of homesteads. Members of the concerned VFCs were found interested in utilizing the interspaces of Neem, Mahua, Karanj for growing medicinal plants like, safedmusli (*Chlorophytumborivillianum*) and ashwagandha (*Withaniasomnifera*) etc. It was estimated that with plantation activity alone in such projects there is a potential to generate employment to the tune of 150 man days per hectare per month during the plantation season. This capacity will further get enhanced when the trees come to fruiting stage and works on collection of seeds, storage, value addition, etc. start. These efforts can also be replicated in other similar areas. However, it was suggested that these plantations should be maintained at least up to three years.

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

Findings could be utilized in rehabilitation programmes of degraded lands.





15. Chemical modification of cellulose and its industrial uses

Principal Investigator: Dr. V.K. Varshney

Duration: 2006

Critical analysis of the research theme & summary of the study

Modification of cellulose through different chemical routes is a versatile transformation to convert this rigid molecule into derivatives possessing different properties for broader applications. In view of it, α -cellulose isolated from cotton linters, and *Dendrocalamusstrictus*, bamboo having Av. DP 2600 and 816, respectively was studied for its chemical modification using different substitution reactions. Reaction conditions were standardized and it was established that the α -cellulose could be transformed into water soluble carboxymethyl celluloses (CMCs) of DS 0.63 and 0.89, hydroxypropyl celluloses (HPCs) of hydroxypropyl contents 48 and 52% and organo soluble cyanoethyl celluloses of DS 1.20, 1.22 using carboxymethylation, hydroxypropylation and cyanoethylation reactions, respectively. All these derivatives were characterized by IR and standard chemical methods for their DS and hydroxypropyl contents. Aqueous solutions of the optimized CMCs and HPCs were also studied for their apparent viscosities at different shear rates and found to be non-Newtonian pseudoplastic. These derivatives may possibly be used in food, pharmaceutical and textile industries.

Scientific findings & contents

Chemical modification of α -cellulose isolated from cotton linters, and *Dendrocalamusstrictus*, bamboo having Av. DP 2600 and 816, using carboxymethylation, hydroxypropylation and cyanoethylation reactions was studied. Optimization of reaction conditions led to production of water soluble carboxymethyl celluloses (CMCs) of DS 0.63 and 0.89, hydroxypropyl celluloses (HPCs) of hydroxypropyl contents 48 and 52% and organo soluble cyanoethyl celluloses of DS 1.20, 1.22. Comparative IR spectral studies of the native cellulose and its derivatives confirmed the modification. Apparent viscosities of the aqueous solutions of the optimized CMCs and HPCs at different shear rates showed them to be non-Newtonian pseudoplastic

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

Developed processes are useful and can be extended to prepare customized cellulose derivatives for specific applications.



16. Development of methods for detection of adulterants and determining purity of sandal oil

Principal Investigator: V.G. Angadi

Duration: 2008

Critical analysis of the research theme & summary of the study

Sandalwood oil is one of the precious essential oils and methods and techniques for its quality control are imperative. Various physico-chemical methods such as optical rotation, refractive index and solubility test using 70%ethyl alcohol, and UV spectrophotometric methods were studied for detection of adulterants and determining the purity of the oil. Several samples of the adulterated oil were examined using these methods and data were compared with those of the pure sandalwood oil. The developed methods are helpful in quality control of the oil.

Scientific findings & contents

Optical rotation, refractive index and solubility test using 70%ethyl alcohol, and UV spectrophotometric methods were studied and found suitable for detection of adulterants and determining the purity of the oil.

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

A follow up project based on the outcome of the completed project could be undertaken for development of an integrated protocol for control of the quality of the oil. This protocol will also be disseminated to various members of the value chain of sandalwood oil through training programmes for their adoption.

17. Investigation on chemical composition and utility of AESP oil from exhausted sandalwood powder

Principal Investigator: S.H. Jain

Duration: 2009

Critical analysis of the research theme & summary of the study

The sandalwood powder considered to be waste after extraction of the sandal oil was investigated for any further value addition. The exhausted sandalwood powder was optimally reacted with acid and new oil named AESP oil was obtained. UV and GC analysis of AESP oil was carried out and found that this oil altogether different from sandalwood oil. The oil was evaluated and found acidic and pungent in nature with bitter almond odor and the color of the milky white soap was getting changed. Cost effectiveness for 1kg of AESP oil was worked out (approximately Rs.10000-12000 per kg. The cosmetic value of the oil was very poor and was not suitable for its application in soap making.

Scientific findings & contents

The spent sandalwood powder on reaction with acid yielded a new oil named AESP oil. UV and GC analysis of AESP oil revealed its properties altogether different from sandalwood oil. The oil was found to be acidic and pungent in nature with bitter almond odor. Cost of production of this was worked out to be approximately Rs.10000-12000 per kg. Functional performance of the oil in soap making was not good.



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

Known uses of spent sandalwood powder include making of incense stick and hawansamigri. However, more studies are needed for its value addition. One approach could be recovery of high value chemicals.

18. **Fatty oil composition and utilization of lesser known tree borne oil seeds (TBOs) *Givotiarottleriformis* Griff., *Madhuca insignis* (Radlk.) H.J. Lam., *Shorea tumbuggaia* Roxb., *Poeciloneuron indicum* Bedd., *Hopea parviflora* Bedd., *Mesua ferrea* Linn. and *Balanites roxburghii* G. Planch.**

Principal Investigator: Dr. S. Mohan

Duration: 2012

Critical analysis of the research theme & summary of the study

The oilseed production in our country presently meets only 60-70% of its total edible oil requirements and the rest is met through imports. India has a vast potential to produce enough vegetable oil to meet its edible oil requirements. Tree-borne oilseeds (TBO) have been accorded very high priority as a source material for bio-diesel production in the country. The increased demand for oil in India due to rise in population has necessitated the investigation of more and more tree species to meet the internal consumption. Many of our native tree species could be a source of edible oil/bio-diesel, but practically no work whatsoever has taken place. Being native species, if found suitable for edible oil purpose or as a source of bio-diesel, they can be grown profitably on a large scale, and anytime they make for ecologically better species. With this background seven TBOs – *Givotiarottleriformis*(GR), *Madhuca insignis* (MI.), *Shorea tumbuggaia*(ST), *Poeciloneuron indicum*(PI), *Hopea parviflora*(HP), *Mesua ferrea*(MF) and *Balanites roxburghii*(BR) which are ethnobotanically known to yield good amount of seed oil have been studied for their physico-chemical properties, fatty oil content and fatty acid composition. The findings of the study were highly useful to the state forest department of Karnataka and Andhra Pradesh since these tree species are found distributed in these two states. Forest Departments could have a knowledge base of these tree species to be included in their mixed species plantation programmes as well as for encouraging tribal population for collection of these TBOs as minor forest produce and earn revenue erstwhile only few selected NWFPs were collected.

Scientific findings & contents

The fatty acid composition of the oil of the MI was almost similar to palm oil except that this oil contained slightly more of poly unsaturated fatty acids (PUFA). Interesting aspect of this oil was high content of oleic acid (41.0%) which is known to have cardiovascular beneficial effects. The fatty acid composition of GR oil was ideal for making soap since it had more of saturated fatty acids such as lauric acid and palmitic acids. Antifungal activity of the oils GR and BR evaluated using disc diffusion technique showed moderate antifungal activity against three plant pathogenic fungi namely *Fusarium oxysporum*, *Alternaria alternata* and *Collectotricum gloeosporoides*. Experiments performed by using different proportions of alkali and alcohol for transesterification and preparation of bio-diesel from MI indicated very good yield of bio-diesel from the species.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

The findings of the work are very interesting. Functional performance of these fatty oils could also



be examined for applications in cosmetics and aromatherapy. Further studies of these oils in collaboration with the oil companies and or Indian Institute of Petroleum, Dehradun could also be taken up for their use as biodiesel. A follow up project could also be undertaken for carrying out above works. As envisaged in the PCR, a booklet based on the outcome of the research conducted should be brought out and circulated to the SFDs and tree growers for promotion and utilization of these TBOs.

19. Studies on essential oils : chemical constituents and toxicity assessment of the leaf oil of *Lantanacamara* Linn Tamilnadu regions

Principal Investigator: Dr. S. Murugesan

Duration: 2013

Critical analysis of the research theme & summary of the study

Plant secondary metabolites derived from, weeds, medicinal and aromatic plants have been found to be a protective biopesticidal agent, cost effective and safe to ecosystem & public health. An ethnobotanical record provides that chemical constituents of about 800 plant species may possess antifeedant, insecticidal, antimicrobial, and other biological properties. In the present investigation, the essential oil of *Lantana camara* collected from the different agro-climatic conditions of Tamilnadu regions was screened and evaluated as an alternative and efficient tool for management of the defoliators of teak and *Ailanthus* species. Though, the extracts from the leaves of lantana have been reported to express antimicrobial, fungicidal, insecticidal and nematocidal activity, investigations on efficacy of secondary plant metabolites have not been carried out in terms of repellent, insecticidal/inhibitory activity towards insects and the growth of microorganisms. The essential oil derived from lantana proved to be interesting source of two terpenoids for their bipesticidal properties against some of the defoliators of forestry tree species. Bioassay screening of two individual compounds identified from the essential oil was tested on target pests such as *Hyblaeapuera*, *Eligma narcissus* and *Attevafabriciella* at different concentrations ranging from 1000 ppm to 10,000 ppm both in the laboratory and field conditions. The bioactivity of 55% to 75% larval mortality was observed when the early instars were exposed to formulated oil applications. Based on the bioassay evaluation studies, an eco-friendly formulation was made and tested in comparison with neem formulation and synthetic pesticide against the target pests. With the promising results obtained both in laboratory and field trials, a new botanical called “Tree-PAL”, *Lantana camara* leaves essential oil based biopesticide was developed and released for the benefit of farmers by the Director General, Indian Council of Forestry Research and Education during “Trees growers mela 2013” held on 21 and 22 February 2013 at the institute. The product received good feedback from farmers and had scope for scaling up through Direct to consumer initiatives of ICFRE.

Scientific findings & contents

The essential oil from *L. camara* leaves was extracted, and its efficacy was examined on the pests of teak and ailanthus viz. *Hyblaeapuera*, *Eligma narcissus* and *Attevafabricella*. Preliminary bioassays showed antifeedant and insecticidal activity of the oil. Bioassay directed isolation and characterization led to the identification of bioactive compounds by GC-MS-MS. Field level bio pesticide applications and experiments were carried out in *Ailanthus excelsa* field station, Salem and State forest nurseries located at Thirumoorthi, Aaliyar and Amaravathi, IFGTB research nursery and





KFRI field station, Milambur, Kerala to confirm the bioactivity of the essential oil and individual compounds at different concentrations. At the concentration of 10,000 ppm highest efficacy was obtained in comparison with synthetic pesticides such as nimbecidine and monocrotophos. It was observed that the larva did not reach the complete life pattern, which actually is responsible for the foliar damage. It affected the growth of the defoliator resulting in the reduction of larval feeding rate and larval weight and attained larval mortality (72%-97%) in both laboratory and nursery conditions. With the promising results obtained both in laboratory and field trials, an eco-friendly new botanical called "Tree-PAL": *Lantana camara* leaves essential oil based biopesticide was developed.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

The invention made in the project could be patented and commercialized.

20. Enzyme aided alternative process for the extraction of oil from *Cymbopogon citratus* (lemon grass)

Principal Investigator: Dr. Rashmi, Scientist-D

Duration: 2015

Critical analysis of the research theme & summary of the study

Essential oil isolated from the leaves of the lemongrass using conventional hydro distillation constitutes one of the raw materials for fragrance & flavor industry. Its antimicrobial, preservative and pesticidal properties are also well known. The quality Yield and quality of essential oils can be improved by pretreatment of the plant material. Use of enzymes in extraction of plant materials is known to improve the yield and properties of their secondary metabolites. The objective of the project was to examine the efficacy of the enzyme(s) on extraction of the essential oil of lemongrass. Practices for pretreatment of lemon grass using stone grinding followed by a combination of enzymes namely cellulase, pectinase and β -galactosidase were developed to yield the essential oil superior in terms of the yield and quality to that obtained by conventional distillation method.

Scientific findings & contents

Enzymes (cellulase, pectinase and β -galactosidase) assisted extraction led to enhanced yield and superior quality of oil and reduced the artifacts formation. GC-MS assisted composition of the essential oil was determined and compared with that of the oil obtained by conventional hydro distillation method. Compositional difference in terms of the enhanced number and quantity of the constituents in the enzymes extracted oil was observed. Amount of the trace compounds present in the hydro distillation produced oil was also increased in the oil extracted using enzymes.

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

A follow up project on optimization of the conditions for enzyme assisted extraction of the lemongrass, upscaling of the optimized process and chemical and sensory evaluations of the oil for industrial applicability may be taken up.



21. Evaluation of *Calophyllum* populations for high oil yield

Principal Investigator: Smt R. Anandalakshmi, Scientist-D

Duration: 2014

Critical analysis of the research theme & summary of the study

The project was aimed to promote the domestication and cultivation of *Calophyllum* (CI) seeds which are known to yield fatty oil. CI is suitable for sandy and poor soil sites and amenable for agroforestry. It assures high percentage of oil which finds application both as a biofuel and medicinal oil. The quantum of seed and oil production is substantially high in CI as in other TBOs. The study provided an opportunity to the farming community for cultivating a promising species that ensures high yield. 159 Candidate Plus Trees (CPTs) from Tamil Nadu, Kerala, Puducherry and Andaman Islands were identified, and a germplasm bank with a broad genetic base was established. 40 CPTs high in both fruit production and oil content were shortlisted, clonally multiplied and laid as multilocation trials. The clonal tests and germplasm bank served as reliable good quality genetic material of CI for seed production that would support large scale planting. Through training programs of the institute and Farmers'Mela, seedlings and clones of CI were supplied to farmers, foresters and awareness created on importance of the species including handling of the economically important tree crop. Interesting findings that emerged from this study on the variability existing among populations of CI and their relationship with oil content enabled to understand the distribution pattern, potential for its improvement and highlighted the need for conservation of this valuable genetic resource. The findings would support *Calophyllum* based industries in the mandated states of IFGTB besides supporting livelihood needs of tree cultivating farmers. This study threw new dimensions of understanding about this tree crop that would stay to support homestead, coastal area agroforestry and plantations in a large way.

Scientific findings & contents

Surveyed and identified populations of *C. inophyllum* in Trivandrum, Allepey, Kollam, Kasargod and Alicode in Kerala, at Nagercoil, Kanyakumari, Courtrallam, Chidambaram, Aliyar, Chennai, Noyal, Coimbatore, Nagapattinam and Sengottai in Tamil Nadu, at Puducherry and Karaikkal in the UT of Puducherry and Havelock, Mayabunder, North Andaman, South Andaman and Middle Andaman in Andaman Islands. In total identified 159 CPTs or accession which includes 44 from Kerala, 82 from Tamil Nadu, 9 from Puducherry and 24 from Andamans. Standardized vegetative multiplication through stem cuttings and produced rooted clones. Conducted germination tests, recorded seedling parameters, raised stock and standardized nursery practices including pest management. Standardized seed processing for oil extraction from *Calophyllum inophyllum* kernels and oil analysis was carried out for each CPT or accession by Soxhlet method. Recorded variations in nut morphology, nut weight related parameters and drawn correlation of these parameters with oil content. Cluster analysis for the 22 populations for nut weight parameters and oil content was carried out which indicated that Courtrallam, Trivandrum, Chidambaram and Andaman populations are distinct. Established a Clonal bank cum clonal trial and a half-sib Progeny trial at Panampally which would also serve as a germplasm bank. Shortlisted 40 high oil yielding clones with oil content 55% and above. Laid out three multilocation trials comprising 40 high yielding clones each at Gudalur, Salem and Nevely research station and provided drip facility. Recorded growth data in the clonal trial and half sib progeny trial at Panampally. Interim results of clonal trial revealed that significant variability existed between the clones which could be exploited in future tree improvement





programs. Extension programs through farmers' mela and trainings were undertaken to popularize the species for cultivation by farmers and planting by forest departments.

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

- Studies towards examination of the chemistry and functionality performance of the seed oil in biofuel, cosmetics, cosmaceuticals, and aromatherapy applications can be undertaken to upgrade the value chain of the seed oil for increased promotion and utilization of the tree.
- The broad genetic base of germplasm created is highly valuable for future breeding program of the species. Through multilocation trials site specific clones can be identified and accordingly clonal varieties can be registered and released.
- Based on the oil content and composition in the high fruit yielding accessions, elite accessions can be identified and recommended for raising large scale plantations.

22. Refining of process for detoxification studies of Jatropha seed oil

Principal Investigator: Dr. Vineet Kumar

Duration: 2015

Critical analysis of the research theme & summary of the study

Oil, in the form of fatty acids methyl esters of glycerol is a major seed storage reserve in most of the plant species which include Jatropha, Pongamia, Sapindus, Sal, Sunflower, Soybean, Maize to name a few. The triglycerides, being the source of energy, accumulate during seed maturation and are stored in the seed until germination, after which they contribute to seedling growth. Humankind relies heavily on plant-derived oils for both food and feed applications. The fatty acids differ by chain length, presence of different unsaturated bonds, and functional groups etc. There are numerous opportunities for further development of existing and new oilseed crops as renewable feedstock for production of renewable energy. Among the seed plants Jatropha is one of the prominent species. Jatropha is a large genus of herbs, shrubs and trees distributed in the tropical and sub-tropical parts of the world. About 12 species occur in India. The oil is composed of tri-glycerides of oleic acid, 34-45%; linoleic acid, 31-43%; palmitic acid, 14-15% and stearic acid, 5-10%. The oil has been used for illumination, soap, candles, adulteration of olive oil, and making Turkey red oil. But after detoxification the seed oil may be utilized for edible purposes and it may lead to lesser burden on import bill of the edible oil which is next to the petroleum fuels. A potential major constraint in the widespread acceptance of Jatropha as a source of fatty oil is the presence of phorbol esters, which, when consumed by man and animal, are toxic and are also co-carcinogens. Phorbol esters are the tetracyclic diterpenoids generally known for their tumor promoting activity. This makes the oil unsuitable for food and feed applications. In view of the current debate of 'oil for food' versus 'oil for fuel', this toxicity is a potential disadvantage for oil for food. Jatropha oil can be seen as 'technical oil', and therefore does not compete directly with the food markets. At the same time this is also a disadvantage. The project was aimed to find economical and facile processes for detoxification of Jatropha seed oil by removal of phorbol esters. Detoxification of Jatropha seed oil is a step forward to make it suitable for edible purpose which in turn is a better option than use of the oil as biodiesel due to non-competitive cost as well as extraordinary high demand. Accordingly, detoxification of Jatropha seed oil was attempted in the laboratory. The laboratory tests indicated that the Jatropha seed oil is devoid of phorbols. The detoxification carried out in the laboratory is very important for the viability,



sustainability and hence wider acceptability of the *Jatropha*-based oil production system.

Scientific findings & contents

A series of methods using liquid-liquid partitioning and solid-liquid partitioning were tried in such a manner that phorbols are removed completely using minimum solvent and reagents. Studies conducted led to removal of phorbols from the *Jatropha* oil.

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

Follow up studies to ascertain the edibility of the oil after detoxification can be undertaken.

23. Evaluation of *Santalum album* grown in Uttarakhand and Himachal Pradesh for yield, quality and composition of essential oil

Principal Investigator: Dr. Rakesh Kumar, Scientist-D,

Co Principal Investigator: Dr. Y.C. Tripathi, Scientist-F

Duration: 2015

Critical analysis of the research theme & summary of the study

The work was taken up in agreement with the views of representatives of SFDs of respective states who uttered during the Stakeholders' and Research Advisory Group (RAG) meetings the need for systematic study on naturally grown and plantations of Sandalwood in the two states to ascertain their economic worth in terms of yield and quality of essential oil. The objective of the project was to evaluate the yield and qualitative characteristics of essential oil derived from sandalwood grown in the Uttarakhand and Himachal Pradesh states. Systematic analysis of sandalwood samples obtained from the two states led to the inference that sandalwood of Uttarakhand origin contained considerable amount of essential oil with quality and composition consistent with prescribed standards, thus qualifies for commercial grade oil. Sandalwood of Himachal Pradesh origin though found to contain somewhat lesser amount of essential oil, however, the oil met all the quality requirements for commercial grade sandal oil. In view of the dwindling natural resource of sandalwood and very high cost of sandal oil in domestic as well as international market, sandalwood of Himachal Pradesh origin may also be economically viable. The study affirmed that the sandalwood grown in the state of Uttarakhand and Himachal Pradesh may encompass reasonable economical feasibility, if managed and utilized scientifically. Further, field survey and interaction with SFDs of the two states revealed that due to frost-intolerant nature sandal trees did not occur at high altitudes rather found in plain and low altitude areas in the two states. The outcome of the project may be useful for SFDs of Uttarakhand and Himachal Pradesh states for protection and conservation sandalwood plantations and can be beneficial to local people, NGOs, entrepreneurs and all concerned with protection, conservation, cultivation and production and marketing of sandalwood oil.

Scientific findings & contents

The yield of essential oil from heartwood samples of Uttarakhand and Himachal Pradesh origin was 2.2% and 1.8% respectively. The values of qualitative parameters of essential oil from sandalwood samples of both the states were well within the specified standard values as per IS 329: 2004. The percentage of major constituents i.e., α -santalol and β -santalol in essential oil derived from sandalwood samples of the two states was also in accordance with prescribed standards. Sandalwood of Uttarakhand origin contained considerable amount of essential oil with quality and





composition consistent with prescribed standards. Though the essential oil yield from sandalwood of Himachal Pradesh origin was less as compared to that of Uttarakhand, met all the quality requirements for commercial grade sandal oil.

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

Findings of the project should be extended to (i) the SFDs of Uttarakhand and Himachal Pradesh states for protection and conservation sandalwood plantations; (ii) local entrepreneurs to acquaint them about the economical feasibility of sandalwood trees grown in these two states; and (iii) NGOs, local people for generation of awareness for protection, conservation and cultivation of sandal trees in respective areas.

24. Studies on phyto-proteins from selected plants of northeast region for the production of protein concentrates with greater food value

Principal Investigator: Dr. Vikas Rana

Duration: 2012

Critical analysis of the research theme & summary of the study

With rapid population growth coupled with limited cultivable land, shortage of protein and consequent malnutrition caused by protein deficiency is wide spread in developing countries. Further, short supply of good quality protein is also a serious concern as soybean and fish in livestock and fish diets, particularly in fish meals, is unaffordable in these countries. Thus search for additional sources of protein is imperative. Leaf protein concentrate (LPC), a concentrated form of protein derived from the foliage of plants, a most abundant and inexpensive source is regarded as potential way out to tackle the protein crisis and malnutrition. LPC is reported to be rich in essential amino acids, polyunsaturated fatty acids, vitamins and trace elements. Nutritional value of foliage derived LPC is comparable to that of animal proteins and superior to seed proteins. LPCs have been assessed as food for children and included in various food formulations. Use of LPCs as a protein supplement in animal feed has also been demonstrated. The project aimed at screening of Northeast flora for protein content and preparation of protein concentrates from high protein yielding plants. Leaves of nine plant species namely *Sambucusfavanica* (SJ), *Antidesmabunius*(AB), *Alocasiamacrorrhizos* (AM), *Cissusadnata*(CA), *C. repens* (CR), *Enydrafluctuans* (EF), *Mimosa diplotricha*(MD), *Diplaziumesculentum*(DE) and *Samaneasaman* (SS), selected based on their natural availability, capacity to pulp and their reported use as food or fodder, were screened under the project for their protein contents. Of these, three most promising species namely *Alocasiamacorrhizos*, *Diplaziumesculentum* and *Samaneasaman* were identified for production of LPC. Protein concentrates and leaf meals (LMs) from these species were prepared. LPCs found to contain higher protein content and nutritive values in comparison to their respective leaf meals. Their functional properties were also comparable with those previously reported in other plant species.

Scientific findings & contents

The protein content (%) in the leaves SJ, AB, AM, CA, CR, EF, MD, DE and SS was found to 14.21, 16.45, 23.15, 12.65, 15.65, 16.78, 21.26, 19.42, and 24.37, respectively. Based on the higher protein content of AM, DE and SS, their LPCs and LMs were prepared. The protein content of the LPCs were higher than their corresponding LMs indicating thereby that fractionation of the leaves enhanced their protein. Nutritional value with respect to the moisture, protein, ash, ether extract, crude fiber, and mineral composition), and functional properties viz bulk density, dispensability,



water absorption capacity, oil absorption capacity, foaming capacity and foaming stability, and emulsification) of the LPCs showed their suitability for use as food/ feed. Use of these LPCs in various industrial products was also predicted. Conditions of temperature and protein solubility at different pH were also optimized to yield LPCs of higher yield and protein content.

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

The findings emanated from the study are promising for development of industrially usable LPCs from *Alocasiamacorrhizos*, *Diplaziumesculentum* and *Samaneasaman*. Further research on the optimization of conditions for production of these LPCs, detailed examination of their nutritional composition and functionality performance in various intended products are required

25. Identification of biochemical marker linked to sex determination in *Casuarinaequisetifolia*

Principal Investigator: Dr. A. Shanthi

Duration: 2011

Critical analysis of the research theme & summary of the study

The project was aimed to identify biochemical markers (isozymes) linked to sex determination in *Casuarinaequisetifolia* and to develop simple biochemical technique for gender identification. Thirteen isozymes viz., Aspartate Amino Transferase (AAT), Peroxidase (POD), Esterase (EST), Glutamate Dehydrogenase (GDH), Superoxide-Dismutase (SOD), Alcohol Dehydrogenase (ADH), Isocitrate Dehydrogenase (IDH), Glucose-6-phosphate Dehydrogenase (G-6-PDH), Malate dehydrogenase (MDH), Malic Enzyme (ME), Polyphenol Oxidase (PPO), Lactate dehydrogenase (LDH), and Aconitase (ACO) were deployed in the study. Five enzymes ADH, LDH, POD, G-6-PDH and ACO found more specific towards gender specific expressions. POD was the most gender specific enzyme. POD was identified as gender specific isozyme marker for gender discrimination in *C. equisetifolia* through electrophoresis. HPLC profiles of the non consistent individuals were compared with those of the consistent males, females and monoecious individuals revealed gave a clear indication of the change in expression of male to monoecious (CHCE0401, retention time 12.36 min) and female to monoecious (CPCE0109, retention time 16.54 min) conditions. Gibberellins were suggested to be effective as a marker to track the sex expression of the clones of *C. equisetifolia* using HPLC.

Scientific findings & contents

Five enzymes ADH, LDH, POD, G-6-PDH and ACO were more suitable expressions towards gender specific among the thirteen different enzymes which were optimized in this species. The maximum number of alleles in LDH was eight followed by five in POD, PPO and G-6-PDH. A specific allele was also investigated. This was designated as male specific in peroxidase enzyme and will help to identify gender discrimination in *Casuarinaequisetifolia*. Endogenous levels of phytohormones like auxin and gibberellin, appeared to determine the fate of flower sex primordia in *Casuarinaequisetifolia*. Higher levels of IAA were found to be correlated with female sex expressions whereas a greater amount of gibberellins favored the differentiation of male sex organs. It appeared that the phenotypic expressions of flower sex is controlled by a balance between male promoting and female promoting hormones.

Suggestions regarding follow up patenting possibility, utilization aspects, prototype

Biochemical markers should be introduced in the breeding programme of *Casuarinaequisetifolia*.





26. Quantitative estimation of sandal oil content from different locations by colour reactions

Principal Investigator: Shri S. H. Jain, Scientist-D

Duration: 2013

Critical analysis of the research theme & summary of the study

Aim of the project was to assess the sandalwood oil in standing tree which would be useful for onsite evaluation of sandalwood plantations in the field. The general method of estimating oil content in laboratory uses Clevenger's apparatus which requires minimum 50g of sample and time consuming. Other two laboratory methods based on visual colour of wood and electrophoretic technique were developed earlier which provided the indication of oil in the wood and not the quantity of the oil present in wood. These practices did not continue due to limitations. Two new approaches were developed and applied in evaluating the oil content in trees of different locations namely, IWSST campus, Bangaluru, Mysuru Forest Division, Hunsur / Madikeri Forest Division and Shivamoga Forest Division of Karnataka, Maryoor Forest Division of Kerala, and Tirupattur Forest Division, Tamilnadu. The estimation of oil content in sandalwood tree by collecting small core sample from standing tree, extracting with hexane and measuring the optical density (OD) of the supernatant using UV spectrophotometer gave accurate estimation of oil content. Another approach utilizing the color reaction of bark tissue with guaiacol peroxidase reagent gave nearest values of the oil in mature trees whereas in the immature trees of girth < 60cm it was a potential indicator of the oil yield in standing trees. Further refinement was done to estimate oil content in standing trees by measuring color intensity using color strip and portable colorimeter. The study also showed that the edaphic and climatic factors play important role in the growth, heartwood formation, oil yield and santalol content.

Scientific findings & contents

Benzidine peroxidase reagent and Guaiacol peroxidase reagent were used in color reaction of living bark sample with these enzymes. Though benzidine and guaiacol found to be useful for distinguishing colour developed in living bark tissue of sandal plants, guaiacol was found to be more effective in terms of the intensity of the color developed, cost and environment and user friendliness for estimating approximate oil content in the standing tree. Spectrophotometric method was found to give accurate estimation of oil content. Varied correlation in the oil yield estimated using spectrophotometric method and enzymatic color reaction was observed. Growth, heartwood formation, oil yield and santalol content were found to be influenced by edaphic and climatic factors.

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

Further studies are needed to validate the findings by evaluating large number of samples from the populations growing at different locations, establishing the statistical correlation between the oil yield and santalol contents determined using the spectrophotometric method and enzymatic color reaction, and developing a suitable model to predict the oil yield and santalol contents in the standing trees.



27. Standardization of processing and storage techniques of Malkangni (*Celastruspaniculatus*), Baheda (*Terminaliabellerica*) & Baividang (*Embeliatsjeriam-cottam*) fruits/seeds

Principal Investigator: Hari Om Saxena

Duration: 2016

Critical analysis of the research theme & summary of the study

Processing and storage of medicinal plants play an important role in retaining their medicinal property which is attributed to their bioactive constituents. Improper storage of medicinal plants or their plant parts causes rapid deterioration of their active ingredients. The seeds/fruits of Malkangni (*Celastruspaniculatus*), Baheda (*Terminaliabellerica*) and Baividang (*Embeliatsjeriam-cottam*) are important herbal medicines. Nearly 90% of these medicinal plants are collected from wild. Collectors often do not care for processing and storage of these medicinal plants due to unavailability of their proper processing and storage techniques. Matured fruits of Malkangni, Baividang and Baheda were collected from the forests of Chhindwara district of Madhya Pradesh during November, December and February, and March, respectively. Different methods for drying of these plant materials including drying in shade, sun and hot air at 40°C. were tried. Processed and dried seeds of Malkangni, rind of Baheda fruits and fruits of Baividang were stored separately in different containers i.e. HDPE (Polythene) bags, Woven sacks, Gunny (jute) bags, Markin bags, Tin, Glass, Plastic containers and in open environment (control) at room temperature. Samples of all species stored in HDPE (Polythene) bags were also kept at 4°C -5°C. Seeds of Malkangni were analyzed for oil content by Soxhlet apparatus, rind of Baheda fruits and fruits of Baividang were evaluated for gallic acid and embelin content, respectively using HPTLC technique quarterly for two successive years. This was shown that drying of fruits/seeds of the above species in Sun could maintain their quality. Further, the seeds of Malkangni in HDPE (Polythene) bags at 4-5°C and rind of Baheda and Baividang fruits in HDPE at room temperature could be stored upto six months without altering the content of seed oil, gallic acid and embelin, respectively.

Scientific findings & contents

Sun drying proved better in comparison to shade drying/hot air drying at 40°C to maintain quality of fruits/seeds of Malkangni, Baividang and Baheda. Malkagni seeds should be washed in water before storage to remove the outer pulpy layer on the seeds which allows the infestation of curculionid seed borer insect pests. Low cost HDPE (polythene) bags were found the best containers to store the materials at 4-5°C (Malkangni seeds) or room temperature (rind of Baheda and Baividang fruits). The best storage period of above materials was found six months from the time of their storage.

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

Findings emerged from the project should be extended to all the members of the value chain of these forest produce and training should also be imparted to them for adoption and use of practices developed.





28. Studies on nutrient management practices in *Flemingia* species for lac cultivation and promotion of rural livelihood

Principal Investigator: Dr. Arvind Kumar

Duration: 2014

Critical analysis of the research theme & summary of the study

Lac is natural resin of animal origin secreted by insect *Kerriallacca* Kerr. India is the leading country in lac production followed by Thailand, Malaya and China. Jharkhand state is the leading lac producer in India followed by Chattisgarh, Madhya Pradesh, West Bengal, Maharashtra and Odisha. The lac insect is reared on its natural host plant namely *Buteamonosperma* (Palash), *Schleicheraoleosa* (Kusum) and *Zizyphusmauritiana* (Ber). Lac production witnessed steep downfall in the past decades due to reduction in natural population of these lac host plants resulted from indiscriminate deforestation. The lac production can be increased either by utilizing the existing host plants or integrating lac hosts with agriculture mainstream through establishing systematic plantation. But raising of new plantation of traditional host trees is time consuming. While *Flemingiasemialata* and *F. macrophylla* have been found to be the potential lac host plant and showed a great promise for lac production. These are the fast growing, short height and short gestation period plants, which however require more nutrients for their developments. It has been proved that a healthy plant produces high and good quality of lac. To study the effect of nutrients on the growth of *F. semialata* and *F. macrophylla*, lac insect development, yield, and insect pest infestation this investigation was undertaken. The results showed that the treatment T5 containing N10:P15:K10g/plant was found better for growth of *F. semialata*, while treatment T2 consisting of N15:P5:K5g per plant was found to be the best for both the species promoting plant growth, lac insect growth and development and resulting into economical lac production, improved yield of brood lac and scrap lac and less insect pest infestation on lac insects. The outcome of this project are useful to promote cultivation of lac on *F. semialata* and *F. macrophylla* and thus helpful to the farmers for augmenting their income.

Scientific findings & contents

The experiments were laid-out at the institute experimental area using RBD. Total ten treatments with different combination of soil nutrients were used to find out the better nutrient combination for *F. semialata* and *F. macrophylla* plant growth and their effect on lac production. This was revealed that the treatment T2 (N15:P5:K5g per plant) was found to be the best in both the species *F. semialata* and *F. macrophylla* for economical lac production. While, the plant growth of *F. semialata* was found to be superior in T5 (N10:P15:K10g per plant) with the highest plant growth of 253.44cm and 208.33 cm in first and second year, respectively. The infestation of lac predator *P. pulvereana* in lac insect of *F. semialata* was found to be lowest in T2 with 1.11 and 1.56 larvae/4cm in the first and second year, respectively in *F. semialata*. Similarly, lowest parasite infestation to the lac insect was noticed in T2 with lowest 6.67 and 18.11 parasite/cm in the first and second year, respectively. The lac production found to be highest in T2 with 284.11g and 434g/plant in *F. semialata* in the first and second year, respectively. In *F. semialata*, weight of dry stick and lac shell found maximum with T2 in the first (81.69g/plant and 0.051g/shell) and second year (129.15g/plant and 0.049g/shell), respectively. The plant growth of *F. macrophylla* was found to be superior in T2 in first (230.00 cm) and second year (257.00 cm). T2 was found the best for lowest infestation of *P. pulvereana* (1.67 and 2.08 larvae/4 cm) in the first and second year, respectively. Likewise, lowest population of *E. amabilis* (1.33 and 1.72 larvae/4cm) was recorded in first and second year, respectively. Lac insect



parasite population was minimum 5.78 and 16.33 parasite/cm in the first and second year, respectively. Brood lac production was found 278.00g/plant and 1040.00g/plant in first and second year, respectively in T2. Stick lac yield (129.03g/plant) was found maximum in T7 in first year, while T2 produced maximum scrap lac in yield 31.17g/plant and 41.33g/plant in the first year and second year, respectively. Maximum weight of lac shell produced by T2 was 0.0477 g/shell and 0.0487g/shell in the first year and second year, respectively in *F. macrophylla*.

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

Though the outcome of the study was disseminated to various stakeholders through demonstration and training programmes, more integrated extension efforts are needed to promote the large scale cultivation of *F. semialata* and *F. macrophylla* for increased lac production and livelihood of the rural people.

29. Study of various factors effecting the quantity of active principles in some commercially important medicinal plants under cultivation

Principal Investigator: Dr. Malabika Ray, Scientist-D

Duration: 2013

Critical analysis of the research theme & summary of the study

Secondary metabolites are not only important for plants to mitigate the adverse effects of the surroundings but also constitute raw materials for various industries. The optimum age of harvesting of medicinal plants parts is very crucial for obtaining the maximum benefit of bioactive principles. This quantity is known to vary with the cultivation practices. Gymnemic acid (GA) is the bioactive principle of *Gymnemasylvestre* found in its leaves. Production of GA in the leaves is influenced by various seasonal and environmental factors. Thus, the project was aimed to study of various factors influencing the quantity of active principles (gymnemic acid, GA) in *Gymnemasylvestre*. It was observed that the spring season facilitated maximum accumulation of GA in the leaves and hence should be harvested during spring to ensure the medicinal quality of the leaves and their finished products. The significance of potassium (K) in plants in combating various insect pests and diseases is well established. K also plays a catalytic role in the biosynthesis of active principles in plants. Studies carried out in the project revealed that the rhythmic level of potassium was concomitant with the seasonal variation of GA in *G. sylvestre*.

Scientific findings & contents

Maximum accumulation of GA in the leaves was found in the spring season (February). The probable reasons for the upsurge of this active principle during this season were attributed to environmental factors (temperature and light intensity), metabolic condition of plants or a combination of these factors. Variation in the content of GA ($\mu\text{g}/\text{mg}$, DW) from 1.72 in the month of December (winter) to 17.0 in the month of February (Spring) was correlated to the levels of available K (ppm) in the soil ranged from 73.4 (December) to 81.2 (February). At the end of the rainy season there was a steady decline both in the potassium level (56.2) ppm and the content of GA (0.211 $\mu\text{g}/\text{mg}$ DW) in the leaves. The low content of GA coincided with the low potassium level in the soil.

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

Studies directed towards examination of the influence of the cultivation practices on the content of bioactive principle(s) of *G. sylvestre* and their standardization may be undertaken as a follow up project.





30. **Isolation and anti-fungal activities of the chemical compounds of *Baccaureacourtallensis* 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

Baccaureacourtallensis (Family: Euphorbiaceae) is a moderate sized evergreen tree distributed from South Konkan to South Kerala and adjoining western parts of Tamilnadu to the evergreen forests upto an altitude of 900 m. Some of the traditional uses of its different parts are known. Chemistry of this plant is rather scarce. Seeds, fruit rind, and bark of *B. courtallensis* were extracted with solvents of increasing polarity and their chemical examination and antifungal activity were undertaken. Seeds after extraction with petroleum ether yielded a yellow coloured fatty oil which was characterized for physico-chemical properties and constituents fatty acids. Utility of the fatty oil because of the presence of palmitic acid and oleic acid in chemical industry was speculated. Phytochemical screening of the extracts indicated presence of compounds belonging to different chemical classes. Methanol extract of the fruit rind and bark displayed varied fungitoxic activity against *Fusariumoxysporum* fungi.

Critical analysis of the research theme & summary of the study

Various extracts of the seeds, fruit rind, and bark of *Baccaureacourtallensis* were isolated. Petroleum ether extract of seeds consisted of 22.5% yellow coloured oil. Its physico-chemical properties and chemical composition were determined. Presence of four fatty acids namely palmitic acid (42.59%), oleic acid (36.15%), stearic acid (16.20%) and myristic acid (4.28%) in the oil was found. Palmitic acid and oleic acid are important fatty acids because of their use as lubricants and also as an additive in industrial preparations. It was found in earlier studies by the PI that tree-borne oilseeds yielding 20% oil or more on dry weight basis of seed hold commercial potential. Thus *Baccaureacourtallensis* was found to be a potential tree species for oil extraction. The petroleum ether extract (1.34 g) of the fruit rind was of yellow color and contained steroids and volatile oil. Brown coloured chloroform extract (1.37 g) of fruit rind indicated the presence of coumarins. Methanol extract (20.11 g) of fruit rind was of reddish brown color and showed the presence of tannins, flavonoids, and quinones. Methanol extract displayed good anti-fungal activity against the *Fusariumoxysporum* fungi. Black coloured hexane extract of bark (4.8g) contained volatile compounds. Ethyl acetate extract of the bark (6.3g) was of brown color and showed the presence of flavonoids. Reddish Brown coloured methanol extract (11.36g) of the bark contained flavonoids and quinones and displayed mild activity against *Fusariumoxysporum* fungi.

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

A follow up project on detailed chemical examination of *Baccaureacourtallensis* for isolation and identification of chemical constituents including fungitoxic compounds may be undertaken. Evaluation of the functional performance of the seed oil for various industrial applications will be a part of this project.



31. Studies on the utilization of seed polysaccharide from *Strychnospotatorum*

Principal Investigator: Dr. Pradeep Sharma

Duration: 2010

Critical analysis of the research theme & summary of the study

The project was directed towards utilization of *Strychnospotatorum* seeds. In India, seeds are abundantly available and used to purify water for drinking in rural and tribal areas. Despite the potential usefulness of the seeds for treatment of turbid water, there have been little efforts to characterize or modify the seed polysaccharides. Seeds contain a galactomannan polysaccharide in conjunction with galactan and these polysaccharides have excellent properties to coagulate the turbidity of water. Therefore, chemical modification of the polysaccharide to enhance its activity was attempted. These seeds were modified by the carboxymethylation and quaternisation reactions. Conditions for these reactions were also optimized. These derivatives (carboxymethylated derivative, CMSP and quaternized derivative, QSP) were tested for their toxicity, wet end additive and sizing property, and in reducing pollution load of pulp and paper mill effluent. CMSP was anionic whereas QSP was cationic. SEM analysis of these derivatives confirmed their derivatization. CMSP and QSP were also characterized for their thermal and rheological behavior. Derivatives were found to be non toxic. Though addition of both the derivatives showed improvement in strength characteristics for both hardwood and agro residues pulp, but QSP was relatively more effective than CMSP. QSP found to be effective in reducing the pollution loads of combined mill effluent.

Scientific findings & contents

Strychnospotatorum seed powder was modified using carboxymethylation and quaternization reactions. Standardization of reaction conditions led to produce CMSP and QSP of DS 0.33 and 0.23, respectively. Thermal stability, paste quality, microbial resistance and viscosity of CMSP was better than the native SP. Rheological determination of CMSP showed it to be of non Newtonian pseudoplastic. Thermal stability of QSP was lower than that of the native SP. Shear thinning effect of QSP was observed in its rheological analysis. QSP at 30 ppm concentration displayed flocculation property to settle 1% kaolin suspension in 60 sec. CMSP was more stable than the QSP. Both the derivatives were non toxic. QSP was more effective in improvement of strength properties of hardwood and agro residues pulp. CMSP and QSP were ineffective to impart sizing effect in paper. CMSP was not effective in reducing COD, color, TDS and AOX from paper machine back water and combined mill effluent collected from wood based mill. QSP was reduced pollution loads specially color upto an extent of 50% of initial level of combined mill effluent.

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

This was shown that high input cost in terms of cost of the seeds and their processing, developed derivatization processes are uneconomical to be immediately adopted by the industry. Therefore, further research is required to make commercial utilization of the seeds in the chemical industry feasible.





Ecology, Soil & Land Reclamation





1. Role of biofertiliser in ecorestoration of problematic site like mine rejects soil in Goa

Principal Investigator:

Duration: 2000-2005

Critical analysis of the research theme & summary of the study

The objectives of the study included VAM dependency of selected species and compatibility of the same. Application of combination of different VAM fungi and N₂ fixing bacteria using mine reject soil and studying efficacy of the treatment. Planting of biofertiliser treated seedlings in the mine reject area to achieve high survival rate in the field, demonstration of biofertiliser application and its uses in degraded land to forest officials and NGOs.

Seedlings of *Eucalyptus camaldulensis*, *Wrightia tinctoria* and *Bombax ceiba* were inoculated with *Azotobacter chroococcum* and VAM fungi singly as well in combination in root trainer and nursery conditions. All treated seedlings exhibited improved growth and biomass but, better response was observed in both VAM alone and VAM+ *Azotobacter* treatment and least response was observed in *Azotobacter*- alone treatment. With good microbial activity of VAM fungi, plants can be established in mine reject area and this experimental plot can be taken as demonstration plot for afforestation of mining dumps. It can be concluded that microbial inoculation to tree species was found to improve the productivity and this has to be practiced as integrated nursery management for quality seedling production and successful forest regeneration.

2. Himalaya eco-rehabilitisation project, ICFRE/IDRC

Principal Investigator:

Duration: 1993-2000

Critical analysis of the research theme & summary of the study

Field trials to evaluate the performance of different tree species in limestone mine spoil during 1995 and 1996 were conducted at Baldwa and Hiyona limestone mine sites of Sirmour district of Himachal Pradesh. The experiments were carried out in Randomized complete Block Design with four replications at both the sites. Results obtained indicated that *Robinia pseudoacacia* showed better performance in comparison to other species at both the sites. In Baldwa site, *Robinia pseudoacacia* was followed by *Populus deltoides*, *Melia azadirach*, *Toona ciliata*, *Pinus roxburghii* and *Cedrus deodara* in term of height and diameter growth, whereas, at Hiyona, *Robinia pseudoacacia* was followed by *Populus deltoides*, *Bauhinia variegata*, *Toona ciliata*, *Quercus leucotrichophora* and *Pinus roxburghii*. Plantation in abandoned mined area was found to increase the organic carbon, available nitrogen, and phosphorus and potassium contents.





Extension





1. Exploration and documentation of indigenous knowledge of Phyto-resources among *Mishing* tribe of Assam

Principal Investigator: Dr. T.C. Bhuyan

Duration: 2008–2010

Summary

The North Eastern region of India is considered as living museum of various ethnic groups and the assimilation of several groups and sub groups. The Mishing also known as Miris are the second largest group of scheduled tribe of Assam. Their knowledge about the use of plant resources in general and medicinal plants in particular developed through centuries and could not be documented till now except some limited information. The present study was conducted with the objective to documentation of indigenous knowledge of Mishing tribe. The study was conducted in 8 districts of Assam viz. Jorhat, Golahat, Sibsagar, Sonitpur, Lakhimpur, Dhemji, Dibrugarh and Tinsukia. The information gathered from the study area was compiled and analysed. Information about more than 150 plants was recorded during the study. Tribal people used plants (phyto resources) for cure of various diseases e.g., Pneumonia, Dysentery, Gastric disorder, Joint pain, Tounge infection, headache, bone fracture and jaundice. The plants used as insect repellent were also recorded during the course of study. Tribal also used plants to cure cattle diseases with the help of plants *Crinum defixum*. Women respondents were also interviewed about the indigenous knowledge about plants. *Mishing* tribe women use *Alstonia scholaris* bark to cure pain during menstrual period. *Euphorbia hirta* was given to women to increase breast milk after child birth. It has also been observed that some time the medicine man use more than one plant to treat a disease more effectively. Some important plants used by tribal are *Asparagus racemosus*, *Caesalpinia bonduc*, *Cassia fistula*, *Coriander sativum*, *Costus speciosus*, *Crinum defixum*, *Emblica officinalis*, *Eupatorium odoratum*, *heteropanax fragrans*, *Mangifera indica*, *Ocimum sanctum*, *Oxalis corniculata*, *Piper nigrum*, *Plubgo zeylanica*, *Polygonum plebeium*, *Solanum indicum*, *Terminalia belerica*, *Terminalia chebula*, *Tinospora cordifolia*, and *Vitex negundo*. Many of the plants are used for more than one ailment. The information gathered in the project will be useful for the researchers working on newer phyto-constituents of therapeutic importance.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The Mishing tribe is one of the riches tribe among all the tribes of North Eastern part of the country in terms of ethnic knowledge. The information generated through this project will be useful in further ethno-botanical research. It will provide new leads for phytochemical studies in development of new plant based drugs. Certain plants have good demand in Ayurveda medicine can be commercially cultivated or sustainable harvested from forests sustainably which will lead to sustainable utilization of plant resources. There It will be helpful in poverty alleviation. There is need to extend the findings of the project to different stake holders for optimum benefit of the study.





2. Mapping and monitoring of Casuarians and Eucalyptus plantations in Tamilnadu using Remote Sensing and Geographical Information System

Principal Investigator: Dr. A. Rajasekaran

Duration: 2013 – 2016

Summary

Plantations by individuals of plantations established by industries have taken important place in maintaining the ecological and environmental balance. Plantations not only play an important role in natural resource management but also provide raw materials for pulping and other engineering works. Monitoring of such plantations is a basic problem faced by the industries. Therefore there is need for quick and reliable monitoring system to keep tract of feeling, planting and timely prediction of wood availability. Keeping above in view, the above study was conducted. The present study followed systematic approach for estimating area and pattern of Eucalyptus and Casuarina plantations by incorporating ground inventory, LISS IV data and GPS data. The study aimed to produce a highly accurate vegetation type map that differentiates Eucalyptus and Casuarina plantations from other land use types and mixed vegetation classes in various districts of Tamil Nadu. Eucalyptus and Casuarina growing areas were quantified in selected districts of Tamil Nadu. Spatial extent of Casuarina and Eucalyptus plantations has been mapped using Remote sensing and GIS in Ariyalur, Karur, Pudukkotti, Sivagangai, Cuddalore and Villupuram districts of Tamil Nadu. The study revealed that among the various districts studied, Pudukkotti district had the largest area under Eucalyptus plantations both during 2013-14 and 2016-17 (28418.86 and 38191.67 ha respectively) while Villupuram district had the largest area under Casuarina plantations (15076.21 and 20420.37 ha respectively).

The results of the study can be used as baseline information for future monitoring activities and for improvement of Eucalyptus and Casuarina plantations. This information on pulp wood quantity available in various farm forestry plantations will be utilized by the pulpwood based industry to plan their future planning. Similarlly the data available on extent of Eucalyptus and Casuarina plantations in selected districts of the state along with data on above ground mass (AGB) can also be used for estimating the carbon sequestration potential of this land use system using GIS. Further, long term monitoring of Casuarina and Eucalyptus plantations should be done using RS and GIS which will also give information on carbon sequestration potential of these species.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The pulp wood based paper industry requires data on extent of Eucalyptus and Casuarina plantations available in various farm forestry plantations of the state which will help the paper industries to plan their production and increase the area under plantations. The outcome of the study need to be shared with industries and further collaborative research on above ground biomass productivity of the plantations will be explored.



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

Principal Investigator: Dr. Dinesh Kumar Meena

Duration: 2013–2016

Summary

In North Eastern region of India there is substantial population of Nepali community particularly in Assam who settled at different historic times. They are rich in traditional knowledge on plant based medicine to treat various ailments. Ethno-medicinal data was collected from 91 key informants from the study areas. Among the 91 informants, 37 persons were medicine men (traditional practitioner), 7 persons were old person and 4 persons were medicine men (Kabirajs). Through the survey, a total of 123 plants species belonging to 64 families, covering 164 prescription and 15 broad diseases categories were recorded. The broad diseases include gastrointestinal problem, fever, respiratory complaints, diabetes, liver disorders, dermatological problem, urinary and rectal diseases, helminthiasis, sexual disorders, heart problems, tooth problems, stone problems, inflammation and pain. Major numbers of medicinal plants were used to cure gastro-intestinal problems (37 species) followed by dermatological problems (32 species), respiratory complaints, lever disorders, helminthiasis each with 15 species. Leaves (55%) were found to be the most used plant part in the ethno-medicinal practice of Nepali community, which was followed by fruit (17%) and root (10%). There are several modes of preparation of ethno-medicines, including juice, decoction, powder, paste, boiled extract, fumigation, Infusion etc. The major mode of ethno-botanical preparations in Nepali community was found to be juice (41 species), followed by paste (34 species) fresh plant (15 species), decoction (13 species) and infusion (8 species). Out of the 123 plant species, 96 plant species appears to be quite extensively used by folk and tribal medicinal practitioners in other parts of Assam as judged from the various ethno-medicinal uses. According to Sorensen similarity indices of commonly used medicinal plants between the Nepali community and other community was found to be high for Tai Ahom (0.22) followed by Barman (0.21), Kasi and Bodo (0.19 each).

The study revealed that the older generation of Nepali community still believes and preferred to use traditional medicine for the treatment of various ailments as compare to the younger generation. The females especially house-wives are having fair knowledge about the medicinal plants and they frequently use these plants in gastrointestinal, dermatological and in liver disorders. More than 60% people accept the modern medical facilities are faster and effective than traditional medicine. However, they want to learn and transfer traditional knowledge to the next generation.

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

The finding of this study will be helpful for (i) Medicinal plants database of North East India (ii) Conservation of biological diversity (iii) The conservation of cultural heritage of Nepali community (iv) Commercialization of important medicinal plants and (v) Understanding the future trend and scope of traditional medicine.





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

Principal Investigator: Dr. Vishakha Kumbhare

Duration: 2013 – 2016

Summary

Madhuca India, commonly known as Mahua in hindi is one of the important Non Timber Forest Produce of India belongs to family Sapotaceae. At present, the flowers are mainly being utilized for development of country liquor which hampers the economy of the tribal population. Mahua flowers are a rich source of sugars and could be utilized in nutritional purpose. The study was conducted in collaboration with the Department of Food Technology, Laxminarayan Institute of Technology, Rashtra Sant Tukdoji Maharaj, Nagpur University, Nagpur. Nutritional constituents of *Madhuca indica* dried flowers were estimated in consideration with FPO specifications. Based on nutritional composition of mahua flowers, technology was developed for preparation of value added food products viz. mahua jam, squash and chutneys using dried mahua flowers as per Food Product Order (FPO) specifications. Consumer acceptability tests for all the three food products developed were conducted. All the three products developed were liked by the consumers. Two training programmes were conducted for disseminating the finding of the project to the user target groups. Demonstration on formulation of value added food products of *Madhuca indica* flowers were given to the women van samiti member of State Forest Department and women self help groups. One video CD was also developed.

The developed technology could be effectively disseminated to the user target groups particularly to the tribal women which will help them in generating income on a sustainable basis round the year and their upliftment of the socio economic status. Further, the value addition work of mahua flowers could be developed as small scale industry in tribal pockets. Value addition of the mahua flowers food products is an important area and can play a very important role in the socio-economic upliftment of the tribal/ rural population residing nearby the forest areas. Mahua has potential for value addition at local level so that more employment and income can be generated in the village economy. The scope for value addition is high and is possible only when the improvised collection methods are adopted by the forest fringe dwellers.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

As the follow up action, the collection methods of *Madhuca indica* flowers needs to be standardized since the current practice is no suitable for raw material to be used in formulation of value added food products. The technology developed on preparation of preparation of value added food products from *Madhuca indica* flowers has good potential for extension. It is recommended to be done widely at all the area of its distribution is forest fringe village through the training programmes.



5. Development of Sandal (*Santalum album* Linn.) Information System

Principal Investigator: Dr. V. Soundarajan

Duration: 2011 – 2015

Summary

Sandal (*Santalum album*) Information System web database is dedicated to provide all the information on Indian sandalwood for the public domain. The web database has scope of information culminated from decades of practical experiences and assortment of information shared from sovereign sources, authentic published sources and sandalwood in Govt. Depots. This web database gives the information about scientific classification, taxonomy, vernacular name, morphology, physiology, habitat, distribution, tree improvement, seed technology, nursery technology, bio technology, cultivation, anatomical properties, physical, mechanical and chemical properties, medicinal uses, handicraft, other uses, Karnataka sandalwood rules, Tamil Nadu sandal wood rules, Andhra Pradesh sandal wood rules, custom rules, national and international trade, conservation status, plantation, agroforestry systems, silviculture, pest and diseases, patent, various biological and physiological traits pertaining to endangered species of *Santalum album*. It will provide more than 500 published articles free access in the future.

This web database has provision to update the information and further modification of the database. This web database also has facility of interactive queries and help in generating information reports on all aspects of sandal. The Sandalwood auction, Stock, Plantation information was collected from forest department's depots in Karnataka, Tamil Nadu, Kerala, Andhra Pradesh and Chhattisgarh. This web database is accessible to the public through the institute website <http://iwst.icre.gov.in>. This will serve as a platform to exchange the information available with others and to serve as an information center for farmer, forest department and end user. The web database on India sandalwood will be extremely useful to various state forest departments, farmers, biotechnology researchers, tree lovers ecologists, research institutes, various government and non-government institutions, perfume & handicraft industries at national and international level. The aims of this project is to provide the technical & research information's to the public for the growing the valuable wood of *Santalum album*.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

Accordingly, end users to whom research findings needs to be circulated must be identified. It must specify the medium/ mode of dissemination/ diffusion to these end users. Limited dissemination of results may hinder the potential utilization of results. Therefore it is necessary to draw a utilization plan for effective diffusion of research findings among the end-users.





6. Studies on ecological and ethnomycological aspects of wild mushrooms of Nagaland

Principal Investigator: Dr. Rajesh Kumar

Duration: 2011 – 2014

Summary

Mushrooms are highly coveted item of food in North-eastern region of India. Nagaland, the northeastern state of India is rich in biodiversity and encompasses large number of edible and non edible mushroom species. Mushrooms are regarded as highly nutritious food containing large amount of proteins. Moreover, mushrooms are also important foreign exchange earners. Mushrooms have been recommended as food item contributing significantly to the protein nutrition of the developing countries like India (FAO), which depend mainly on the cereal diets. But the knowledge of edible mushroom in Nagaland is confined only to the ethnic tribes of the state. The consumption of wild edible mushrooms is increasing due to a good content of proteins and trace minerals.

In the present study young and matured capophores of 165 wild mushroom species were collected and identified from 12 locations in different districts of Nagaland. The selected species were analysed for their moisture, protein, carbohydrates, fat and fiber content. The protein content varied from 22.50-44.93 % and carbohydrates were recorded 32.43-52.07 %. The traditional knowledge of mycological information with respect to each one of them was collected seeking response to questionnaire containing 15 questions, in which personal observations and interviews with the old and experienced persons and local informants was recorded in the field itself, an inventory of wild mushroom has been developed. The consumption of different mushrooms varies from tribe to tribes. The Aoo tribes of Kohima and Mokokchung had some knowledge to identify the edible and poisonous forms of mushrooms. All details Ecological study of sites such as topography, forest type, habitat on which mushroom is growing specific association of fruit body with surrounding trees, herds and shrubs has been recorded at the time of collection. A database of ethno mycological information of wild mushrooms used by different ethnic groups of Nagaland was prepared.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The current environmental issues of global warming and climate change could adversely affect the regeneration and growth pattern of the delicate fungi which requires a specific micro-climate. Consequently, the high nutritional quality and unique flavor of these mushrooms are likely to be lost if these wild edibles are not properly conserved. The findings of the study are useful for the mushroom collectors and must be disseminated to user groups for sustainable utilization of mushrooms.



7. Growth and yield studies on forest plantations of teak in Karnataka for their sustainable management

Principal Investigator: Dr. V.P. Tewari

Duration: 2010–2014

Summary

Teak (*Tectona grandis*) is one the most important timber species occurring naturally in India. Appropriate growth models, based on advanced modeling techniques are not available but are necessary for the successful management of teak stands of the country. Long term forest planning requires mathematical models and the principles of Dynamical System Theory provide a solid foundation. Linear and non-linear equations were used to model the relationship of the volume with respect to dbh and total height. Merchantable volume equations for estimating merchantable volume to any minimum top diameter or bole length have also been constructed. The equations tested mostly fitted well to the data.

Stand Density Management Diagram (SDMD) has been constructed for Teak forest of Karnataka, India. The relationship between stand density, dominant height, quadratic mean diameter, relative spacing and stand volume has been represented. The relative spacing index was used to characterize the population density. Two equations were fitted simultaneously to the data collected from 27 sample plots measured annually for three years: one relates quadratic mean diameter with stand density and dominant height while the other relates total stand volume with quadratic mean diameter, stand density and dominant height.

A biologically consistent whole-stand growth model has been presented which uses the state-space approach for modeling rates of change of three state-variables: dominant height, stems per hectare and stand basal area. The model includes a stand volume equation as an output function to estimate this variable at any point in time. A continuous autoregressive error structure is included in the modeling process. For fitting volume equation, generalized method of moments was used to get efficient parameter estimates under heteroscedastic conditions. A simple model containing few free parameters performed well and is particularly well suited to situations where available data is scarce. Forest management planning relies on mathematical models that involve time. The study will be helpful in deciding the type and timing of management strategies and assessing the growth potentials and current and future economic value of the forest stands. Moreover, the study would be helpful in estimating current carbon stock, projecting increment and preparing state/species specific carbon tables.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The data generated, outcome of the study and growth models developed are extremely useful for the State Forest Department in estimating the yield with greater precision and accuracy, and are helpful in formulating effective policy & planning to manage the teak stand on a sustained basis. These are also useful in refining the growth & yield predictions for preparation of working plans in teak forests. The results of the study need to be disseminated to different stakeholders.





8. Fuel wood utilization and its impact on women's health in Jaunsar (Uttarakhand)

Principal Investigator: Dr. Rajeev Pandey

Duration: 2007 – 2009

Summary

Fuelwood is important source of cooking energy in the majority of households of rural India. Household biomass combustion for cooking purposes produces pollutants. Exposure to these pollutants has various adverse health impacts and is a major contributor to disease burden. This study focuses on positive and negative externalities of fuelwood use including forest conservation and the health, welfare and environment for the forest-dependent tribal community of Jaunsar, based on survey data and visual observations from this remote area of the Lower Himalayas, India. Health issues due to fuelwood use are explored among tribal women from 50 randomly selected households spread in 13 randomly selected villages. The pattern of fuelwood use including hardships in terms of time spent and distance travelled for collection of cooking energy and the kitchen structures are also elaborated. The emission of four major pollution gases—CO, SO₂, NO₂ and CO₂—due to fuelwood burning in kitchens is found to be beyond acceptable air standards, causing various reported health problems.

Kitchen-structure-related issues, biomass burning schedules and emission of smoke during the cooking process, which ultimately determine the exposure levels of family members, were investigated. The study revealed that residents' houses are in general made of wood with small kitchens with poor ventilation. More than 90% of households use traditional chulhas and burn unseasoned fuelwood. Chulhas typically burn for about 5 hours and cook 2–3 meals/day. High smoke concentration was observed during the start of burning in chulhas, for from 3 to 30 min depending upon the quality of fuel. The total annual particulate matter (PM) emission of the 14,399 Jaunsar households as result of fuelwood combustion was estimated at 0.67 Mt with annual black carbon (BC) emission of 0.33 Mt. This has serious implications for climate change as well as health of the rural population. The important finding of this study is that fuel wood burning is the ultimate requirement for cooking and is inextricably associated with indoor pollution and health of users.

Policy implications arise concerning options of local people to utilize other energy options. It is recommended that the adverse impacts should be tackled by framing household energy policy in totality, not limited to concern over the energy crisis but also considering associated implications including health and drudgery.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The outcome of the study will have implications for policy makers when deciding on an effective exposure reduction strategy and describes the risks connected between these health hazards and the health outcome of inhabitants exposed to them. The study will also be helpful in intervention strategies for “addressing” the issues relevant to fuel-wood generated exposure.



9. Inventorization, characterization and conservation strategies of selected rare and endangered plant species of India - Uttarakhand

Principal Investigator: Dr. Anup Chandra

Duration: 2012–2017

Summary

The state of Uttarakhand, India is endowed with rich biodiversity and has number of endemic and threatened plant species. In the present study, population status of select threatened species in their specific locations was carried out. Belt transect sampling method was used for survey which is one of the most widely used technique for estimating the size of the populations. *Catamixis baccharoides*, *Pittosporum eriocarpum*, *Ilex pseudo-odorata*, *Indopiptadenia oudhensis*, *Ilex nutans*, *Cyathea spinulosa*, *Mahonia jaunsarensis*, *Sophora mollis*, *Trachycarpus takil* and *Incarvillea emodi* were selected for study. *Catamixis baccharoides* was reported from Viasi, Tehri Garwal and Mohand areas in rocky hill slopes. *Pittosporum eriocarpum* was found in Mussoorie and Hathipav region. Only 5 trees of *Ilex pseudo-odorata* were observed in Hathipav and adjoining areas. *Indopiptadenia oudhensis* is reported from Champawat region. Regeneration of species was also observed in the area. *Ilex nutans* and *Sophora mollis* were observed in Sahastradhara and adjoining areas of Dehradun. Population of *Sophora mollis* is highly critical with about 10-12 fragmented populations. *Cyathea spinulosa* and *Trachycarpus takil* were reported from Pithoragarh district. *Mahonia jaunsarensis* was reported from Chakrata area. *Incarvillea emodi* was found in Vaiva and Khirsu areas. The habitats of these threatened species are facing severe threats, which includes invasive species, grazing, forest fire, agriculture and developmental activities. Density of invasive species like *Lantana camara* and *Eupatorium adenophorum* was very high.

It was observed that these species have limited distribution and very low population. It is therefore, essential to adopt suitable conservation measures to save these species from extinction. Efforts were made for ex-situ conservation of these important threatened species in the Botanical Garden of the institute. The findings of the study will provide baseline information on threatened species of Uttarakhand.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

As population of these species is very low, efforts should be done to mass multiplication of these species and then reintroduce these species in their natural habitat. The findings of the study need to be disseminated to different stake holders. Awareness programmes on conservation and sustainable utilization should be carried out because conservation of these species is not possible without active participation of local people.





10. Ecological Impact of Urbanization on Floristic Diversity in Natural and Manmade Forests of Doon Valley

Principal Investigator: Dr. Nirmal Ram

Duration: 2007–2010

Summary

Urbanization directly alters forest ecosystems by modifying ecological status, nutrient cycling, introduction of non-native (exotic) species and hydrology defining disturbance regions and changing microclimatic conditions. As per 1981, 1991 and 2001 census, urban population of Dehradun district has increased by 48.86 %, 50.28% and 52.94% respectively. Dehradun valley is surrounded by natural forests. To assess the impact of urbanization on floristic diversity the above study was conducted in Doon valley. The study revealed that urban habitations located on forest fringes reduced density of trees and subsequently have negative impact on its diversity and evenness in forest fringe area. Increase in tree density, diversity and evenness was observed when distance from the village increases. Less density was observed in highly disturbed forests located nearer to human habitations. Ecological impact of urbanization and village habitations on edge forest ecosystem is severe. Improvement in forest ecosystem was observed with the increase in distance from urban and village habitations. In some forest ecosystems impact of urbanization was visible even after three years during study period.

Socioeconomic survey of village and urban habitations located on forest fringe reveals that majority of house hold collect fuel wood and green fodder from nearby forests. Decrease in temperature and increase in humidity in comparison to open land was observed from highly to least disturbed forests during winter, spring and summer season. Undergrowth biomass production from highly disturbed forests was much less than moderately, partially and least disturbed forests. Energy and fodder trees plantations can reduce biotic pressure on forests up to some extent.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The findings of the study will be very useful to the state forest departments. The findings of the study need to be disseminated to different stake holders. It is suggested that permanent plots of different magnitudes from urban habitations should be established by State Forest Department to monitor long term impact on forest ecosystem functioning. Local people should be made aware about their negative impact on forest ecosystem functioning and intangible benefit of forests to them.



11. Periodic income generation for communities involved in coastal plantations

Principal Investigator: Dr. M. Balaji

Duration: 2003 – 2008

Summary

Shelterbelt plantations are known to protect the sea coast by curtailing soil erosion, stabilizing the land forms and protecting the coast and hinterland by action as wind breakers during cyclones and tsunamis. While these benefits could be reaped by resorting to regular plantation programmes that generate revenue only at the end of about 5 years or so, the income of communities involved in the work can be supplemented from time to time by the addition of intermittent income generating species like *E. citriodora* with no extra burden either in terms of investment or labour. In addition, the mixed plantations improve the green cover thereby leading to enhanced carbon sequestration too.

Plantation of *Eucalyptus citriodora* along with traditional *Casuarina equisetifolia* were tried as shelter belt plantations in 3 hectare area in a coastal Vana Samrakshana Samiti in Chippada, Visakhapatnam district, Andhra Pradesh. Analysis of soil at the site revealed that the soil is very poor in terms of nutrients. Three types of spacing with Quinquinox design in spacing, i.e. 3m x 3m; 2.5m x 2.5m and 2m x 2m was adopted for the plantation.

Herbage from *E. citriodora* was collected at quarterly intervals from selected plots and essential oil was distilled by a pharmaceutical firm near Visakhapatnam. Since computed value of 'F' is less than the standard value of 'F', it is to be concluded that difference in essential oil yield among the three spacing, i.e. 3m x 3m, 2.5m x 2.5m and 2m x 2m is non-significant. That means no discernable difference could be noticed in the oil yield obtained from the three spacing's adopted for raising the plantations. The study revealed that mixed plantations of *C. equisetifolia* and *E. citriodora* in 2.5m x 2.5m spacing gives relatively better results than either a mixed plantation of 3m x 3m spacing or a block plantation of the later species alone. The yield of essential oil was 23.34 liters during the project duration. Present market price of the oil at Visakhapatnam was Rs. 300/- per kg. Yield of timber from *C. equisetifolia* after harvesting was estimated to be 30m³.

Trials on NTFP species, *Aloe vera*, *Gymnema sylvestre* and *Asparagus racemosus* revealed that the soil and atmospheric conditions at the site were not congenial for the survival of above medicinal plants and mortality of the same were noticed.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

The plantations of *E. citriodora* along with *C. equisetifolia* in a coastal area have proved to yield notable financial returns by way of essential oil from the herbage. Even if *Casuarina* were harvested after attaining sizeable growth, the area will have the plantation of *E. citriodora* to act as a bio-shield against natural sea borne vagaries. The findings of the study will be very useful to the state forest departments and may be extended to SFD, coastal VSS, coastal EDC and coastal industrial corridors.





12. Quantitative estimation of Livestock feed from forest in Uttarakhand Himalayas

Principal Investigator: Dr. Rajeev Pandey

Duration: 2007 – 2010

Summary

Livestock sector forms an important livelihood activity for number of farmers, through supporting agriculture and supplementing incomes especially in the rural India. However, the scarcity of livestock feed i.e. roughages and concentrates is one of the major limiting factors for better productivity. Fodder under roughages is available at various sources- public forest, agricultural residue, etc. However, for hills the main source of feed is the forests.

Primary data has been collected as per pretested questionnaire form 364 randomly selected households engaged in livestock rearing from 66 villages distributed in various forest types of Uttarakhand to generalize the feed quantity for hilly and plain region i.e. for regions on forest dependent and without dependent. Information pertaining to the fodder utilization and socio-economic attributes were collected from each household to understand the consumption behavior and the feed status from all sources i.e. market, non forests and forests regions for all types of livestock. Based on the analysis of the estimates of livestock feed derived or obtained from various predefined sources, the quantity required and their economic value with respect to different types and proportion wise distribution for each has been worked out for various livestock. The prices of various livestock were either collected from market mechanism or through non market valuation technique (two scenarios- contingent valuation and ratio of dry & green matter of 0.40) for tree fodder. The analysis revealed that average proportion of feed quantity consumed from various sources was 58% from forests, 39% from non forests and 3% from markets for hilly region i.e. for forest dependent. However, for Plain region i.e. without forest dependent, the contribution of fodder for livestock feed was 97% from non forest region and 3% from markets with no contribution from forests. For hilly region the proportion of value in terms of price varies from 40-41% for forest; 40-41% for forests and 18% from market for the two scenarios. The value of quantity derived from forest was Rs. 4815 crore in Scenario 1 and Rs. 5210 crore for Scenario 2 for the state.

The share in value terms of rupees (in monetary term) for livestock feed derived from different sources in the country on annual basis as extrapolated was 4% from forest; 74% from non forests and 22% from markets in the Country with total value of Rs. 2813706 crore. Based on this analysis, the value of forest derived feed was Rs. 125272 crore, which is quite huge and reflects the value of India's forests for livestock feed.

Suggestions regarding follow up patenting possibility, utilization aspects and prototype

Though extrapolations suffer with systematic scientific approach and biased upward logically due to nature of extrapolation from the data of Uttarakhand, a hilly forest dominated state but may provide some indications for future line of research/actions. Therefore, these results may be utilized with precautions to allocate/decide the livestock feed value under the Forestry Sector, which may ultimately yield for improved reflections in the outlay of the sector and may better qualify to the sector.



Non-Wood Forest Products





1. Development of Suitable model for intercropping of commercially important medicinal plants with horticultural plantations in the temperate region of Himachal Pradesh

Principal Investigator: Jagdish Singh,

Co Principal Investigator: Sandeep Sharma, K.D. Sharma and A. Rajasekaran

Critical Analysis of the Research Theme & Summary of the Study

The research theme of the project is of great national and international importance and is in consonance with the govt policy to promote livelihood options through diversification of existing cropping systems.

A large hectareage of land is under horticultural cropping in the Himalayan states primarily under Apple orchards in the Higher zones and Mango and other fruiting species in the lower regions. Most of the land under these tree crops remains unutilized or underutilized.

The project aimed at utilising these available land resources for optimal utilization of cultivable land by integrating the medicinal crops in the interspaces resulting in diversification of cropping system on one hand and providing opportunities to enhance the economic returns to the farmers.

In summary, the project provided for development of medicinal plant intercropping practices in the Kullu and Shimla districts in collaboration with 19 progressive farmers. The species selected included *Aconitum heterophyllum*, *Valeriana jatamansi*, *Picrorrhiza kurroa*, *Polygonatum verticillatum* and *Angelica glauca* – all of them being in high demand in the herbal pharma sector worldwide. These species were intercropped under Apple and Cherry plantations.

The average economic gain varied from species to species under different horticultural species. The results showed that it is economically viable and physically possible to integrate the medicinal plants with existing horticultural crops in the selected districts.

Therefore, above models can be successfully used to enhance the income of the farmers significantly from such underutilized lands in the study area.

Scientific Finding & Contents

The project has successfully developed two intercropping models based on Apple and Cheery plantations. The species wise suitability / compatibility under both the horticultural crops is as under:

Aconitum heterophyllum

This species is suitable for intercropping with plantations of Apple (*Malus domestica* Borkh.) and cherry (*Prunus avium* Linn,) in high temperate zone

Rotation Period: 27 months

Final Yield: 202 kg/ha

Final Net Returns: INR 152,000 to 300,000

Valeriana jatamansi

This species is suitable for intercropping with plantations of Apple (*Malus domestica* Borkh.) and cherry (*Prunus avium* Linn,) in high temperate zone

Rotation Period: 27 months



Final Yield: 1200 kg/ha

Final Net Returns: INR 40,000 to 80,000

Polygonatum vericelluatum

This species is suitable for intercropping with plantations of Apple (*Malus domestica* Borkh.) and cherry (*Prunus avium* Linn,) in high temperate zone

Rotation Period: 27 months

Final Yield: 585 kg/ha

Final Net Returns: INR 46,800 to 58,500

Picrorhiza kurooa

This species is suitable for intercropping with plantations of Apple (*Malus domestica* Borkh.) and cherry (*Prunus avium* Linn,) in high temperate zone

Rotation Period: 27 months

Final Yield: 700 kg/ha

Final Net Returns: INR 40,000 to 57,000

Angelica glauca

This species is suitable for intercropping with plantations of Apple (*Malus domestica* Borkh.) and cherry (*Prunus avium* Linn,) in high temperate zone

Rotation Period: 27 months

Final Yield: 2300 kg/ha

Final Net Returns: INR 38,000 to 130,000

The study further revealed that the active principle (secondary metabolites) did not differ much from their wild relatives which is sign of their being equally effective therapeutically.

Suggestions regarding follow up patenting possibility, utilization aspects, and prototypes

The models developed needs to be tried on commercial scale under ICFRE umbrella in the states of J&K and Uttarakhand apart from other regions of Himachal Pradesh so that ICFRE can take lead in the livelihood development efforts.

The department of AYUSH may be apprised of these modes so that they can take it up as an AICRP project to enhance productivity of existing medicinal plant in demand. The results may also be shared with state Medicinal plant Boards of UK, HP & J&K for promoting amongst farmers.

Furthermore medicinal plants need to be explored for integration under the high altitude horticultural crops.

Some models also need to be developed for the lower Himalayan farmers undertaking Mango cultivation.

The plants need to be evaluated on API standards as well since most of these species are used by Herbal pharma industry for production of AYUSH drugs.

Protection (Entomology)



1. Assessment of insect pest problems of selected fast growing indigenous tree species in Tamil Nadu and Kerala

Principal Investigator: R. Raja Rishi, Research Officer

Duration: 2006-2009

Critical Analysis of the research theme & summary of the study

The study has helped to understand the periodic occurrence of insect pests, the type of damage and symptoms of attack caused by different pests, influence of biotic and a-biotic factors, on the occurrence, multiplication and spread of pests which are helpful in identification and management of specific pests of particular tree species at a given time. Insect pest damaging seedlings, saplings and young trees, the periodicity of their incidence, incidence of attack and nature of attack and nature of damage was studied for tree species like *Ailanthus excelsa*, *Melia dubia*, *Gmelina arborea*, *Thespesia populnea*, *Morus alba*, *Bombax cieba* and *Dalbergia sissoo* in 6 nurseries, eleven plantations and 3 forest areas of Tamil Nadu and Kerala by carrying out periodic surveys. 54 species insect pests were recorded in Tamil Nadu while 29 species were reported from Kerala which were then separated in major and minor pests. As many as 12 species were evaluated as major pests of these tree species in both the states. Biology of three species of defoliators was studied in detail. A pest calendar was also prepared based on the nature of damage, injury and intensity of attack in nurseries and plantations for each pest recorded. The study also recorded natural enemies associated with these pests. Abiotic factors like temperature, Humidity and Rainfall were recorded during the study and correlated with population and infestation intensity of insect pests in nurseries and plantations in different locations. Temperature, humidity and rainfall were found to have a significant positive correlation with some species of insect pests, reported in this study. The study revealed that for the above mentioned tree species sap suckers like *Myllocerus hirsutus*, *P. marginatus*, *T.beesoni*; defoliators *E.narcissus*, *A. fabriciella*, *M.discolor*, *M. viridanus*, *M. tenuicornis*, *D. pulverulentalis*, *E.geminata* and the borers, *I. quadrinotata* and *S. malabaricus* are serious pests in TamilNadu and Kerala. The study will be beneficial for forest department, farmers and industries engaged in practising forestry with these tree species.

Scientific findings and contents

The results have been presented tree species wise in a common format for each pest which have been classified into sap feeders, defoliators, Stem and bark feeding borers with common sub head i.e. Name of the pest, Insect classification, Pest type/status, description, damage caused, period of occurrence, alternate hosts and natural enemies along with images of many species. Biology in brief of a few species i.e. *Eligma narcissus*, *Atteva fabriciella*, *Eupterote geminate* is also given. All the pests have been characterized into Major & minor pests. The pest calendar of tree species given the name of the pests along with its, type of feeding habit/injury, level of infestation month wise for both the states separately. Biotic and abiotic factors are dealt with separately. Natural enemies of twelve species of insects are listed. Soil types of plantation and natural forests were studied by determining their Texture, pH, EC, Macro nutrients (N,P,K) and micro nutrients (Cu,Mg, Fe, Zn) for different localities. Average monthly temperature, humidity and rainfall was also determined for locations of nurseries, plantations and natural forests. Correlations were then established between average monthly temperature, humidity and rainfall with each pest population in both the states, separately.





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

A field guide was to be prepared based on the findings of this study and released for the benefit of the users as mentioned in the conclusion section of the PCR. A follow up project has already been taken up to develop specific IPM techniques for the key pests of *A. excelsa*, *G. arborea* and *D. sissoo*, as mentioned in the conclusion section of the PCR. Knowledge and experience gained out of the project can help in planning a training programme and practical demonstration of pest management techniques to end users like field foresters, farmers and wood based industries.

2. Development of rearing technique for production of insect predator, *Canthecona furcellata*, as bio-control agent for larval defoliators

Project Investigator: Mr. Subash Chander, Scientist-C, TFRI, Jabalpur

Duration: 2012

Critical Analysis of the Research Theme & Summary of the study

Investigations were carried on the occurrence of the predator *Canthencon furcellata* in sal, teak and bamboo plantations in Madhya Pradesh, Chhattisgarh and Maharashtra. The objectives were periodical surveys, host-development stage specificity tests of predator against larval defoliators, effect of temperature on development of predator and screening alternate hosts for rearing the predator throughout the year. Best practices protocol developed for mass culture of *C. furcellata* in laboratory.

Scientific Findings & Contents

The objectives included collection, host-development stage specificity tests of predator against larval defoliators, effect of temperature on development of predator and screening alternate hosts. The findings reveal irregular occurrence in forest areas, with increase in population from July onwards. The rice moth, *Corcyra cephalonica* was the best host insect under laboratory conditions at 27°C for mass multiplication of the predator followed by Bamboo leaf roller, *C. coclesalis*; Teak Skeletonizer, *Eutectona machaeralis*; Sisham defoliator, *Plecoptera reflexa* and sal defoliator, *Caviria sericea*, respectively in Central India. The bug has a predatory potential of consuming 154-212 larvae of *C. cephalonica* in its total life span varying between 20°C-35°C. The Nymphal period of the predatory bug was inversely proportional to increase in temperature, while longevity and total life span were negatively affected with temperature rise. Predatory potential was maximum on *P. reflexa* in three different temperature regimes, as compared to other species of hosts. Eggs cards of *C. furcellata* were also prepared for developing a delivery medium for the field. Best practices protocol developed for mass culture and release of *C. furcellata* in laboratory against insects pests of forests of central India

Suggestions regarding follow up, patenting possibility, Utilization aspects, prototype

The PI has himself suggested “detailed experimentation on the subject as a separate project for investigating related factors” as follow up of this project. Protocol developed for mass rearing of host moth and the predatory bug may be published and circulated in biological control programmes of Central India.



3. Survey and identification of insect pest associated with *Dalbergia sissoo*, *Gmelina arborea* and *Shorea robusta* of Jharkhand

Principal Investigator: Dr. Arvind Kumar, Scientist-C, IFP

Duration: 2011-2014

Critical Analysis of the research theme & summary of the study

The PI had surveyed nineteen districts of Jharkhand for insect pests. 17 species are reported infesting *Dalbergia sissoo* with nine species as major pests. *Gmelina arborea* were infested with twenty insects of which 10 are major pests. 18 insects were recorded infesting *Shorea robusta* with seven species being major pests. District wise relative infestation by insect pests was also determined for all the three plant species separately to determine the major pests. No control measures are given.

Scientific findings and contents

Nine insect pests were recorded as a major pest of *D. sissoo* with their maximum per cent infestation viz. *Apoderus sissu* (29.82%), *Mylocerus discolor* (16.25%), *Plecoptera reflexa* (78.40%), *Ascotis infixaria* (57.50%), *Dichomeris eridantis* (86.15%), *Leucoptera sphenograptia* (82.17%), *Leptocentrus taurus* (91.57%), *Myzus persicae* (62.88%) and *Odontotermes obesus* (95.40%).

Ten were found to be the major insect pest of *G. arborea* with their maximum plant infestation viz. *Alcides gmelinae* (24.62%), *Dihammus cervinus* (13.00%), *Calopepla leayana* (18.82%), *Xyleutes ceramicus* (16.43%), *Indarbela quadrinotata* (91.92%), *Pagyda* sp. (90.90%), *Phyllocnistis amydropa* (91.17%), *Tingis beesoni* (91.37%), *Megalurothrips peculiaris* (86.55%), and *Odontotermes* sp (34.27%).

Seven insect pests were found major for *S. robusta* in Jharkhand with their maximum plant infestation viz: *Hoplocerambyx spinicornis* (5.05%), *Mylocerus* sp. (95.31%), *Arna bipinctapex* (16.38%), *Rhynopsylla stylata* (22.68%), *Leptocentrus taurus* (31.33%), *Drosicha stebbingii* (13.17%) and *Odontotermes* sp. (91.43%).

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

The species list of major and minor pests given in the report along with the damage caused (Tables 1, 2 & 3) may be published along with the photographs of insects in the form of a pamphlet for Jharkhand state.





4. Biological Control of insect pests of medicinal plants-“*Abelmoschus moschatus*, *Gloriosa superba* and *Withania somnifera*”

Principal Investigator: Dr. P.B. Meshram, Scientist-F.

Duration: 2010-2014

Critical Analysis of the research theme & summary of the study

Seventeen insect pests viz. defoliators *Anomis flava*, *Sylepta derogata*; shoot borer *Earias viteila*; red cotton stainer *Dysdercus cingulatus* on *A. moschatus*; defoliators *Polytela gloriosae*, *Amsacta lactineus*, *Diacrisia oblique*; banded blister beetle *Malabris pastulata* on *G. superba* and bug *Plautia crossota*, aphid *Aphis gossypi*, sphingid larva, *Deilephila nerii*, mealy bug *Ferrisia virgata*, cow bug *Oxyrachis tarandus*, green stink bug *Nezara virudula*, weevil *Myloccerus* spp, cotton bollworm *Helicoverpa armigera*, leaf minor *Phytomyza* spp on *W. somnifera* were recorded and identified on the these 3 species of medicinal plants. Two parasites *Ichneumon* spp and *Stermia* spp. were also recorded on kalihari defoliator, *P. gloriosae*. On the basis of field experiments it was concluded that *Bacillus thuringensis* (Dipel) 1% followed by neem based pesticide (Gronim) 1% was found to be most effective against kalihari defoliator, *P. gloriosae*, muskdana defoliator, *Anomis flava* and shoot/fruit borer *Earias vitella*,. Neem based pesticide (Gronim) followed by *Bacillus thuringensis* (Dipel) 1% was found to be most effective against red cotton bug/stainer, *Dysdercus cingulatus* on the fruits of *A. moschatus* and aphid, *Aphis gossypi* on Ashwagandha, *Withania somnifera*. Predator, *Chrysoperla cornea* @ 500 per 100 sq m followed by parasitoid *Trichogramma chilonis* @1500 per 100 sq m was also found to be most effective for reduction of the larval population of defoliator *P. gloriosae* on *G. superba* and *A. flava* on *A. moschatus*.

Scientific findings and contents:

The results of the above study revealed that seventeen insect pests viz. defoliator *Anomis flava*, *Sylepta derogata*; shoot borer *Earias vitella*; red cotton stainer *Dysdercus cingulatus* on *A. moschatus*; defoliator *Polytela gloriosae*, *Amsacta lactineus*, *Diacrisia oblique*; banded blister beetle *Malabris pastulata* on *G. superb* and bug *Plautia crossota*, aphid *Aphis gossypi*, sphingid larva, *Deilephila nerii*, mealy bug *Ferrisia virgata*, cow bug *Oxyrachis tarandus*, green stink bug *Nezara virudula* weevil *Myloccerus* spp, cotton bollworm *Helicoverpa armigera*, leaf minor *Phytomyza* spp. infest *W. somnifera*. Two parasites *Ichneumon* spp and *Stermia* spp were recorded on defoliator, *P. gloriosae*. *Bacillus thuringensis* (Dipel) 1% followed by neem based pesticide (Gronim) 1% was found to be the most effective against kalihari defoliator, *P. gloriosae*, muskdana defoliator, *Anomis flava* and shoot/fruit borer *Earias vitella*. Neem based pesticide (Gronim) followed by *Bacillus thuringensis* (Dipel) 1 % was found to be the most effective against red cotton/stainer, *Dysdercus cingulatus* on the fruits of *A. moschatus* and aphid, *Aphis gossypi* damage Ashwagandha, *Withania somnifera*. Predator, *Chrysoperla cornea* @ 500 per 100 sq m followed by parasitoid *Trichogramma chilnois* @ 1500 per 100 sq m was also found to be most effective for reduction of the larval population of defoliator *P. gloriosae* on *G. superba* and *A. flava* on *A. moschatus*.

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

Life history details of major pests (Annexure-I) along with protocol developed for their biological control should be published in the form of a pamphlet for the states of M.P., Chhattisgarh & Maharashtra and circulated.



5. **Exploration of potential native natural enemies with a special emphasis on microbial bio-control agents for management of Casuarina hairy caterpillar, *Lymantia ampla* (Walker) and Ailanthus defoliators, *Eligma narcissus* Cramer and *Atteva fabriciella* Wallengren”**

Project Investigator: Dr. A. Balu, Scientist-F

Duration: 2010-2013

Critical Analysis of the research theme & summary of the study

The needle feeder *Lymantria ampla* and the defoliator, *Eligma narcissus* and *Atteva fabriciella* are considered as the key pests of *Casuarina* and *Ailanthus* respectively. 22 surveys in plantations located in different parts of the Tamilnadu. Two species of entomo-pathogenic fungus and 15 isolates of bacteria on *Casuarina* hairy caterpillar, *L. ampla* and 11 isolates of bacteria, a species of dipteran parasite and a species of predatory bug on *Ailanthus* defoliators, *E. narcissus* and *A. fabriciella* were recorded.

Morphological characterization of the fungi isolated from *Casuarina* hairy caterpillar, *L. ampla* was done and identified as *Beauveria bassiana* and *Metarhizium anisopliae*.

Scientific findings and contents:

Morphological and biological characterization for 12 isolated from the targeted pests of *Casuarina* and *Ailanthus* was completed characterized to the genus level. All the isolates were found belonging to *Bacillus thuringiensis*. Molecular characterization using RAPD technique exhibited genetic among the bacterial isolates.

The potential isolates were sequenced through 16s rRNA technique and submitted to EMBL (European Molecular Biology Lab) and obtained accession numbers AC HF545005, AC HF 545006.

The fungi species referred above were tested at two different concentrations against the targeted pests in the laboratory condition. The species *B. bassiana* at 2×10^8 spores/ml exhibited 80-90% larval mortality only in the case of *Ailanthus* defoliator, *A. fabriciella*. Whereas in the case of *Casuarina* caterpillar, *L. ampla* the product did not show effective mortality. It resulted in only 20% larval mortality.

Bioassay of the study of the 12 isolates of bacteria carried out against the pests, *A. fabriciella*, *E. narcissus* and *L. ampla* at the laboratory exhibited that the concentration 1×10^8 cells/ml of 3 isolates were only potential to effect 100% larval mortality over a period of 72-96 hrs.

Liquid and powder formulations of these 3 potential isolates were formulated and field tested on the targeted insect species. The liquid formulation was found more effective than the powder formulation. While the liquid formulation at 1×10^8 cells/ml resulted in 70-90% mortality of both the defoliators of *Ailanthus* over a period of 120 to 144 hrs and it was observed to be 60-70% mortality over a period of 168 hrs in the case of *Casuarina* caterpillar.

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

The protocol developed with potential isolates of the microbial pathogens identified can further be improved, developed into products and extensively tested in the field for management of targeted insects pest of *Ailanthus* & *Casuarina*, before recommending them for commercial use.





6. IPM for the key pests of *Ailanthus excelsa*, *Gmelina arborea* and *Dalbergia Sissoo* in nursery and in young plantations

Principal Investigator: Dr. A. Balu, Scientist-F

Duration: 2009-2012

Critical Analysis of the research theme & summary of the study

Defoliators such as *Aiteva fabriciella*, *Eligma narcissus* (defoliators in nurseries and plantations) and the sap sucker, *Maconellicoccus hirsutus* (plantations) are reported to be the major pests of *Ailanthus excelsa*, *Euptrote geminate* (in nurseries and plantations), *Sahydrassus malabaricus*, *Indarbela quadrinotata* and *Tingis besoni* (in plantations) are considered as serious pests on *Gmelina arborea*. Similarly, beetles such as *Mylocerus discolor* and *Mylocerus viridanus* (in nurseries) are found the major pests causing severe damage on *Dalbergia sissoo* plants. In the present study development of species specific IPM was attempted involving cultural, mechanical, biological, botanical and chemical methods for management of the above said key insect pests.

Scientific findings and contents

The bioassay study were carried out with six commercial Insecticides, Chlorpyrifos 20 EC, Quinalphos 25 EC, Monocrotophos 36 SL, Thiodicarb 35 SC, Imidacloprid 200 SL and Dimethioate 30 EC at five different concentrations such as 0.005%, 0.01%, 0.025%, 0.05% and 0.075% against the insect pests *Atteva fabricilla*, and *Eligma narcissus* (*Ailanthus excelsa*), *Mylocerus discolor*, *M. viridanus* (*Dalbergia sissoo*) and *Euptrote geminate* (*Gmelina arborea*) revealed that the concentrations 0.025 to 0.075% were effective resulting 100% mortality over a period of 24hrs. However the field evaluation of these effective concentrations against the pests studied only the chemical Monocrotophos at 0.025% was effective against all the pests resulting 100% mortality at 24hrs. Whereas all other chemicals were found effective between 0.05 to 0.075%

Bioassay studies with entomopathogenic fungus, *Beauveria bassiana* at 4 different concentrations (10^4 , 10^6 , 10^8 and 10^{10}) against the bark feeder, *Indarbela quadrinotata* and the stem borer, *Sahydrassus malabaricus* at the laboratory exhibited that the concentrations 10^6 , 10^8 and 10^{10} were effective in killing the larvae over a period of seven days. However the field evaluation revealed that spraying of fungal solution at 10^8 and 10^{10} concentrations over the frass tunnels, feeding areas on the bark and applied over the bore holes in the case of *J. quadrinotata* and removal of frass mat and injecting or spraying into the bore holes in the case of *S. malabaricus* were found effective. Similarly the seed oils such as *Jatropha*, *Pongamia* and *Neem* tested at five different concentrations (1 to 5%) showed that the concentration 5% could act as good antifeedant or repellent but they could exhibit only 30 to 40% mortality of the insect.

A *Neem* based formulation, *Neem Azal* 1% tested at 5 different concentrations (0.1 to 0.5%) expressed that the formulation 0.5% was effective against all the defoliators and sapsuckers studies in the present project. The product was able to result in 96 to 100% mortality of the pests in 24 to 48 hours in the lab bioassay and field efficacy tests.

Crude Leaf extracts of *Ailanthus excelsa*, *Aegle marmelos* and *Lantana camara* at 1, 2.5, 5, 7.5 and 10% tested against the targeted insect pests did not show any effect on the pest species studied.

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

The protocols developed with potential isolates of the microbial pathogens seed oil and leaf extracts identified, can be developed into products by extensively testing them in the field for management of



targeted insects pest of *Ailanthu excelsa*, *Gmelina arborea* and *Dalbergia sissoo*, before recommending them for commercial use in the form of a pamphlet.

7. Studies on the Impact of *Indarbela quadrinotata* on growth of *Casuarina equisetifolia*, factors influencing the pest infestation and developing eco-friendly management practices

Principal Investigator: Dr. K.R. Sasidharan, Scientist-E

Duration: 2009-2013

Critical Analysis of the research theme & summary of the study *C. equisetifolia* is grown mainly in the costal and riverine areas of Tamilnadu because of its short rotation and profitability, this tree is considered as one of the “farmer's favourite species” in the state. The farmers grow *C. equisetifolia* as monoculture plantation in blocks or under agro-forestry system along with many compatible agriculture and horticultural crops. The Tamilnadu Forest Department has raised extensive plantation of *Casuarina* along the sea shore as Bio shield to protect the coastal areas from natural calamities like Tsunami and cyclone. The Tamilnadu Forest Department Development Corporation (TAF CORN) has raised *Casuarina* plantations as a commercial venture, mainly along the river banks.

About 60 species of insects have been reported to feed on *C. equisetifolia* the bark eating caterpillar, *Indarbela quadrinotata* is considered as the most destructive pest in grown up plantations. A study showed that the bark eating caterpillar infestation was able to cause a loss of 6.66 percent in terms of diameter growth and 7.31 percent in terms of height growth per annum. A positive correlation was found between the infestation level of the bark eating caterpillar and the growth of the trees, with significantly higher impact on diameter increment.

A number of botanicals and a few entomo-pathogenic fungi (bio-control agents) were evaluated against the bark eating caterpillar in the laboratory condition and those materials found suitable/promising were tested in the field to know their efficacy.

Scientific findings and contents

The botanicals found to be effective against the pest in the laboratory condition were the seed oils of *Jatropha curcas*, *Pogamia pinnata*, *Hydnocarpus pentandra* and seed kernel extract of *Melia azedarach*. The entomo-pathogenic fungus, *Beauveria bassiana* was effective in the laboratory whereas the same result could not be obtained in the field conditions.

The naturally occurring strain of *B. bassiana* was found to be very effective against the pest in the field condition. The formulations such as *Melia azedarach* seed kernel extract (5%), *Pongamia pinnata* seed oil (5%), *Hydnocarpus pentandra* seed oil (10,000 ppm) and Neem oil (5%) as well as the plant based formulation A (1%) were found to be very effective in the field condition. Considering the easy availability of the material to *Casuarina* growers formulations of *Pongamia pinnata* seed oil (5%), Neem oil (5%) and Formulation –A (1%) developed by the Bio-prospecting Division of IFGTB, are recommended for managing the bark eating caterpillar.

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

The protocols developed with potential isolates of the microbial pathogens and botanicals found effective identified, can be developed into products by extensively testing them in the field for management of targeted insects pest of *Ailanthus excelsa*, *Gmelina arborea* and *Dalbergia sissoo* in the form of a pamphlet, before recommending them for commercial use.





8. **Isolation and Characterization of phytoecdysteroids from *Achyranthes aspera* and *Achyranthes bidentata* and their effect on the economic traits of *Mombyx mori* L.**

Principal Investigator: Dr. Rashmi, Scientist-C

Duration: 2012

Critical Analysis of the research theme & summary of the study

A plant product named as 'Samriddhi' was developed from the weeds (*Achyranthes aspera* and *Achyranthes bidentata*) which is a silk productivity enhancer for sericulture industry and tested at Regional Sericulture Research Station, Sahaspur on Silkworm, *Bombyx mori* L. The development of silk cocoons takes place in 24-36 hrs for complete spinning (maturity) but after spraying of 'Samriddhi' on the food (mulberry leaves) of Silkworm, *Bombyx mori*, the development time of cocoon reduced exceptionally low duration i.e., 12-15 hrs only. The Regional Sericulture Research Station, Sahaspur, Central Silk Board, D.dun has certified these results on the basis of their field trials carried out using 'Samriddhi'. Due to shortening of time period, consumption of mulberry leaf was less and uniform spinning is obtained. Labour cost and feeding cost is also reduced. The product is proposed to give an edge to the farmers in terms of competitiveness, financial gain and economic upliftment.

Scientific findings and contents

To the best of PI knowledge the occurrence of α -Lrhamnopyranosyl - (1-4) - (β -D-glucopyranosyluronic acid) - (1-3) oleanolic acid (A) and (α -Lrhamnopyranosyl - (1-4) - (β -D-glucopyranosyluronic acid) - (1-3) - oleanic acid - 28 - O- β -D-glucopyranosyl - (1-4) - β -D-glucopyranoside) (C) have not been reported earlier from nature and these two steroids were isolated from roots of *A. aspera* namely (24R) - Stigmata-5, 22 (E) - dien-3 β -ol or Stigmasterol [D-1] and (24S) - Stigmata-7, 22(E) - dien-3 β -ol or α -Spinasterol [D-2] is creation of "Samriddhi". The 'Samriddhi' is in process of filing a patent.

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

The 'Samriddhi' is in process of filing a patent when the report was written. The status may be now known. If it has attained success with farmers then it can be commercially sold by the Institute to the silk industry and given to farmers and protocols published in the form of a pamphlet.



9. Studies on thrips of forest and medicinal plants, problems caused by them and their management in Uttarakhand

Principal Investigator: Dr. Neena Chauhan, Scientist-E

Duration: 2015

Critical Analysis of the research theme & summary of the study

Thrips are minor pests of forestry and medicinal plant species in Uttarakhand. They may cause leaf malformation and transmit many kinds of diseases in plants; therefore, this study was undertaken in the state of Uttarakhand to examine their role in plant health. Survey and collection of insects belonging to order Thysanoptera from Uttarakhand was done in the Doon valley and Upper Himalayan. The study recorded 17 thrips species with new host record were collected and described: *Astrothrips tumiceps* (Karny,1923), *Ayyaria chaetophora* (Karny,1923), *Caliothrips indicus* (Bagnall,1913), *Doonothrips moundi* Kulshrestha & Vijay veer,1984, *Gynaikothripes uzeli* (Zimmerman), *Haplothrips gowdeyi* (Franklin,1908), *Helionothrips kadaliphilus* (Ramakrishna & Margabandhu,1931), *Lefroyothrips lefroyi* (Bagnall,1913), *Microcephalothrips abdominalis* (Crawford, DL1910), *Monilothrips kempi* Moulton,1929, *Panchaetothrips indicus* (Bagnoll,1912), *Scirtothrips dorsalis* (Hood, 1919), *Selenothrips rubrocinctus* (Giard,1901), *Trips flavus* (Schrank,1776), *Thrips hawaiiensis* (Morgan,1913), *Thrips tabaci* (Linderman) and *Ecaacanthothrips saguineus* (Bagnall,1936). Database of Thysanoptera included 25 species in 34 genera in two suborders was prepared. Keys were provided from the order up to species level of every new record. Experiments were conducted for the control of thrips attacking the *Mallotus philippinesis*. *Terminalia chebul*, *Ficus bengalensis* using two systemic insecticides. ; viz dimethoate and monocrotophos at 0.02, 0.03 and 0.04% in 3 replications respectively.

Scientific findings and contents

The 17 thrips species with new host record were collected and described were: *Astrothrips tumiceps* (Karny,1923), *Ayyaria chaetophora* (Karny,1923), *Caliothrips indicus* (Bagnall,1913), *Doonothrips moundi* Kulshrestha & Vijay veer,1984, *Gynaikothripes uzeli* (Zimmerman), *Haplothrips gowdeyi* (Franklin,1908), *Helionothrips kadaliphilus* (Ramakrishna & Margabandhu,1931), *Lefroyothrips lefroyi* (Bagnall,1913), *Microcephalothrips abdominalis* (Crawford, DL1910), *Monilothrips kempi* Moulton,1929, *Panchaetothrips indicus* (Bagnoll,1912), *Scirtothrips dorsalis* (Hood, 1919), *Selenothrips rubrocinctus* (Giard,1901), *Trips flavus* (Schrank,1776), *Thrips hawaiiensis* (Morgan,1913), *Thrips tabaci* (Linderman) and *Ecaacanthothrips saguineus* (Bagnall,1936). Dimethoate and monocrotophos at 0.02, 0.03 and 0.04% in 3 replications were applied to test their effectiveness in controlling the trips, respectively. The results revealed that even the 0.04% of both Dimethoate and monocrotophos insecticides were not found effective against the thrips, as mentioned in the report.

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

Important from the point of view to trips taxonomy and host plants affected. However, no control measures were developed.





10. Studies on the diversity of soil borne entomopathogenic fungi in different land use systems of North East India and their utility for the management of major defoliators of *Gmelia arborea* Roxb. and *Aquilaria malaccensis* Lamk.

Principal Investigator: R. Raja Rishi, Scientist-C, RFRI

Duration: 2013-2014

Critical Analysis of the research theme & summary of the study

The present study was carried out to develop a biological control system of major defoliators of *G. arborea* and *A. malaccensis*, specifically by making use of native EPFs collected from soil. The defoliators targeted in the study were *Heortia vitessoides* and *Craspedonta leayana*. Field tours were carried out to various land use systems of Assam, Meghalaya and Nagaland states and 97 soil samples were collected from different locations. The entomopathogenic fungi were trapped using insect bait method by *G. mellonella* (wax moth) larvae. Seventeen fungi were isolated from the infested insects and identified

Scientific findings and contents

Seventeen fungi were isolated from the infested insects and identified as the soilborne fungi, i.e. *Fusarium oxysporum*, *Fusarium* sp. (2 Nos.) *Mucor* sp. (2.Nos) *Aspergillus ochraceus*, *A. flavus*, *Trichoderma hamatum*, *Trichophyton* sp. (2 Nos) and *Metarhizium anisopliae* (2 Nos.) were isolated. Pathogenicity of the isolated fungi, i.e. *Fusarium* sp., *Beauveria bassiana*, *Metarhizium anisopliae*, *Aspergillus flavus*, *A. ochraceus*, *Trichoderma hamatum*, *Verticillium lecanii* and *Mucor* sp on the targeted pests were tested in laboratory condition. *B. bassiana* and *M. anisopliae* were found very effective in controlling the pest.

The efficacy of the potential isolates, i.e. *B. bassiana*, *M. anisopliae*, *V. lecanii* and *Paecilomyces* sp., were evaluated against *Heortia vitessoides* (III Instar) in field condition with different concentration of fungal spore concentration, i.e. 2.4×10^{10} , 2.4×10^8 , 2.4×10^6 and 2.4×10^4 spores/ml. *B. bassiana* concentration 2.4×10^8 and 2.4×10^{10} spores/ml were effective for the control of *H. vitessoides* and causing 84-90 percent larval mortality. The efficacy of *B. bassiana*, *M. anisopliae*, *V. lecanii* and *Paecilomyces* sp., was evaluated against the targeted pests *C. leayana* (III instar larvae and adult beetle) in field condition with different concentration of fungal solutions, i.e. 2.4×10^{10} , 2.4×10^8 , 2.4×10^6 and 2.4×10^4 spores/ml. The potential isolates of *B. bassiana*, *M. anisopliae*, *V. lecanii* and *Paecilomyces* sp. were tested for their safety to egg parasitoids *Trichogramma chilonis* and *Samia ricini* (Eri silkworm) and found safe to the beneficial insects.

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

The eco-friendly management techniques to control the important pests of forestry plant species were transferred to the user groups and stakeholders by conducting trainings and demonstrations in Assam. Two pamphlets of the same have already been published for the users but do not give proper guideline or protocols for the users. The protocols developed with potential isolates of the microbial pathogens found effective identified, can be developed into products by extensively testing them in the field for management of targeted insects pest of *Gmelina arborea* and *Aquilaria malaccensis*, before recommending them for commercial use by the PI.



11. Relative resistance of neem provenance to insect pest and mites and their bio-management in arid areas

Project Investigator: Dr. S.I. Ahemed

Duration: 2006-2009

Critical analysis of the research theme & summery of the study

The study was nicely conducted on 39 provenances of neem against *Myllocerus tenuicornis* and all the objectives were covered very nicely. The findings of the study are scientifically presented and summarized in the manuscript. The study revealed that neem provenances of Palampur and Jhansi were found to be the most resistant. The biology of *M. tenuicornis* has also been studied. It was also found that larvae of *M. tenuicornis* can be controlled using root decoction of Dhatura, *Calotropis procera* and *Euphorbia* gava and fungal pathogen *B. bassiana*.

Significant findings and contents

The study was conducted to assess the relative resistance is 39 (thirty nine) provenances of *Azadirachta indica* against insect pest.

A check list of 27 species of insect pest, 2 species of mollusk and 5 species of mites was prepared. Among these insect pests were found viz. termites, thrips, bugs, butterflies and moths, beetles and weevils. Five species of mites were recorded viz., *Eutetranychus orientalis* (Klein), *E. maximae*, *E. Phaseoli* Nassar and Ghai, *E. bilobatus* Nassar and Ghai and Red spider mite, *Tetranychus spp.*

A detailed study of major insect pest *Myllocerus tenuicornis* has been done. It undergoes five generations annually and complete life cycle in an average period of 43.76+2.65 days. The pre-oviposition, incubation, larval and pupal periods are recorded as being 5.96+1.22 days, 18.60+1.75 days, 2.95+0.45 days, 13.67+1.82 days, 11.92+0.15 days respectively. The sex ratio between males and females i.e., 1:1.12. It was also found that individually reared larva *M. Tenuicornis* has gained an more average weight 0.091+0.001 mg/ L, as compared to in groups (40 larvae/cage) 0.053+0.002 mg/ L weight.

The eggs, larvae, pupae and adults of *M. tenuicornis* were most abundant during July to September. The population was recorded to be the lowest during the moths from March to June.

Laboratory efficacy against larvae of *M. tenuicornis* different botanicals has also been recorded as root decoction of Dhatura (87.50%); whereas root decoction of *Calotropis procera* (53.7%), whereas application of Dhatura followed by *Euphorbia* gava (66.00%) mortality. Application of microbial control agent of neem weevil it has been observed that some adult weevils were found infected with the fungal pathogen *B. bassiana* and most of the weevils were killed at concentration 3.5×10^4 after 11 days. Integrated pest management is required for pest control of neem as Silviculture, chemical, biological and microbial control is useful for this.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

This study has not shown any such findings which could be replicated in future or could be patented. Most resistant provenances may be used for urban forestry, social forestry and useful to the forest department, NGO, urban development department.





12. Dynamics of insect populations in Agroforestry systems

Principal Investigator: Dr. Y. Sridhar, Scientist-C

Duration: 2008

Critical analysis of the research theme & Summary of the study

The theme of the study is very scientific and study was nicely conducted. Findings of the study is nicely articulated and summarized. It is reflected from the findings that cotton aphid, *Aphis gossypii*, thrips, *Scirtothrips dorsalis* and Cotton Jassid, *Amrasca biguttula biguttula*, spotted boll worm, *Earias vitella* and leaf roller, *Sylepta derogate* population influenced by the forestry component especially, Neem, custard apple, and *Eucalytus sp.* in agroforestry system. The results revealed that cropping of cotton in agroforestry system reduces the insect pest density and infestation. Subsequently it favors to the increase the population of natural enemies of insect pest in the ecosystem.

Significant findings and Contents

The study has been conducted as agroforestry system in five tree components namely; *Annona squamosa*, *Azadirachta indica*, *Dendrocalamus strictus*, *Emblica officinalis*, and *Eucalyptus sp.* alongwith cotton, *Gossypium herbaceum* as intercrop. Though a large of insect pest infesting to cotton have been recorded by many workers but in this study insect pest infesting to cotton in Hyderabad (A.P.) condition were recorded viz., cotton aphid, *Aphis gossypii*, thrips, *Scirtothrips dorsalis* and Cotton Jassid, *Amrasca biguttula biguttula*, spotted boll worm, *Earias vitella* and leaf roller, *Sylepta derogate*. In the intercropping of cotton with different agroforestry tree species has significant impact as:

Though population densities of *A. gossypii* though relatively non-significantly lower population density was recorded under different agroforestry combinations in Neem, custard apple and aonla. In case of thrips infestation was more in sole cotton as compared to that in intercrop of with Bamboo and custard apple systems. Consistently lower Jassid *Amrasca biguttula biguttula* population density was recorded in Bamboo intercropping system as compared to sole cotton crop. The spotted boll population was found to be lowest in Bamboo + cotton system percentage infestation was lowest but percentage bolls infested per plant were the highest. Cotton leaf roller, *S. derogate* infestation in terms of percentage plants infested was significantly higher in bamboo + cotton system and lowest in eucalyptus + cotton system as compared to control.

Natural enemy were reported higher in agroforestry component as compared to sole cotton crop. With respect to *C. sexmaculatus*, Aonla + cotton system was recorded for significantly higher populations consistently across the observation periods. Spider population was higher in neem + cotton and custard apple + cotton systems as compared cotton as sole crop.

Insect pest attacking to the tree species were not any new findings were observed with regards to insect pest of Neem, Bamboo, custard apple, *Eucalytus sp.* and Aonla.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

Follow up project on this aspect is not required as this type of many studies have been done by agroforestry institutes of ICAR. Subsequently, there is no such finding which could be patented. Further, it can be recommended that to get best cotton crop production agroforestry models can be adopted rather to go for sole cropping.



13. Studies on recruitment and metamorphosis of marine wood borer larvae

Principal Investigator: Dr. M. Balaji, Scientist-C

Duration: 2003-2008

Critical analysis of the research theme & Summary of the study

The theme of the project is very innovative and important for the sea dwellers, fishermen and wood dealers. The study is well covered all the objectives and finding are nicely and scientifically summarized. The project was well executed and content is rich with the scientific factors. Study revealed that larvae of *Lyrodus pedicellatus* survive on any unicellular algae in marine ecosystem. After growing very soon they attach to the wood surface, at the time of attachment to the wood surface presence of *Serratia ficaria* and *Pseudoalteromonas sp.* bacteria play a positive role on recruitment. Thought, wood surface exposed with *Halomonas sp.* and *Aeromonas sp.* bacteria can deter the *Lyrodus pedicellatus* larvae get recruited on the wooden wafers.

Significant findings and contents

Shipworms (*Lyrodus pedicellatus*) are belonging to Teredinids has sedentary mode of life adopted to bore and thrive in marine wood. The study is well covered of its objectives as per its methodology. It is revealed from the study that larvae of *Lyrodus pedicellatus* did not prefer any specific algal species and there was no difference in their survival and activity. The larvae did not exhibit any difference in activity when fed on combination of two species of algae. There was no any difference in development and metamorphosis of Teredinids larvae fed on two or single algae feed.

Different bacteria were also isolated from the natural biofilms and pure cultures of the maintained in the laboratory. They were characterized through a series of biochemical tests. Wooden wafers were coated with the pure cultures of the bacteria and offered to the teredinid larvae for their reaction to the bacteria. The larval response to the wooden wafers coated with *Serratia ficaria* and *Pseudoalteromonas sp.* was positive. It was revealed that more number of larvae compared to controls got recruited on these wood wafers. In contrast, the larvae did not get recruited on the wooden wafers coated with *Halomonas sp.* and *Aeromonas sp.* the percentage of successful larvae recruited on the wooden wafers coated with the above bacteria was 10.4% and 12.4%, respectively. From the experiment, it is clear that the larvae respond differently to different bacterial components of the biofilm. This may be because of the chemosensory mechanisms between the bacteria and the teredinid larvae, as proved in the case of several fouling organisms.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

These studies is very scientific and its follow up study focusing on the signal that emanates from different species of bacteria and response of the *Lyrodus pedicellatus* larvae will defiantly contribute a lot to protect the marine wood due to wood borer loss in eco-friendly manner. There is no such scientific content to patent.





14. Development of integrated pest management package for forest nursery insect pests of some economically important tree species

Principal Investigator: Dr. YP Jacob, Scientist-D

Duration: 2007

Critical analysis of the research theme & summery of the study

This study is very important, informative and useful. The theme of the research is very important for forestry afforestation point of view. Study has been well executed and nicely summarized its findings. The study has made on key nursery insect pest of *Albizia labbeck*, *Aegle marmelos*, *Ailanthus excelsa*, *Azadrachta indica*, *Mimusops elengi* *Phylanthus emblica*, *Pongamia pinnata*, *Syzagium cumini* and *Tectona grandis* and to develop a successful nursery it was suggested that : (1). Regular monitoring of nursery is important to manage the insect pest. (2). Sanitation of unwanted weeds and removal of alternate host plant of insect pest. (3). Eco-friendly botanical insecticide viz. spray of Pongam/ neem oil, NSKE and tobacco extract has been recommended for low to medium level of infestation. (4). In a very severe attack of insect pest in the nursery spray of chemical insecticide Dimethoate @ 0.06; Monocrotophos % 0.05% and Dichlorvos @ 0.076 % has been recommended

Significant findings and contents

The field study was conducted to assess the key nursery insect pest of *Albizia labbeck*, *Aegle marmelos*, *Ailanthus excelsa*, *Azadrachta indica*, *Mimusops elengi* *Phylanthus emblica*, *Pongamia pinnata*, *Syzagium cumini* and *Tectona grandis*. Myllocerus beetle and Grasshopper were considered separately.

IPM for the insect pest of *Albizia labbeck* –Cultural: removal and avoiding of alternate host, removal of affected seedlings. and spray of Pongam/ neem oil, NSKE @ 5% and chemical insecticide Dimethoate @ 0.06; Monocrotophos % 0.05% has been recommended. To avoid the insect pest infestation from the seedlings of *Azadrachta indica*: pruning of infested tree with insect pest should be done; spray of tobacco extract % 5% or Pongam oil % 2%; spray of Dimethoate @ 0.06 has been recommended. For *Aegle marmelos*: alternate host plant of insect pest should be avoided. and spray of NSKE @ NSKE @ 5% and chemical insecticide Dimethoate @ 0.06; Monocrotophos % 0.05% has been recommended.

For *Ailanthus excelsa* insect pest: Hand picking and destruction of larvae from the plants; spray of *Beauveria bassiana* fungus; tobacco extract @ 5%; NSKE @ NSKE @ 5% and chemical insecticide Dimethoate @ 0.06; Monocrotophos % 0.05% and Dichlorvos @ 0.076 % has been recommended.

For insect pest management of *Pongamia pinnata*: Hand picking and destruction of larvae from the plants; spray of *Beauveria bassiana*, *Verticillium lecanii* fungus; tobacco extract @ 5%; NSKE @ NSKE @ 5% and chemical insecticide Dimethoate @ 0.06; Monocrotophos % 0.05% and Dichlorvos @ 0.076 % has been recommended. For insect pest management of *Tectona grandis*: regular monitoring of the nursery, Hand picking and destruction of *Hyblaea puera* larvae from the plants; spray of *Beauveria bassiana*, *Verticillium lecanii* fungus; tobacco extract @ 5%; NSKE @ NSKE @ 5% and chemical insecticide Dimethoate @ 0.06; Monocrotophos % 0.05% and Dichlorvos @ 0.076 % has been recommended.

Additionally, an insect pest calendar has also been developed in this study which will support to the end users to manage the nursery insect pest.

**Suggestion regarding follow up, patenting possibility, utilization aspect and prototype**

The findings of the study are very useful for the nursery growers, foresters and farmers. The findings of this study can be extended to the end users through folders, information booklets in different language. There is no need of its any follow up study and also there is not any scientific novelty which can be patented.

15. Bio-ecology and integrated management of insect pest of Aonla, *Emblica officinalis* Gaertn.

Principal Investigator: Dr. Y. Sridhar, Scientist-C

Duration: 2009

Critical analysis of the research theme & Summary of the study

The objectives of the study were well covered in the study. The theme of the study is very scientific and nicely conducted. Findings of the study are well articulated and summarized. Bio-ecology of the aonla aphid, *Schoutedenia emblica* has been studied first time in this study very scientifically. *S. emblica* is found to be the most damaging insect pest of Aonla which can cause upto 100 percent fruit loss and even plant mortality. It was also found that this aphid can be controlled using chemical insecticide only.

Significant findings and contents

The study was carried out on *Emblica officinalis* and twenty one insect pest species of economic importance and eight natural enemy species were recorded. Yield from these treated individual trees were compared with yield from untreated controls. Five to 100 % reductions in yield and mortality of the plant was noticed due to aonla aphid, *Schoutedenia emblica*, whereas *N. viridis* occurrence is sporadic.

Biology of *Schoutedenia emblica* was worked out in laboratory on potted aonla plants. It is also a monoecious species living only on one host species i.e., *E. officinalis*. From birth to become viviparous female adult it takes about 6.54 to 8.5 days (n=10) at 30°C. A matured female adult gave birth to 4.7 nymphs first day of their life maximum fecundity was observed on fourth day. For the management of aonla aphid *Schoutedenia emblica* chemical and botanical insecticides were tested in field conditions six insecticides namely, Dimethoate 30 EC, Imidacloprid 17.8 SL, Spinosad 45 EC, Profenophos 50 EC, NSKE 15 EC, and Acetamipride 20 SP were found to be effective. However Knock-down was quick with Dimethoate followed by Profenophos, Confidor, and Acetamipride, Spinosad and Neem Seed Kernel Extract.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The finding of the study is very useful for the farmers and other stakeholders to take care the aonla plants from aphid and other sucking insect pest infestation. Though, there is no need to replicate it or its follow up study. Additionally, there is not any such findings which could be patented.





16. The Diversity of Bee Fauna of The Nilgiris

Principal Investigator: K. R. Sasidharan

Co Principal Investigator: C. Kunhikannan

Duration: 2005-2008

Critical analysis of the research theme & Summary of the study

The research theme of this study is very important from the insect diversity and role insects on floral diversity point of view. Study is well scientifically carried out and all the objectives were covered in this study. Findings of the study are nicely summarized for easy understanding of about the study. During the course of study maximum diverse genus was *Halictus* with its 17 species followed by *Nomiawith* 10 species. But most dominated species among the all the forest type was *Apisceranaindica* and *Apis dorsata* species, Though, *Apis mellifera* bee species have not been recorded from any forest type of Nilgiris. The dry deciduous forests type was recorded as most favorable habitat for bees followed by the Semi-evergreen forests though thorn forests exhibited least favorable habitat. The most of the bees favors diversified habitat with mixed species forest instead of monoculture plantations and the forest fire was found to be the most threat for the bees. The above finding of the research is very useful for the researchers and academicians and environmentalist.

Significant findings and contents

The studies have revealed the occurrence of about 92 species of bees in the Nilgiris district. These species fall under 14 genera viz. *Apis*, *Amegilla*, *Braunsapis*, *Ceratina*, *Chelostoma*, *Halictus*, *Lasioglossum*, *Megachile*, *Nomada*, *Nomia*, *Sphecodes*, *Thyreus*, *Trigona* and *Xylocopa*. But it was very important that European honey bee (*Apis mellifera*) was not recorded from the Nilgiris, during the present study. The highest diversity of bees was noticed in the dry deciduous forests, followed by the Semi-evergreen forests. The sub-tropical broad leaved hill forests, the moist deciduous forests and the swamp forests showed intermediate diversity, while the Montane Wet Temperate forests (Shola Forests) and the thorn forests exhibited lower diversity. The diversity of bee species in monoculture plantations was found to be low, compared to the natural mixed forests. Association of about 113 species of plants with different bee species was recorded in the study area. It has also revealed that rise in temperature has negative impact on bee fauna. The result also revealed that the monoculture plantations posed the highest threat to the bee fauna, though many of the invasive exotic plant species available in the district were source of nectar/pollen for the bees, considering the havoc caused by them to the natural forests. The Nilgiris South Forest division was found to be the maximum threatened to bee fauna diversity, followed by the Nilgiris North and Gudalur Forest Divisions. The Mudumalai Wildlife Sanctuary and the Mukurthi National park were found to have least threat to bee faunal diversity.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The research is very good and useful for the users and forest ecology point of view. This type of study should be undertaken in each state and forest type along with the relation study of bee fauna and flora diversity. There is none any such content which could be patented.



17. Eco-friendly management of bark eating caterpillar, *Indarbela quadrinotata* on aonla (*Emblica officinalis*) in plantations

Principal Investigator: Dr. P.B. Meshram, Scientist-F

Duration: 2015

Critical analysis of the research theme & Summary of the study

The theme of the study is very scientific and practical utility, further study was nicely conducted. Result of the study is well articulated and summarized. *Indarbela quadrinotata* is a major pest of *Emblica officinalis* this pest may cause tree mortality. Hence, the research theme of the study is very important and justified. The objective of this study: to assess the impact of damage bark eating caterpillar, screening of *E. officinalis* varieties and study the efficacy of bio pesticides against the bark eating caterpillar are well covered in the experimentation and scientific result has been mined. The result of the study is well articulated and nicely summarized in the report. As per the result Anand-1, Hatizoal followed by Kanchan, Francis, Chakaiya, NA-7 varieties are least susceptible, subsequently, clean cultivation of *A. officinalis* is one of the best and effective methods to reduce the infestation of *I. quadrinotata*, additionally, effective eco-friendly management has also been recommended.

Significant findings and contents

The result of extent of damage revealed that incidence of *I. quadrinotata* was very low in well managed plantations of *E. officinalis*; but very high incidence was recorded in poorly managed plantations in Madhya Pradesh.

Out of 12 hybrid and 01 desi variety of *E. officinalis* in eight different localities in Madhya Pradesh indicated that Anand-1, Hatizoal followed by Kanchan, Francis, Chakaiya, NA-7 were found to be least preferred by *I. quadrinotata*.

On the basis of the results combination of *Cleistanthuscollinus* + cow urine + verminwash 10% followed by combination of Neem + cow urine + verminwash 10% were found to be most effective to control the insect pest *I. quadrinotata* without harm to the natural environment. Three new records of the entomopathogenic fungi – *Fusariumoxysporum*, *F. moniliformae* and *Aspergillusniger* were also recorded on the infected larvae of bark eating caterpillar, *I. quadrinotata* in *E. officinalis* as a new records. Among these, application of *Fusariummoniliformae* 1.5×10^6 cell/ml followed by *F. oxysporum* was found to be most effective against *I. quadronotata*.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

This finding of the study is very useful for farmers, NGO, forest and horticulture department. Additionally, eco-friendly recommended treatments may be applied for other insect pest management in forestry. Though, there is not any such finding which could be patented at this stage.





18. Population dynamics of pests and suitable control measures in selected Silv-Horticultural models in Karnataka

Principal Investigator: Raja. Muthukrishnan

Duration: 2011-2014

Critical analysis of the research theme & Summary of the study

The study was scientifically conducted containing Sandalwood, *Greviliarobusta* and *Tectonagrandis* along with different horticultural species. Collection and identification of important insect pest was nicely done. Result of this study is very scientifically articulated and insects are grouped in sap sucking, wood borers, leaf defoliators and seed and flower feeder insect pest. Subsequently, safer insecticidal management has also been evaluated and recommended. Findings of the research study is nicely summarized and presented in the report.

Significant findings and contents

The more common and potential economically important pest in sandalwood based silvi-horti plantations were coccids viz. *Nipaecoccus viridis*, *Ceraoplastes actiniformis* and *Megapulvinaria maxima*, than any other insect pest. *Zeuzeracoffeae* was found common in all sandalwood based silvi-horti plantations.

Two new stem borers on sandalwood were encountered during the study viz. *Purpuricenussanguinolentus*, *Derolus volvulus* and *Exocentus sp.* the stem borer *Purpuricenussanguinolentus* was found to cause extensive damage to sandalwood plants grown with *Acacia auriculaeformis* plants.

A new sandal wood seed borer *Aracerus fasciculatus* Linn. (Anthribidae: Coleoptera) was found to cause serious damage of about 20% to sandalwood seeds in silvi-horti plantations. New weevils were found as defoliators of sandalwood grown with *Sesbaniagrandifolia* viz. *Peltotrachelus cognatus* Faust *Myllocerusedelicatulus*, *M. undecimpustulus*, *M. transmarinus*, *Dereodus vigilans* and *D. denticolis*. Other new defoliators belonging to the order Lepidoptera were *Amatapassalis*, *Micronia aculeate* and *Parallelia sp.* One species of grasshopper *Crotogonus sp.* belonging to the order Orthoptera was observed on all sandalwood based silvi-horti models in Karnataka. Pollen feeders collected from sandalwood plants were identified as *Oxycetoniaversicolor* and *O. juncunda*.

Imidacloprid was found to be the most effective insecticide followed by Chlorpyrifos and Metasystox to reduce the insect pest population in Silvi-Horticulture system.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The findings of the project will be very useful for the tree growers, horticulture farmers, forest department, NGO and researchers. Follow up project of this kind of study should be taken up and to be done regularly. Regular survey of every economically important forestry species has to be done, to find out the insect pest status of each region so that serious loss of forest from insect pest infestation could be avoided. Though, there is no such content which could be patent.



19. Studies on larval parasitoids, *Apanteles* spp. (Hymenoptera: Braconidae) of major defoliators of teak and sal forests of Orissa

Principal Investigator: Dr. N. Roychoudury, Scientist F

Duration: 2013

Critical analysis of the research theme & Summary of the study:

The theme of the research is very important and of practical utility. Findings of the study revealed that *Apanteles* sp. parasitoids play a vital role to minimize the insect pest population of Teak and Sal. Ten *Apanteles* species were associated with *Hyblea pœura*, a record 27 *Apanteles* species were found to be associated with the *Eutectona machaeralis*, both the major teak insect pest, followed by Sal insect pest *Lymantria mathura* seven *Apanteles* species and only three on *P. subapicalis* were recorded. Most of the *Apanteles* species are new to the insect pest and teak and sal ecosystem.

Significant findings and contents

Teak and sal forest of 106 localities belonging to 13 districts of Orissa (Angul, Bargarh, Balangir, Boudh, Ganjam, Jharsuguda, Kalahandi, Koraput, Phulbani, Nawapara, Sambalpur, Sonapur, Sundargarh) were surveyed for the collection of larvae and pupae of major defoliating insects of teak, namely *Hyblaea puera* Cramer (Lepidoptera : Hyblaeidae) and *Eutectona machaeralis* (Walker) (Lepidoptera: Pyralidae) and sal, namely *Lymantria mathura* Moore (Lepidoptera : Lymantriidae) and *Paectes subapicalis* Walker (Lepidoptera : Noctuidae), 336 samples of larvae and pupae of teak and sal defoliators were collected from field during their population outbreak. 37 species of *Apanteles*, viz. *Apanteles agilis*, *A. antipoa*, *A. aristolochidae*, *A. ashmeadi*, *A. australiensis*, *A. bambusae*, *A. belippae*, *A. caniae*, *A. calycinae*, *A. colemani*, *A. creatonoti*, *A. deliadis*, *A. detrectans*, *A. effrenus*, *A. endymion*, *A. erionatae*, *A. expulsus*, *A. fuscinervis*, *A. hasorae*, *A. hemitheae*, *A. hyblaeae*, *A. hyposidrae*, *A. javensis*, *A. lakhaensis*, *A. lamprosemae*, *A. leptothecus*, *A. machaeralis*, *A. neocajani*, *A. neotaeniaticornis*, *A. obliquae*, *A. philoeampus*, *A. prodeniae*, *A. prosper*, *A. recusans*, *A. rudius*, *A. tachardiae* and *A. taprobanae*, were identified as larval parasitoids on teak and sal defoliators. All these species are indigenous and are recorded for the first time from Orissa. The field parasitization potential of all these *Apanteles* species has been worked out. The biology of a major larval parasitoid of teak pests *A. machaeralis* and its laboratory tests against target insect pests have been carried out to find out its potential to mass multiply and act as biocontrol agent in management of key defoliators of teak and sal.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The finding is very important to the bio-control point of view. Further study may be undertaken to explore the possibilities of laboratory rearing and mass multiplication of *Apanteles* sp. Though there is no such scientific finding which could be patent.





20. Studies on insect biocontrol agent, *Chrysoperla carnea* and its potentiality as insect predator

Principal Investigator: Subhash Chander, Scientist-D

Duration: 2016

Critical analysis of the research theme & Summary of the study:

The theme of the study is very scientific and study was nicely conducted. Findings of the study is nicely articulated and summarized. The study is concentrated on the seasonal and feeding behavioral studies of predator *Chrysoperla carnea*. The study revealed that *C. carnea* prefers larvae of *Plecoptera reflexa* and its eggs as compared to others. Though, this predator is more effective against soft bodied insect like ahids, jassids and white fly in rainy season.

Significant findings and contents:

Occurrence of different stages of *C. carnea* varied in different areas surveyed. Although, available throughout the year except winters, the maximum population was available in the field during the months July to September. The eggs of the predator had maximum occurrence, followed by larvae, pupae and adults. Larvae of the predator consumed more number of teak skeletonizer larvae during its complete life cycle, followed by bamboo leaf roller and others. The larval stage of the predator exhibited shortest period when feed throughout its life on *Plecoptera reflexa* with longest in teak skeletonizer larvae.

The predator's adults developed from its larvae fed throughout life on bamboo leaf roller had maximum longevity, followed by bamboo leaf roller. It consumed more number of teak defoliator's eggs as compared to other eggs.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The finding is very important to the bio-control point of view, though, this predator is more effective against soft bodied insect like ahids, jassids and white. Further, many studies has already been done in the county on this line, hence further study on this theme should not be conducted. Though, there is no such scientific finding to patent.



21. Status of sal heartwood borer, *Hoplocerambyx spinicornis* Newman and its management

Principal Investigator: Dr. N. Roychoudhury, Scientist- G

Duration: 2016

Critical analysis of the research theme & Summary of the study

The theme of the research is very important and experimentation was nicely conducted, subsequently obtained results of the study is well articulated and summarized in the report. Though, finding of the study revealed that infestation of the *Hoplocerambyx spinicornis* beetle in MP and Chhattisgarh is in serious condition and this may cause epidemic situation. Further, the management strategies suggested in the result may not be very useful to manage the field situation.

Significant findings and contents

Study was undertaken to find the current status of sal borer, their natural enemies and possibility of its ecofriendly management in MP and Chattisgarh. Data on number of sal borer infested trees revealed that a total of 3764, 39572, 87427 and 32199 sal trees were found to be affected during the year 2012, 2013, 2014 and 2015, respectively. Minimum and mean temperatures of the study area are positive correlated with the borer affected trees.

A total seven natural enemies species have been recorded on sal borer, out of which one inhneumonid larval-pupal parasitoid and six predators. Among the predators, four species of insect predators, namely *Alaus sordiadus*, *Oecophylla smaragdina*, *Componotus compressus* and small red ant were found feeding on eggs/grubs/pupae of sal borer in the forest. During the present survey, feeding holes of woodpecker bird were also observed in the tree.

Pesticidal experiments revealed that in captivity, sprayed bark with Spinosad (0.4%), Hydrochloride and Monocrotophos (0.4%) showed 100% morality. It was also observed that female beetles which survived after sub-lethal treatments laid unfertilized eggs which did not hatch and shrinkage of eggs occurred.

Further, the results suggest that spraying of 0.4% Cartap Hydrochloride or 0.4% Monocrotophos followed by 0.4% Spinosad can be used in tree traps for killing sal borer beetles.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The finding is very important to make attention that the sal heart wood borer population is multiplying in the MP and Chhatisgarh. Further study may be undertaken to explore the possibilities of identification of insect pheromone under biorational management of sal heart wood bored should be taken up because other methods are not much effective. Identification of insect pheromone of *Hoplocerambyx spinicornis* beetle would be a breakthrough to make the effective pheromone based trap. Findings are useful for the SFD and forestry researchers. Though, there is no such scientific finding which could be patent.





22. Studies on seed insect pests of indigenous and exotic forest tree species and to develop IPM package for major insect damages in Gujarat

Principal Investigator: Dr. Meeta Sharma Research officer

Duration: 2014-2015

Critical analysis of the research theme & Summary of the study

The study is well executed and all the objectives were well covered. The findings of the study very nicely articulated and summarized. The study revealed that all kind of management strategy viz. cultural, mechanical, biological and chemical must be applied to prevent or protect the seed of the forestry tree species on the field or in the storage.

Significant findings and contents

A wide range of insect species belonging to the groups these include: Coleoptera -77 species, Lepidoptera -65 species, Hemiptera -18 species, Hymenoptera -2 species, Orthoptera - 8 species, Thysanoptera - 6 species, Isoptera - 04 species and Diptera - 6 species. Insects of family Bruchidae and Chrysomelidae were dominant on stored seeds of forest tree species of selected eight forest tree and three grass species of Gujarat was done.

The insect pests are greatly influenced by season whereas monsoon to early winters is the preferred season. August, September and October were the months when the population of *Carydon serratus* and *Bruchus bilineatopygus* were at its peak. This season critically monitored to avoid the pest incidence.

The IPM strategies recommended that clean cultural practices, follow rotation, agroforestry, social forestry and management of weeds proved effective for pest control. Infested seed or collection of seed should be avoided in the months of monsoon. Seeds should be stored in air-tight containers are recommended. Light trap may be used to attract the seed insect pest at the time of flowering to maturity of seed.

Fumigation of dried leaves of *Calotropis procera* is found effective to prevent the egg laying and sitting of adult moth on the plant. Fumigation of some dried leaves directly at the plantation sties and tobacco powder sprinkling during this period has gives effective positive results.

Rockon (0.2%) was the most effective botanical insecticide in plantations of *Ailanthus excels* and *Tectona grandis*, whereas Wepan (0.2%) was effective for stored seeds of *Acacia nilotica* and *Prosopis cineraria*.

Quinalphos 0.1 % and Monocrotophos 0.15 % were found the most effective chemical insecticides to check the spread of the insect pests upto epidemic level in field.

Suggestion regarding follow up, patenting possibility, utilization aspect and prototype

The finding is very important to protect the seed material on the tree or in the storage. Though, this kind many other studies have also been done hence, further study is not required. This study is useful for the SFD, NGO, farmers and researches. Though, there is no such scientific finding which could be patent.



23. Bio-ecology and management of insect pests of *Prosopis* sp., with special emphasis to gall forming insects in Indian Thar Desert

Principal Investigator: Dr. S.I. Ahmed, Scientist-SF

Duration: 1994-1999

Critical analysis of the research theme & Summary of the study

Under the present project, research work has been carried out on gall inducing agents of *Prosopis cineraria*. Mainly two insect species: *Contarinia prosopidis* and *Eurytoma settitibia* and one species of mite *Eriophyes prosopidis* have been recorded. Other insects including Coleopterans, Lepidopterans, Orthopterans and sucking insects of Hemiptera & Thysanoptera, wood borers, seed pests and nursery pests of *P. cineraria* were also recorded. A detailed study has also been carried out on the bioecology of gall inducing insects and gall mite. This work includes morphology as well as histopathology of different types of galls on stem, rachis, leaf and inflorescence. Two insect pests: *Contarinia prosopidis*, *Eurytoma settitibia* and one mite: *Eriophyes prosopidis*, causing galls on *Prosopis cineraria* have been described in detail. Moreover, in the present study, main focus has been given on histopathology of these galls. An attempt has also been made to study the histological changes during the gall formation in rachis, stem, leaf and inflorescence of *Prosopis cineraria*. Observations were also made to record the structural damage during gall formation. Effect of annual lopping of *Prosopis cineraria* has also been studied on the formation of mites induced galls and resultant pod production. Results on lopping study are clearly showing that the lopping allows the trees to attain a well developed crown and a balanced canopy and the lopped trees remained less infested by the gall mite attack.

Scientific findings & contents

During the studies in the present project, two gall forming insects: *Contarinia prosopidis* and *Eurytoma settitibia* and one mite species: *Eriophyes prosopidis* have been recorded on *Prosopis cineraria* which have also been recorded by several earlier researchers but in the present investigations, stem gall producing agent *Eurytoma settitibia* on *Prosopis cineraria* is a new pest record from Rajasthan. In previous records four species of moths: *Assura albicostalis*, *Anarsia triaenota*, *Eucosma lioplintha* and *Ascalenia* sp. were recorded, causing inflorescence gall on *Prosopis cineraria* but in present investigation, involvement of these microlepidopterans in gall formation is negligible. The mite: *Eriophyes prosopidis* shows highly monophagous nature, especially on *Prosopis cineraria*. During the study on host specificity test, larvae of *E. prosopidis* exhibited negative feeding response on five other thorny species, namely *Acacia nilotica*, *Prosopis juliflora*, *Acacia tortilis*, *Acacia senegal* and *Acacia catechu*. Experiment on lopped and un-lopped trees of *Prosopis cineraria* revealed that the percentage of gall formation per inflorescence in lopped trees was minimum (5.56%) and pod production was maximum (13.3%) whereas in un-lopped trees gall formation was maximum (49.5%) and fruit production was minimum (3.37%). These findings indicate that the higher production of pods and the lesser formation of galls in the lopped trees is because of the minimum infestation of gall mite. Earlier researchers also indicated this fact, but the present study has been carried out systematically to prove that the lopping allows the trees to attain a well developed crown, balanced canopy and lopped trees remained less infested by the gall mite attack.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up: In order to minimize the attack of gall forming mite: *Eriophyes prosopidis*, on *Prosopis cineraria*, lopping should be followed, for attaining a well developed crown, balanced canopy and maximum pod production. The lopped trees will remain less infested by the gall mite attack.

Patenting possibility: Nil





Utilization aspects: Practically, lopping can be applied in the field for minimizing the attack of gall forming mite: *Eriophyes prosopidis*, on *Prosopis cineraria*, so that the trees may attain well developed crown, balanced canopy and maximum pod production. Present study has also an academic value as the detailed morphology & histopathology of different types of galls on *Prosopis cineraria* has been studied.

24. **Morphology, bionomics and control of Rohida defoliator, *Patialus tecomella* Pajni et. al. (Curculionidae: Coleoptera)**

Principal Investigator: Dr. S. I. Ahmed, Scientist-SF

Duration: 1994-1999

Critical analysis of the research theme & Summary of the study

Research work under the present project has been carried out on the weevil, *Patialus tecomella*, a serious insect pest of *Tecomella undulata*, distributed throughout the north-western Rajasthan. This weevil has no other alternative host plant, except *Tecomella undulata*. Hence, it is known as “Marwar teak weevil”. Present study reveals that *P. tecomella* causes large scale skeletonization of young saplings of *Tecomella undulata* in various forest nurseries and plantations in Rajasthan. Other insect pests belonging to orders Coleoptera, Hemiptera, Isoptera, Lepidoptera, Orthoptera and Thysanoptera have also been recorded from *Tecomella undulata*. Majority of the insects are polyphagous. Under the category of defoliators, about 27 species (Coleopterans, Lepidopterans and Orthopterans) cause mild to severe damage. 13 species of sap sucking, 2 species of stem and root borers and 5 species of isopterans are major nursery insect pests, damaging *Tecomella undulata*.

Population dynamics and optimum ecological conditions; particularly temperature, relative humidity, rainfall, sunshine and food for the development of *Patialus tecomella* have been studied. Morphology of adults and larvae, life history and effect of crowding of larvae of *P. tecomella* have also been studied in detail. Relative resistance in 13 different provenances of *Tecomella undulata* against *P. tecomella* has been worked out. Provenance TUT9- Bhaislana, TUT11-Sundarpur and TUT7-Ratangarh were found least susceptible and performed the best in growth among all 13 provenances.

Scientific findings & contents

Under the present project, severe infestation and wide distribution of *Patialus tecomella* on *Tecomella undulata* has been recorded from Rajasthan. Observations have been taken on detailed morphology, bionomics, ecology and integrated approach for the management of *Patialus tecomella*. Infestation of *P. tecomella* along with its pest status and host specificity has also been recorded from Jodhpur and adjacent areas of Rajasthan, for the first time. Effect of larval crowding on the development and reproduction of *P. tecomella* has also been studied in detail, for the first time. Detailed morphometric study of adults & larvae of *Patialus tecomella* has also been carried out for the first time.

In the present study, some other important insect pests such as defoliators, leaf miners, sap sucking insects; stem, root, dry and dead wood borers, seed pests and nursery insect pests of *Tecomella undulata* have also been recorded. Attack of *Achaea janata* on *Tecomella undulata* has been noticed for the first time. Five species of foliage feeders: *Schistocerca gregaria*, *Pyrgomorpha brachycera*, *Poekilocerus pictus*, *Hieroglyphus banian* and *Locusta migratoria* have been recorded as new pests of *Tecomella undulata*. Study on detailed morphometrics, population dynamics, effect of crowding



of larvae of *P. tecomella* and screening of relative resistance in 13 different provenances of *Tecomella undulata* against *P. tecomella* has been studied for the first time.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

As the resistant provenances of *Tecomella undulata* against *P. tecomella* have been worked out. These resistant provenances of *Tecomella undulata* (Provenance TUT9- Bhaislana, TUT11-Sundarpur and TUT7-Ratangarh) which are least susceptible for infestation of *P. tecomella* and performed the best in growth among all 13 provenances. In future these provenances can be utilized in plantations of *Tecomella undulata*. Intra-specific crosses can also be followed for the tree planting stock improvement of *Tecomella undulata*.

Patenting possibility: Nil

Utilization aspects:

Resistant provenances of *Tecomella undulata* against *P. tecomella* (Provenance TUT9- Bhaislana, TUT11-Sundarpur and TUT7-Ratangarh) which are least susceptible for infestation of *P. tecomella* and performed the best in growth, can be utilized for plantations of *Tecomella undulata*. Detailed study on morphometrics of adults & larvae of *Patialus tecomella* has also its academic value.

25. Integrated Pest Management of Forest Insect Pests

Principal Investigator: Dr. S. I. Ahmed, Scientist SF

Duration: 1996-2002

Critical Analysis of the research Theme & Summary of the study

Under the present project, IPM has been developed for major insect pests of Khejri and Rohida. Four botanical pesticides: *Datura metal*, *Azadirachta indica*, *Euphorbia hirsuta* and *Calatropis procera* were tested against *Patialus tecomella* larvae, resulting highest mortality (80%) by *Datura metal*. Efficacy of neem seed oil in combination with insecticides has been carried out against larvae of *Patialus tecomella* and resulted the lowest larvae in the treatment of chlorpyrifos with neem seed oil. Anti feedant activity of methanolic extract of Neem Seed Kernel powder (NSKP) was also tested against *Patialus tecomella*, resulting the maximum anti feedant activity by 0.5% concentration. Twenty species of parasitoid, thirteen species of predators and three species of entomo-pathogens were recorded on insect pests of khejri and Rohida. *Eupelmus* sp. is egg parasitoid of *Halys dentatus*, *Eurybrachis tomentosa* and *Homoeocerus prominulus* on *Prosopis* spp.; *Tetrastichus spirabilis* is larval parasitoid of rachis gall midge *Contarinia prosopidis*. *Apanteles* sp. parasitizes *Achaea janata*, *Noorda* sp., *Bruchidus uberatus* and *Caryedon serratus*. *Trichogramma raoi* and *Brachygrammatella aligarhensis* parasitize *A. janata* and *Oxyrachis tarandus*. *Ufens brevifuniculata* parasitizes *O. tarandus*. *Encarsia acaudaleyrodis*, *Encarsia* sp. and *Eretmocerus rajasthanicus* parasitize *Acaudaleurodes rachipora*. Six species of spiders: *Neoscona thesis*, *Theridon* sp., *Peucetia* sp., *Cyrtarachne* sp., *Parawixia* sp. and *Cheiracanthium* sp.. were also recorded. *Holotrichia consanguinea* is parasitized by *Scolia aureipennis*, *Campsomeria collaris* and *Tiphia* sp.. Larvae of dry wood borer, *Acmeodera aurifera* were parasitized by *Bracon* sp., *Chaoilta* sp.. *Carcellia buitmezorgiensis* parasitized *Streblote siva*. *Billeae atkinsoni* parasitizes Rohida defoliator, *Patialus tecomella*.





Chrysopa scelestes feeds on flower thrips, *Frankiniella schultzei* and *F. dampfi*. *Canthecona blanchia* and *C. furcellata* feed on immature of *Oxyrachis tarandus* and *Eurybrachis tomentosa*. *Clavata jugatoria* feeds on *Taragama siva*. *Halymorpha picus* feeds on larvae of *Achaea janata*. *Acanthaspis flavipes* feeds on white flies, aphids and thrips. *Creoboter urbana* feeds on *T. siva* and *Achaea janata*. *Ploceus philippinus philippinus* (Baya), *Nectarinia asiatica* (Indian purple sunbird), *Turdoides striatus* (Jungle Babbler), *Copsychum saularis saularis* (Red Vented Bulbul), *Acridotherus tristis* (Indian Mayna), *Dicrurus paradiseus paradius* (Racket-tailed Drango), *Upupa epops epops* (Hoopoe), *Merops orientalis* (Common green Bee-hunter), *Nyctornus athertoni athertoni* (Blue bearded Bee hunter) are bird predators of several insects of *Prosopis* spp.

Two species of Entomopathogenic fungi: *Beauvaria bassiana* and *Aspergillus parasiticus*; and one virus: Nuclear Polyhedrosis virus attack on insect pests of *Prosopis* spp. *Holotrichia consanguinea* was infested by *Beauvaria bassiana*. *Streblot siva* was susceptible to Nuclear Polyhedrosis virus.

Observations were also taken on biological control of *Patialus tecomella* and *Taragama siva*. Biology of *Billeae* sp. was studied. Field efficacy was carried out of pupal parasite *Billeae* sp. against *Patialus tecomella*. Efficacy of *Beauvaria bassiana* was also carried out against *Patialus tecomella*. Observation was also taken on biological control of *Taragama siva*. Biology and efficacy of *Tetrastichus spirabilis* and *Eupelmus* sp. was also carried out.

Integrated Pest Management of *Patialus tecomella* was studied, where observations were taken on biology of *Billeae atkinsoni* and field efficacy of *Billeae atkinsoni* against *Patialus tecomella*. Pathogenicity of *Beauvaria bassiana* was also tested against *Patialus tecomella*. Efficacy of four botanical products were also tested against *Patialus tecomella*. Efficacy of neem seed oil in combination with insecticides was also tested against *Patialus tecomella*. Organophosphorus and neem seed oil were also tested against *Patialus tecomella*. Relative toxicities of different insecticides were tested against *Patialus tecomella*.

Scientific findings & contents

Findings of the project have observations on IPM of insect pests of Khejri and Rohida. Four botanicals: *Datura metal*, *Azadirachta indica*, *Euphorbia hirsuta* and *Calatropis procera* were tested against *Patialus tecomella*. Efficacy of neem seed oil in combination with insecticides has been carried out against *P. tecomella*. Anti feedant activity of methanolic extract of Neem Seed Kernal powder (NSKP) was also tested against *P. tecomella*. Twenty parasitoids, thirteen species of predators and three species of entomopathogens were recorded on insect pests of khejri and Rohida. *Eupelmus* sp. is egg parasitoid of *Halys dentatus*, *Eurybrachis tomentosa* and *Homoeocerus prominulus*; *Tetrastichus spirabilis* is larval parasitoid of *Contarinia prosopidis*. *Apanteles* sp. parasitizes *Achaea janata*, *Noorda* sp., *Bruchidus uberatus* and *Caryedon serratus*. *Trichogramma raoi* and *Brachygrammatella aligarhensis* parasitize *A. janata* and *Oxyrachis tarandus*. *Ufens brevifuniculata* parasitises *O. tarandus*. *Encarsia acaudaleyrodis*, *Encarsia* sp. and *Eretmocerus rajasthanicus* parasitize *Acaudaleurodes rachipora*. Six species of spiders: *Neoscona thesis*, *Theridon* sp., *Peucetia* sp., *Cyrtarachne* sp., *Parawixia* sp. and *Cheiracanthium* sp. were also recorded. *Holotrichia consanguinea* is parasitized by *Scolia aureipennis*, *Campsomeria collaris* and *Tiphia* sp.. Larvae of dry wood borer, *Acmeodera aurifera* were parasitized by *Bracon* sp., *Chaoilta* sp.. *Carcellia buitonzorgiens* parasitizes *Streblote siva*. *Billeae atkinsoni* parasitizes *Patialus tecomella*.

Chrysopa scelestes is a predator of *Frankiniella schultzei* and *F. dampfi*. *Canthecona blanchia* and



C. furcellata feed on *Oxyrachis tarandus* and *Eurybrachis tomentosa*. *Clavata jugatoria* feeds on *Taragama siva*. *Halymorpha picus* feeds on larvae on *Achaea janata*. *Acanthaspis flavipes* feeds on white flies, aphids and thrips. *Creoboter urbana* feeds on *T. siva* and *Achaea janata*. *Ploceus philippinus philippinus* (Baya), *Nectarinia asiatica* (Indian purple sunbird), *Turdoides striatus* (Jungle Babbler), *Copsychum saularis saularis* (Red vented Bulbul), *Acridotherus tristis* (Indian Mayna), *Dicrurus paradiseus paradisi* (Racket-tailed Drango), *Upupa epops epops* (Hoopoe), *Merops orientalis* (Common green Bee-hunter), *Nyctyornis athertoni athertoni* (Blue bearded Bee hunter) are bird predators of several insect pests of Khejri.

Entomopathogenic fungi: *Beauveria bassiana* and *Aspergillus parasiticus*; and one virus: Nuclear Polyhedrosis virus attack on insect pests of *Prosopis* spp. *Holotrichia consanguinea* was infested by *Beauveria bassiana*. *Streblot siva* was found susceptible to Nuclear Polyhedrosis virus. Observations were also taken on biological control of *Patialus tecomella* and *Taragama siva*. Integrated Pest Management of *Patialus tecomella* was studied. All above observations and study is systematic and scientific.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

Results and observations on Integrated Pest Management of insect pests of Khejri and Rohida are important and these results are helpful for controlling the insect pests of Khejri and Rohida. Chemical control and botanicals along with neem oil can be utilized for controlling the insect pests of seedlings of *Prosopis cineraria* and *Tecomella undulata* in nurseries and plantations. Parasitoids, predators and Pathogens, studied during the project can also be utilized in biological control of insect pests of *Prosopis cineraria* and *Tecomella undulata*. Such systematic and detailed studies should also be carried out for the insect pests of other Key forest tree species.

Patenting possibility: Nil

Utilization aspects:

Observations and studies carried out on chemical insecticides and botanicals along with neem oil can be utilized for controlling the insect pests of seedlings of *Prosopis cineraria* and *Tecomella undulata* in nurseries and plantations. Parasitoids, predators and Pathogens, studied during the project can also be utilized in biological control of insect pests of *Prosopis cineraria* and *Tecomella undulata*. Results of project are applicable in field. Several parasitoids and pathogens, studied in the project have academic as well as applied importance in biological control of insect pests of *Prosopis cineraria* and *Tecomella undulata*.

Prototype:

Such systematic and detailed studies should also be carried out for controlling the insect pests of other Key forest tree species.





26. Studies on seed pest of Forest tree species in Arid and Semi arid region

Principal Investigator: Smt. Seema Kumar, Scientist D

Duration: 1995-2000

Critical Analysis of the research Theme & Summary of the study

Under the present project, research work has been carried out mainly on six seed insect pests: *Bruchidius albizziae*, *Bruchus pisorum*, *Caryedon serratus*, *Caryedon prosopidis*, *Caryedon gonagra*, *Caryedon acaciae* infesting the seeds of forest tree species including *Albizia procera*, *Acacia catechu*, *Acacia nilotica*, *Acacia tortilis*, *Dalbergia sissoo*, *Prosopis cineraria*, *Prosopis juliflora* and *Tecomella undulata*. Main seed borer *Bruchidius albizziae* attacks the seeds of six forest trees: *Acacia nilotica*, *Acacia tortilis*, *Dalbergia sissoo*, *Prosopis cineraria*, *Prosopis juliflora* and *Tecomella undulata*. Some observations were also taken on sap sucking insect *Oxyrachis tarandus* on *Prosopis juliflora*; flower feeding insect, *Atteva fabriciella* on *Ailanthus excelsa*; Flowers damaging *Heliothis armigera* on *Leucaena leucocephala* and Fruit and seed damaging *Carpomyia* sp. on *Zizyphus* sp. Some observations were also taken on biology of *Caryedon serratus* and *Caryedon gonagra*. Few observations were taken on infestation of *Caryedon* sp., *Bruchidius albizziae* and *Bruchus pisorum* on seeds of these forest tree species in storage conditions. During storage moisture content of seeds should be brought below 8% and RH of container should not be higher than 65%. Drying of seeds very well before storage and application of Phorate 10 gms per Kg seeds was observed to give 72% seed germination. Finally, seed drying and application of Phorate 10 gms per Kg seeds during storage has been recommended.

Scientific findings & contents

Under the present project, most of the insects recorded on the seeds of forest tree species are common seed insects, recorded earlier by several other researchers. All observations are common, but the study has definitely Scientific findings, as the insect pests during this study have been identified up to species level. *Caryedon acaciae* infesting the pods and seeds of *Acacia ampliceps* has been recorded for the first time. Attack of *Bruchidius albizziae* on six forest trees: *Acacia nilotica*, *Acacia tortilis*, *Dalbergia sissoo*, *Prosopis cineraria*, *Prosopis juliflora* and *Tecomella undulata* has been given in detail for the first time. Observations on biology of *Caryedon serratus* and *Caryedon gonagra* are also having additional data on the periods of life cycles. Damage by rose-ringed parakeet and Bulbul on seeds & pods of *Dalbergia sissoo* and *Leucaena leucocephala* are common observations.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up: Application of present findings can be done by the researchers for observations and identification of seed insect pests of forest tree species. In storage conditions application of drying of seeds is common point to follow and the mixing of Phorate in seeds during storage can also be applied in future for storing the seeds of forest tree species.

Patenting possibility: Nil

Utilization aspects: Mostly applicable for future research work, identification and academic work. Findings have practical utility. Drying of seeds before storage is very common and usually applied. Mixing of Phorate in seeds during storage can also be applied for storing the seeds.

Prototype: It is a general study on insect pests of seeds of forest tree species in arid and semi-arid region.



27. Field manual for the insect pests and their control in agro-forestry plantations

Principal Investigator: Dr. Shamila Kalia, Scientist-E

Duration: 2015

Critical analysis of the research theme & Summary of the study

Under the present project, work has been carried out on field manual which contains a brief account of the insect pests of agro-forestry plantations and their control measures. This work included a comprehensive insect pest survey in the agro-forestry areas of Uttarakhand, Punjab and Haryana and important insect pests are included which are associated with important agro-forestry tree species such as *Bamboos*, *Dalbergia sissoo*, *Eucalyptus* sp., *Melia dubia*, and *Populus deltoides*. Total work of this project has been focused on the compilation of work, carried out by various researchers and information available on insect pests of important agro-forestry tree species in various forms in different literature resources and Internet. The field manual has been prepared for its easy understanding for common man and also for its suitability to take in practice and convey to all the workers, associated with agro forestry in different regions.

Scientific findings & contents

Present project work has been carried out totally based on the information available related to important insect pests of few agro-forestry tree species (*Dalbergia sissoo*, *Eucalyptus* sp., *Melia dubia*, and *Populus deltoides*) and *Bamboos*, compiled in a form of manual. This manual has been incorporated the information on seeds, nursery, plantation, clum & shoot borers and defoliators of *Bamboos*, 114 important insect pests of *Dalbergia sissoo*, 25 insect pests of different species of *Eucalyptus* like *Eucalyptus citriodora*, *E. glauca*, *E. leucoxydon*, *E. marginata*, *E. oblique*, *E. robusta*, *E. rostrata* & *E. tereticornis*; 15 insect pests of *Melia dubia* and 37 insect pests of *Populus deltoides* with brief description of their status, nature of damage, time of infestation and control measures.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

This is an incomplete field manual for the insect pests of Agro- forestry plantations. Only insect pests of four tree species (*Dalbergia sissoo*, *Eucalyptus* sp., *Melia dubia*, and *Populus deltoides*) and *Bamboos* are included with few literature based information. In future, field manual on insect pest of agro-forestry plantations should be prepared after thorough literature consultation and systematic field observations and including all available information on the subject. It should have an up-dated compiled information on insect pests of all agro-forestry tree species, utilized in plantations. Field photographs showing the damage, caused by insect pests should also be included. All information including physical control, mechanical control and application of bio-pesticides, chemical pesticides and biological control should be given in control measures.

Patenting possibility: Nil

Utilization aspects:

“Field manual for the insect pests and their control in agro-forestry plantation” is not useful in the present form. Most of the information given in the present manual are already available in literature and internet.





28. Development of Model for Integrated Pest Management with special reference to *Cedrus deodara*

Principal Investigator: Dr. Ranjeet Singh, Scientist- D

Duration: 2006

Critical analysis of the research theme & Summary of the study

Under the present project, model for Integrated Pest Management for the insect pests of *Cedrus deodara* could not be developed. Only some observations have been taken on the bio-ecology of *Ectropis deodarae*, a key defoliator of *Cedrus deodara*. Brief report on host-plant relationship, seasonal history, nature and extent of damage, cause of epidemic, host range and food preference of *Ectropis deodarae* has been given. Study area included three forest sites: Naldehra forests, Chhota Godown forests and Shimla catchment forests of Himachal Pradesh. Study revealed that *Ectropis deodarae* is a key defoliator of *Cedrus deodara* but also infest three other conifers: *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow*. Only three parasitoids: *Apanteles glomeratus*, *Apanteles ruficrus* and *Apanteles flavipes* were recorded, parasitizing *Ectropis deodarae*. *Calosoma beelsoni* was found to feed on larvae of *Ectropis deodarae*. The larvae and pupae of *Ectropis deodarae* were also found to be highly susceptible to the pathogens: *Aspergillus flavus*, *Bacillus cereus*, *Bacillus thuringiensis*, *Beauveria bassiana* and Nuclear Polyhedrosis virus. Study also revealed that natural control of *E. deodarae* has been broken down, due to grazing, removal of litter, thinning and lopping. Outline of early detection of outbreak of *Ectropis deodarae* has also been given.

Scientific findings & contents

Present study has very brief observations on bio-ecology of *Ectropis deodarae*. Only three parasitoids: *Apanteles glomeratus*, *Apanteles ruficrus* and *Apanteles flavipes* were recorded from the larvae of *Ectropis deodarae*. For controlling the epidemic of *Ectropis deodarae*, closing the forest for grazing was suggested for restoration of normal humus layer and ground flora consisting natural associates of deodar such as *Berberis aristata*, *Desmodium tiliaefolium*, *Desmodium elegans*, *Rosa macrophylla*, *Rubus biflorus* and *Rubus ellipticus*. Three conifers: *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow* have also been observed as hosts for *Ectropis deodarae*. *Dioryctria abietella* a cone worm of deodar has also been recorded.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

During a long project period of six years (2000-2006) with the team of five researchers (P.I., Co P.I. and three project associates) outcome of the project is below expectations and model for Integrated Pest Management with special reference to *Cedrus deodara* could not be standardized. Systematic work for the management of *Ectropis deodarae* should be carried out, in order to develop a package of Practice for the management of insect pests of *Cedrus deodara*.

Patenting possibility: Nil

Utilization aspects: Present study has only a little academic value, as some observations have been taken on bio-ecology of *Ectropis deodarae*. Only three species of parasitoids: *Apanteles glomeratus*, *Apanteles ruficrus* and *Apanteles flavipes* could be recorded from the larvae of *Ectropis deodarae*. Tree species such as *Berberis aristata*, *Desmodium tiliaefolium*, *Desmodium elegans*, *Rosa macrophylla*, *Rubus biflorus* and *Rubus ellipticus* were suggested to be taken as associates of *Cedrus*



deodara in order to minimize the attack of *Ectropis deodarae*; but this statement is merely an statement which is not supported by any experimental lay out and observations.

Prototype: Not applicable.

29. **Development of appropriate integrated management methods for the *Eucalyptus* gall wasp problem in nurseries**

Principal Investigator: Dr. John Prasanth Jacob, Scientist- E

Co Principal Investigator: Dr. V. Sivakumar, Scientist- D

Duration: 2010-2012

Critical Analysis of the research Theme & Summary of the study

In the present project, research work has been carried out for the development of suitable integrated pest management for the control of *Eucalyptus* gall wasp in nurseries. Gall formation by *Leptocybe invasa* has a major impact on the seedlings of *Eucalyptus* and its major outbreak was observed in nurseries and young plants in plantations. The present study illustrates that the seedlings with severe infestation show poor growth and form. Assessment of impact of gall damage on nursery seedlings, identification and impact of chemical and non chemical methods of management for gall wasp problem in nurseries and also the assessment of economic loss due to gall wasp infestation has been carried out. All experiments were laid out at eucalyptus nursery beds at the Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil nadu; News Print Ltd; Karur and Tamil nadu Forest Development Corporation, Pudukotai. This study pertains the testing of controlling methods for *Eucalyptus* gall wasp. These methods include net collection, trap methods i.e. sticky trap sweeping, sticky colour traps, light trap, Chemical treatments i.e. pesticides and plant based pesticides, Changed watering schedule, deployment of gall tolerant clones and biological control methods. The study revealed that the suspending different coloured sticky traps and light trap methods gave no response to adult gall wasps. Gall wasps tend to show no attraction to different colours or to the light source by the adult insects. Light trap was also not found suitable. Application of eight chemical treatments, tested against gall infestation in nursery beds were also not suitable, but soil application of Phorate showed the most effective treatment against gall infestation; other pesticides: Profenofos, Imidacloprid, Dichlorvos and plant based products, Nimbecidine and Citronella oil in Foliar treatment have not been found effective in reducing the gall incidence. The study also revealed that the clone C191 which is a gall tolerant clone showed minimum gall incidence of about 4%, where as clone CBE 5 is moderately susceptible clone and Clone C66 is highly susceptible clone, recorded 44% and 86% incidence respectively. Reduced watering regime did not show reduced gall infestation in nursery seedlings. Significant reduction in gall formation has been recorded when gall tolerant clones have been deployed along with the release of natural enemies *Quadrastichus mendeli* and *Megastigmus* sp. against gall wasp *Leptocybe invasa*.

Scientific findings & contents

Under the present project, work has been carried out for the management of *Leptocybe invasa*, a gall inducing wasp on *Eucalyptus* through the integrated pest management. The study reveals that the trap methods like light, colour and sticky trap did not reduce the gall wasp population. Application of plant based extracts and foliar application of pesticides also did not have significant impact on gall population except soil application of Phorate. The study also gives an important scientific finding that the clone C191 is tolerant, showing minimal gall incidence of about 4% and C66 is highly





susceptible clone recorded about 86% of gall incidence. Deployment of gall resistant clones of eucalyptus along with biological control of gall wasp will help to avoid extensive use of pesticides in nurseries and plantation sites and it will improve environment quality. The integrated method of application of gall tolerant clones and release of bio control agents like *Quadrastichus mendeli* and *Megastigmus* sp. against gall wasp *Leptocybe invasa* can be used by farmers, tree growers and forest based industries in their nurseries for controlling the gall wasp outbreak situation and to avoid loss of productivity of planting material.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

Findings of this research project clearly revealed that trap methods, application of insecticides and plant based extracts/ insecticides have not given the significant control of gall wasp infestation. Only the intergrated application of gall tolerant clones and release of biocontrol agents: *Quadrastichus mendeli* and *Megastigmus* sp. have given significant reduction of gall wasp infestation. Gall tolerant clones of Eucalyptus should be taken for development of planting stock for plantations. Application of Biocontrol agents: *Quadrastichus mendeli* and *Megastigmus* sp. can also be applied for controlling the gall wasp infestation.

Patenting possibility: Nil

Utilization aspects:

Findings of the present project are useful and these findings can be utilized for controlling the Eucalyptus gall wasp infestation. Application of the gall tolerant clones can be utilized for developing planting stock for Eucalyptus plantations. Release of Biological control agents: *Quadrastichus mendeli* and *Megastigmus* sp. can be applied in Eucalyptus nurseries and plantations for controlling the gall wasp infestation.



30. Influence of Eucalyptus species on the natural enemies incidence on the gall wasp *Leptocybe invasa*

Principal Investigator: Dr. John Prasanth Jacob, Scientist- E

Duration: 2010-2013

Critical Analysis of the research Theme & Summary of the study

Under the present project, research work has been carried out on the impact of *Eucalyptus* sp. on the incidence of natural enemies of gall wasp, *Leptocybe invasa*. The study includes the identification of oviposition preference; growth rate of gall wasp *Leptocybe invasa* on different species and clones of *Eucalyptus*; identification of host preference; growth and development of natural enemies like *Quadrastichus mendeli*, *Selitrichodes kryceri* & *Megastigmus* sp. on galls in different eucalyptus species and clones. It also includes the identification of the biochemical basis of attraction/ redressal of *Leptocybe invasa* by *Quadrastichus mendeli*, *Selitrichodes kryceri* & *Megastigmus* sp. In this study four Eucalyptus spp. i. e. *E. camaldulensis*, *E. tereticornis*, *E. grandis* and *Corymbia citriodora*; and clones : IFGTB 75, IFGTB 69, IFGTB 19, IFGTB 53, Clone 283, Clone 413, ITC3 and ITC 7 have been tested. Maintenance of gall wasp population and life cycle studies; mass culture of *Quadrastichus mendeli*, *Selitrichodes kryceri* & *Megastigmus* sp. and their life cycle studies have been carried out. Studies on the behavioral mechanism of gall wasp and natural enemies on different species and clones of Eucalyptus have also been worked out. The study revealed that the oviposition preference of any gall wasp population did not sustain *Leptocybe invasa* in *Corymbia citriodora*. The percentage incidence of gall wasp population also showed parallel increase & decrease during the different quarters of a year. The incidence of *Leptocybe invasa* is more in *E. camaldulensis* than in *E. tereticornis*, *E. grandis* and no incidence of gall wasp was seen in *Corymbia citriodora*. In case of clones, population of gall wasp was maximum in IFGTB 75 followed by ITC 3 & IFGTB 69 but very low population in clone ITC 7 and on the other hand clone IFGTB 19, IFGTB 53, Clone 283 and Clone 413 did not support any gall wasp population. Percentage incidence of galls on different clones showed that Clone 283, Clone 413 were found free from galls, clone ITC7 was recorded with very low percentage of galls and clone IFGTB 75, IFGTB 69 were highly susceptible with very high percentage of gall incidence. The study revealed that natural enemies of gall wasp like *Selitrichodes kryceri* did not survive during quarantine stage at the NBAII, therefore experiment has been carried out with *Quadrastichus mendeli* and *Megastigmus* sp. Extraction of volatiles from clones Entrapment method has been used. Different volatiles in eucalyptus germ plasm have also been studied by GCMS. Different eucalyptus sp. showed major volatile compounds i.e. *E. camaldulensis* like α Pinene, 1,8 Cineole; *E. tereticornis* also showed α Pinene as a major volatile. In *C. citriodora* α Pinene, β Pinene, 1, 8 Cineole limonene, β Caryophyllene, 1, 2 epoxytadecane and Cyclotetracosane have been identified.

Scientific findings & contents

In the present study, assessment of population levels and identification of oviposition preference of gall wasp *L. invasa* showed that the three species i.e. *E. camaldulensis*, *E. tereticornis* and *E. grandis* have been preferred by gall wasp except *Corymbia citriodora*. Among the different clones like IFGTB 75, ITC 3 & IFGTB 69 are highly susceptible to *L. invasa* with high percentage of gall incidence and clones like IFGTB 19, IFGTB 53, Clone 283 and Clone 413 were free from gall infestation. In case of *Corymbia citriodora* the present study suggested that due to having the hairs on all over the leaves and stem in *C. citriodora* may inhibit the gall wasp from oviposition. The thick





cuticle in resistant clones may also play a role in inhibiting oviposition by *L. invasa*. The life cycle duration of *L. invasa* on *E. camaldulensis* and *E. tereticornis* have been found shortest. In the present study the population level of parasitoids like *Quadrastichus mendeli* & *Megastigmus* sp. remained at a higher level on *E. camaldulensis* and *E. tereticornis*; besides susceptible clones like IFGTB 69, IFGTB 75 & ITC 3. No significant difference in life cycle of *Q. mendeli* & *Megastigmus* sp. have been observed on different clones and species of Eucalyptus. Several important compounds like α Pinene, β Pinene, 1, 8 Cineole limonene, β Caryophyllene, 1, 2 epoxytadecane and Cyclotetracosane have been identified from *C. citriodora* which can act as good repellent for *L. invasa*. The different volatile chemicals which were identified from eucalyptus have been incorporated into a delta trap for gall wasp management and natural enemy reinforcement in gall affected areas may helpful in future. Use of gall free clones and the natural enemies along with the volatile chemicals may reduce loss of productivity in nurseries and plantations due to gall wasp attack.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

The different volatile chemicals which were identified from eucalyptus can again be incorporated in future studies for delta trap for gall wasp management. Natural enemies should also be applied in gall affected areas for controlling gall infestation. Use of gall free clones along with the volatile chemicals may be taken for further studies for their application for controlling the gall infestation in Nurseries and plantations of Eucalyptus species and clones.

Patenting possibility: Nil

Utilization aspects:

All resistant clones, studied during the project period can be utilized for developing planting stocks for their field application. Natural enemies along with the volatile chemicals can be utilized for controlling the gall infestation in Nurseries and plantations of Eucalyptus species and clones. Other studies like biology and life cycle of gall wasp and its natural enemies are also of academic importance.



31. Development of coccinellids based biocontrol programmes for the Management of sandal scales and mealy bugs

Principal Investigator: Dr. R. Sundararaj, Scientist- G

Duration: 2016

Critical Analysis of the research Theme & Summary of the study

The present project or research work based on the management and control of *Ferrisia virgata* (striped mealy bug), *Nipaecoccus viridis* (coconut mealy bug) by *Cryptolaemus montrouzieri* and *Ceroplastes actiniformis* (coconut wax scale) by *Chilocorus nigrita* on *Santalum album*. The main objective of the study to focus on the management and control of scales and mealy bug of sandal by development of coccinellids through biocontrol programmes. This project work included monthly and quarterly field survey of sandalwood reserves i.e. Bangalore, Jarakbande, sandal plantation sites located in Gottipura, Kadugudi and Kadur respectively. Collection, preservation and identification of coccinellids have also been described in brief. The graphical representation of population dynamics of *F. virgata* and *N. viridis* have also been given. Field release and evaluation of coccinellids, predatory potential and standardization of rearing techniques for more potential coccinellids have also been described.

This study has revealed that 31 species of scales and mealybugs representing seven families i.e. Coccidae, Diaspididae, Kerridae, Margarodidae, Monophlebidae, Ortheziidae and Psuesococcidae were found infesting sandalwood out of which seven mealy bugs i.e (Family: Coccidae) *Coccus viridis*, *Pulvinaria polygonata*; (Family: Diaspididae) *Abgrallaspis cyanophylli*, *Chrysomphalus aonidum*, *Hemiberlesia lataniaev* and *Ischnaspis longirostris*; (Family: Monophlebidae) *Labioproctus poleii* were found breeding for the first time on sandalwood. The survey also revealed highly diversified beetles of 25 species have also been found active in sandalwood growing areas. The infestation of *Cardiococcus bivalvata*, *Parasaissetia nigra*, *Saissetia coffeae*, *Ceroplastes actiniformis*, *Parasaissetia* and *Paratachardina silvestri* results in drying branches causing die-back symptoms and ultimately death ion seedlings and trees were also found.

Scientific findings & contents

Under this present project work the major scientific finding was that the control of mealy bugs *Ferrisia virgata* and *Nipaecoccus viridis* by *Cryptolaemus montrouzieri* and the scale *Ceroplastes actiniformis* by *Chilocorus nigrita* very effective and ecofriendly. Seven mealy bugs *Coccus viridis*, *Pulvinaria polygonata*, *Abgrallaspis cyanophylli*, *Chrysomphalus aonidum*, *Hemiberlesia lataniaev*, *Ischnaspis longirostris* and *Labioproctus poleii* have been first record on sandal wood. *Cryptolaemus montrouzieri* and *Chilocorus nigrita* have also been identified as potential predatory coccinellids on sandal wood scales and mealy bugs. Mass multiplication of *Cryptolaemus montrouzieri* and *Chilocorus nigrita* were done and evaluated in field condition against *Nipaecoccus viridis*, *Ferrisia virgata* and *Ceroplastes actiniformis* respectively. The study revealed that release of *C. montrouzieri* and *Chilocorus nigrita* could control *Nipaecoccus viridis*, *Ferrisia virgata* and *Ceroplastes actiniformis* respectively within two months at the rate of 5 and 10 beetles per tree. The potential of these coccinellids in controlling the scales and mealy bugs have also been demonstrated in field conditions. *Paratachardina lobata lobata* and *Paratachardina silvestri* two species of family Kerridae have been found infesting very severely on sandalwood. Field release and evaluation of Coccinellid shows that release of *C. montrouzieri* against *Nipaecoccus viridis* and *Ferrisia virgata* could control these mealy bugs within two months at the rate of 5 and 10 beetles per





trees respectively and release of *Chilocorus nigrita* against *Ceroplastes actiniformis* also control within two months at the rate 5 to 10 beetles per trees but the effect was quick and more pronounced at the rate of 10 beetles per trees. The present context of growing *Santalum album* in agro-forestry conditions outside forest a holistic approach for the better management of economically important coccids is very much required to increase the production of sandalwood in pace with increased area of cultivation.

32. Damage assessment of gall making insect species of eucalyptus and its management by pesticides

Principal Investigator: Dr. N. Roychoudhury, Scientist-G

Duration: 2013

Critical analysis of the research theme & Summary of the study

Under the present project, work has been carried out on the evaluation of gall forming insect *Leptocybe invasa*, its natural enemies and management practices with bio-pesticide and chemical pesticides. This study also includes the observations on morphology of galls and gall insect; assessment of damage and effect of galls on the growth of seedlings. In order to assess the damage, caused by gall insect, survey has been carried out in five forest nurseries (SFRI, Pariyat, Majitha, Panagar and Mandla forest division, Katra) and five plantations (Khamariya, Dindori, Barganw, Badgarh and Anoopur forest division Patana). The damage caused by *L. invasa* in growth of seedlings and gall production in genotype/ hybrids of eucalyptus has been studied. The average height of seedlings and number of galls developed were compared among the different groups. One bio-pesticide (Spinosad) and five chemical pesticides (Dichlorvos, Dimethoate, Imidacloprid, Monocrotophos and Acetamiprid) have been tested for the management of galls. Periodical surveys of nurseries and plantations revealed that seven species of defoliators (*Achaea janata*, *Catopsilia crocale*, *Dasychira grotei*, *Eurema hecabe*, *Hyposidra talaca*, *Lymantria sobrina* and *Spodoptera litura*) and one sap sucker (*Chrysocoris purpureus*) have also been recorded on eucalyptus. Lady bird beetle, *Illeis indica* has been recorded as a predator of gall insect? The study also revealed that the infestation percentage of gall insect is less in hybrids. Spraying of bio-pesticide and chemical pesticides (0.05%) for six months at 15 days interval significantly reduced galls & increased height of seedlings. Monocrotophos was assessed best followed by Imidacloprid, Acetamiprid, Dimethoate, Dichlorvos and Spinosad.

Scientific findings & contents

The present study revealed that *Leptocybe invasa* is a major pest of eucalyptus. Eucalyptus galls affect the growth of seedlings. In order to minimize the galls infestation, bio-pesticide and chemical pesticides were tested and gave the effective results. Apart from *Leptocybe invasa*, seven defoliators (*Achaea janata*, *Catopsilia crocale*, *Dasychira grotei*, *Eurema hecabe*, *Hyposidra talaca*, *Lymantria sobrina* and *Spodoptera litura*) and one sap sucker (*Chrysocoris purpureus*) were also recorded for the first time feeding on eucalyptus. *Illeis indica* has been recorded as a predator of gall insect? Two eucalyptus hybrids (FRI-4, FRI-5) and one genotype (*E. tereticornis*) have been taken for monitoring the infestation of gall insect. The infestation percentage of gall insect in seedlings observed in hybrids FRI-4 (2.86%), FRI-5(20.54%), is much lesser as compared to genotype, *E. tereticornis* (90%). Regarding the development of galls with the age of seedlings, data reveal that one month old seedlings were free from galls. The use of biopesticide (Spinosad) and chemical



pesticides (Dichlorvos, Dimethoate, Imidacloprid, Monocrotophos and Acetamiprid) have been tested for the galls management and the results revealed that the spraying of these bio-pesticide and chemical pesticides (0.05%) on seedlings of eucalyptus for six months at 15 days interval, significantly reduced the gall formation and increased the height of seedlings. Observations indicated that seedlings growth affected by the galls, minimum growth was recorded in case of maximum galls whereas less galls were noticed with maximum height of seedlings. The expenditure involved for minimizing the infestation of gall insect and enhancement of seedling growth by the concentration of 0.05% bio-pesticide and chemical pesticides, Dichlorvos shows the lowest cost per plant, followed by Dimethoate & Monocrotophos whereas the highest expenditure was recorded by application of Spinosad.

Suggestions regarding follow up, patenting possibility, utilization aspects, Prototype

Follow up:

Application of tested Bio-pesticide and chemical pesticides can only be limited up to the nursery seedlings mostly and rarely in plantations, up to few years after plantation. These pesticides are not the permanent solution of Eucalyptus gall insect, *Leptocybe invasa*. Biological control of Eucalyptus gall wasp, *L. invasa* should be developed for its effective control. Yousuf, (2012-2017) has developed and applied biological control of eucalyptus gall wasp *L. invasa* in Punjab, by releasing the parasitoids: *Quadrastichus mendeli* and *Megastigmus viggianii*. Similar work can be applied, as and when required for controlling the eucalyptus gall wasp in nurseries and plantations in other eucalyptus growing areas of India.

Patenting possibility: Nil

Utilization aspects:

Bio-pesticide (Spinosad) and chemical pesticides (Dichlorvos, Dimethoate, Imidacloprid, Monocrotophos and Acetamiprid) can be utilized for controlling the gall wasp *L. invasa* mostly at nursery stage of eucalyptus seedlings, rarely in plantations up to few years. Cost effective analysis revealed that gall wasp management by Dichlorvos requires lowest cost per seedling, followed by Dimethoate & Monocrotophos whereas Bio-pesticide Spinosad application needs highest expenditure. Record of other insect pests: *Achaea janata*, *Catopsilia crocale*, *Dasychira grotei*, *Eurema hecabe*, *Hyposidra talaca*, *Lymantria sobrina*, *Spodoptera litura* and *Chrysocoris purpureus*, feeding on eucalyptus seedlings has its academic importance.





33. Studies on the teak heartwood borer, *Alceterogystia cadambae* (Moore) and its Management

Principal Investigator: Dr. O.K. Remadevi

Duration: 2006

Critical Analysis of research Theme and Summary of the study

Teak (*Tectona grandis*) is important, both ecologically and economically and one of the most durable timbers has been used from many centuries for a wide range of products and services. Teak heartwood borer (*Alceterogystia cadambae*) was a minor pest of teak in southern India, affected unhealthy and mechanically damaged tree, has assumed major pest status causing extensive damage to timber in Karnataka with mean infestation level was found to be 13.01 per cent. Higher infestation was recorded in roadside plantations indicated that the abundance and distribution of pest was more in biotic disturbed plantations. Complete life history of this borer studied in the laboratory and under field conditions.

The insect damage to teak plantation can be managed by adopting the integrated management strategies, including mechanical, physical, biological and cultural methods. Mixed plantation shall be helpful to restrict the spread of pest from tree to tree in the forest. Application of *B. thuringiensis* (var. kurstaki) @ 2-3 gram in 250 ml of diet kill the 100 per cent larva in the laboratory conditions. Biopesticide, Soluneeem @ 1g /lit. was found to be effective to control the pest in field conditions. Nematode, *Heterorhabditis indica* @ 400 ijs was also useful to contain the pest under check.

Scientific findings and contents

Exploration of make use of nematodes viz. *Heterorhabditis indica* and *Strinernema feltiae* in controlling the *Alceterogystia cadambae* attack is a new area of pest management in forestry. Preliminary trials showed that both species were effective in causing the larval mortality.

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

Further research on application of Microbial pesticides, *B. thuringiensis* and use of nematodes in soil can be explored to kill the pupal stage of the pest. Use of Pheromones for mass trapping of pest in suppressing the pest shall go a long way in successful management programme. Conservation of predacious birds species also helps in reduction of pest population.



34. Isolation, Identification, Evaluation and Mass Production of Native Entomopathogenic fungi for the management of Teak and Casuarina Stem Borers

Principal Investigator: Dr. A. Balu

Duration: 2006

Critical Analysis of research Theme and Summary of the study

Teak (*Tectona grandis*) and Casuarina are the most valuable tree species for wood productions in India and south Asia. These species are extensively planted in marginal land by the farmers and state forest department. Pest related damage to these species is mainly caused by insect borers viz. *Alcterogystia cadambae*, *Sahyadrassus malabaricus* and *Inderbela quardinotata*. To develop a biologically control based management system, native Entomopathogenic Fungi (EPF) were isolated, identified and tested in the field. 15 isolates of EPF were isolated from the different forest ecosystem and grouped under 8 species. Of which 3 species *Paecilomyces variotii*, *Cunninghamella echinulata* and *Trichoderma harzianum* are new to the science. 7 native isolates were found to have potential in controlling the *Sahyadrassus malabaricus* and *Inderbela quardinotata*. A method of application of EPF has also been developed.

Scientific findings and contents

Identified EPF as *Beauveria bassiana*, *Metarhizium anisopliae*, *Aspergillus flavus*, *Cunninghamella echinulata*, *Fusarium oxysporum*, *Fusarium sp.*, *Trichoderma harzianum* and *Pacilomyces varioti* from the different forest ecosystem have pathogenic effect on insect borers viz. *Sahyadrassus malabaricus* and *Inderbela quardinotata* only. Out of them, *Beauveria bassiana* and *Metarhizium anisopliae* have the potential as biocontrol agents of the containing the insect borers viz. *Sahyadrassus malabaricus* and *Inderbela quardinotata*.

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

Successful use of native Entomopathogenic Fungi will depend on the right propagule, formulated in an optimum fashion, and applied in the field at a right time.. Research and development must then concentrate on developing a method of mass production of, formulation, and application that retain the ability of the pathogen to the kill its host. Native Entomopathogenic Fungi viz. *Beauveria bassiana* and *Metarhizium anisopliae* have the potential as biocontrol agents to control insect borers viz. *Sahyadrassus malabaricus* and *Inderbela quardinotata*.





35. Studies on the insect pests of *Emblica officinalis* and *Gmelina arborea* in Agroforestry and plantation ecosystem

Principal Investigator: P.B.Meshram

Duration: 2006

Critical Analysis of research Theme and Summary of the study

Agroforestry is an effective way to increase timber yield per unit area and the best method of meeting the growing demand for forest produce and services. *Gmelina arborea* is a suitable species for reclamation of waste land, marginal lands and social forestry programme of afforestation. While *Emblica officinalis* fruit crop of commercial significance. In total 14 insect species were reported to damage the *E. officinalis* and *G. arborea* belonging to the order Lepidoptera, Hemiptera and Diptera. Among all *Indarbela quadrinotata* is the most serious pest. The insect pest damage, seasonal incidence and some biological aspects of reported insect were studied in detail. Phassus borer, *Sahyadrassus malabarcus* (Moore) another borer of serious concern. The larva bored into the stem, leading to the mortality of plant. The infestation can be controlled with application of Nuvan, (Dichlorovos 76 EC) @ .05 per cent

Scientific findings and contents

Prepared base line data on the insect pests associated with agroforestry species viz. *Emblica officinalis* and *Gmelina arborea*

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

Regular insect pest survey is essential to document the occurrence of pest incidence in agroforestry ecosystem and take action to manage them in economical and compatible control method. Integrated Pest Management should be developed for their control.



36. Properties of Coffee Wood as Indicators of White Stem Borer Resistance

Principal Investigator: R. Vijendra Rao

Duration: 2008

Critical Analysis of research Theme and Summary of the study

Xylotrechus quadripes (Coleoptera: Cerambycidae) is a major pest problem in coffee plantations in India. If control measures are not taken up on a regular basis, this can cause havoc in coffee plantations especially during the year when environmental factors are favorable for pest build up. Interaction of *X. quadripes* with hybrid descent such as Sln, 5A, Sln, 6A Sln, 8A and Sln, 11A was studied. Presence of food ingredients like starch, proteins and lipid in the stem tissue of these selections at different level of damage studied. Analysis tannin in the bark and wood tissue was also examined for resistance to white stem borer.

Scientific findings and contents

The food ingredients scored visually in the section of these selections indicate that there is no larger difference in the presence and / or density of food ingredients between the stem of healthy and susceptible one.

The tannin test, however, have a large difference between healthy and susceptible plants of the selections (Sln, 5A, Sln, 6A Sln, 8A and Sln, 11A).

The lower damage of the coffee selections of interspecific hybrid descent can be substantiated as due to three factors, first the anatomical presence of sclerotic parenchyma, second the abundance of tannins in the sclerotic parenchyma cells and the third is the high level of endogenous chitinase activities in the green tissue.

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

Tropical trees revealed heavier defense by qualitative factors (Toughness. Low water, high phenolic content), however relatively high levels of tannins and also the highest levels of attack, indicating that tannins alone were not effective, a defense, but other physiological changes such a leaf aging was also involved.





37. Studies on Entomofauna of Mangroves of Karnataka, Goa and Andhra Pradesh

Principal Investigator: Dr. O.K. Remadevi

Duration: 2005

Critical Analysis of research Theme and Summary of the study

Mangroves constitute unique tropical ecosystem occurring most extensively along the protected coastal shores with muddy to sandy bottoms. The challenges to mangrove forest include both natural hazards and destructive human activities. There is a great diversity of insect species in this ecosystem, but the details on the faunal elements and their ecological implications remained least explored. Baseline data on the entomofauna of selected eighteen species of mangrove, along with seasonal incidence and bio-ecology of important insect were studied. In total, 201 species or insects were identified, coleoptera forms the most dominant insect order with 22 per cent of the total species. Maximum number of species was obtained during the wet season (55.9%). Among all insect, the serious species were found to be *Nephoterix syntaractis*, *Dasychira mendoss*, *Caloptilia scaeodesma* and *Pteromoa plagiophleps*.

Scientific findings and contents

Insect fauna of 18 species of mangrove, belonging to 10 families were collected and identified. The trophic diversity showed the distinct seasonal pattern of insect fauna. 341 species of insects belonging o 122 families of 11 insect orders collected. Or this 201 of them could be identified. The highest number of species belonged to the order Coleoptera, which constituted 22 per cent of the total species collected. Chrysomelidae was the dominant family with 22 per cent of the species. Lepidoptera (19%), Heteroptera (17%), Hymenoptera (15%) and Diptera (12%) were the other insect orders.

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

Ecologically, mangroves represent a sharp transitional gradient between the marine and fresh water ecosystem. Mangrove ecosystem helps in coastal stabilization, prevention of erosion, biological filtration and sinks for several pollutants. In biodiversity conservation campaign, mangrove ecosystem stands a very important position. Along with other biotic disturbances, insects also contribute to their degradation. Data generated on diversity of insects is useful in developing the effective and compatible management measures to restore and conservation of ever-degrading habitat.



38. Biosystematic Studies on Parasitoid Complex of Sandal Coccids and their Utilization in Biological Control

Principal Investigator: Y.B. Srinivasa

Duration: 2005

Critical Analysis of research Theme and Summary of the study

Sandal (*Santalum album*) is one of the most economically important tree species found in peninsular India. It has many traditional uses and most of them related to its prestigious fragrance. Although about 150 species of insects are known to be associated with sandal, only few like *Kerria lacca* has been reported as a serious pest, causing mortality of plant. The major coccids of sandal are *Saissetia* spp., *Inglisia bivalvata*, *Ceroplastes actiniformis* and *Ceroplastes ceriferus*. Among all, *Inglisia bivalvata* has been reported to cause considerable damage to Sandal crop.

Scientific findings and contents

12 parasitoids belonging to 5 families viz. Encyrtidae, Aphelinidae, Pteromalidae and Eulophidae were collected from coccid (*Inglisia bivalvata*) and identified. Population dynamics of 4 major parasitoids, *Cocophagus bivittatus*, *Marietta leopardiana*, *Anicetus inglisise* and *Scutellista caerulea* along with their host, *Inglisia bivalvata* was studied to control the pest.

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

Among the 4 identified parasitoids, only 2 parasitoids viz. *Cocophagus bivittatus* and *Scutellista caerulea* have potential to suppress the population of coccid pest, *Inglisia bivalvata* and can be exploited under biological control programme.

39. Studies on taxonomy of the family Eulophidae (Hymenoptera: Chalcidoidea) present in National Forest Insect Collection (NFIC) (except Doon Valley)

Principal Investigator: Dr. Sudhir Singh

Duration: 2016

Critical Analysis of research Theme and Summary of the study

Hymenoptera with over, 1, 30,000 species are the third largest order after Coleoptera and Lepidoptera. Majority of Hymenopteran; about 80 per cent are parasitic in nature and attack a wide range of pest species (Hosts). Chalcidoidea (Chalcid wasps), a superfamily of order Hymenoptera, are primary parasitoids of insects and are important biological control agents for regulating the insect population. Within the superfamily Chalcidoidea, the Eulophidae is the largest family with 4300 species (Approx.) in 294 genera. The majority of the Eulophidae are primary parasitoids of concealed larvae and they attack insect species belonging to the order Lepidoptera, Diptera, Hymenoptera and Coleoptera.

The present studies aimed identification of unidentified Eulophid collection in National Forest Insect Collection (NFIC) deposited by earlier workers. Before this study, only 10 species of this family were identified and a lot of unidentified material was kept in NFIC. In total, 89 species were identified taxonomically and discussed under respective genera and sub-families. 13 new species of Eulophid were added to the science of Entomology.





Scientific findings and contents

In total 89 species belonging to the subfamilies Tetrastichinae (31 spp); Euderinae (2spp); Eulophinae (39 spp.) and Entedoninae (17 spp) were identified and discussed under respective genera and subfamilies. 13 new species of Eulophid have been identified.

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

Eulophids are important group of parasitoids which need to be further studied in India. Rich biodiversity under this family, is still unexplored and collection to be made and identify these insects from different bio-geographic regions of the country. All the species which have been identified are important parasitoids of different insect many of which are the pests. In total, 89 species of Eulophids have been added to the Collection of NFIC, FRI, Dehradun.

40. Studies on taxonomy of the family Encyrtidae (Hymenoptera: Chalcidoidea) present in National Forest Insect Collection (NFIC) (except Doon Valley)

Principal Investigator: Dr. Sudhir Singh

Duration: 2015

Critical Analysis of research Theme and Summary of the study

Hymenoptera with over, 1, 30,000 species are the third largest order after Coleoptera and Lepidoptera. Majority of Hymenopteran; about 80 per cent are parasitic in nature and attack a wide range of pest species (Hosts). Chalcidoidea (Chalcid wasps), a superfamily of order Hymenoptera, are primary parasitoids of insects and are important biological control agents for regulating the insect population. Within the superfamily Chalcidoidea, the Encyrtidae is the largest family with 3700 species (Approx.) in 460 genera. They play an important role in insect communities, as they are endoparasitoids or hyperparasitoids of other insects

The present studies aimed identification of unidentified Encyrtidae collection in National Forest Insect Collection (NFIC) deposited by earlier workers. Before this study, only 60 species of this family were identified and a lot of unidentified material was kept in NFIC. In total, 190 species were identified taxonomically and discussed under respective genera and sub-families. new genus *Noyesencyrtus* Singh and 4 species were added to the science of Entomology.

Scientific findings and contents

In total 190 species belonging to the subfamilies Encyrtinae (151 spp) and Tetracneminae (39 spp) were identified and discussed under respective genera and subfamilies. A new genus *Noyesencyrtus* Singh along with 4 new species of Encyrtidae have been identified and described in detail.

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

Encyrtids are important group of parasitoids which need to be further studied in India. Rich biodiversity under this family, is still unexplored and collection to be made and identify these insects from different bio-geographic regions of the country. All the species which have been identified are important parasitoids of different insect many of which are the pests. In total, 190 species of Encyrtidae have been added to the Collection of NFIC, FRI, Dehradun.



41. Developing mathematical models for understanding infestation pattern of herbivorous insect pests

Duration: 2012

Critical Analysis of research Theme and Summary of the study

Herbivores insect pests essentially build large populations, and populations build over generations. Therefore, generation cycles provides important information for pest managers to control the insect outbreak and save their resources. Resource was considered exhaustive and non exhaustive in two different situations. Model revealed that under single resource / single-consumer situation, consumption rates were considerably dependent on growth rate of resources. In time-unlimited situation, as the growth rate of resources decreases, it appears that the consumption rate of insect herbivores decreases. Models also revealed that herbivores feeding on slow growing, time unlimited resources might tend to show strong spatial aggregations. Aggregations weaken for herbivores feeding on fast growing, time limited resources. It was also predicted that the insect herbivores feeding on slow growing, time-unlimited resources may tend to show discrete generations.

Scientific findings and contents

The impotent finding is that discrete and continuous generations among insect populations appear to be the result of mating strategies. Insects with shorter lifecycle lengths may have continuous generations, while insect with longer life cycle lengths have discrete generations. This is the result of the mating opportunities that such insect have.

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

Herbivores insects and plants are united by intricate relationship. Animal life, including that of insect, cannot exist in the absence of green plants' which serve as the primary source of energy-rich compounds for heterotrophic organisms. A long exposure of plants to animals has been a major cause in developing great diversity in the plant kingdom. This the basic research to understand the infestation pattern among herbivores insects, which can serve to our greater understanding of the natural system. It generated the basic information on the interaction between insects and plants and put light on the basic aspects of insect biology.





42. Orthopteran Diversity of the Nilgiri Biosphere Reserve (Tamil Nadu)

Principal Investigator: Dr. N. Senthilkumar

Duration: 2013

Critical Analysis of research Theme and Summary of the study

The Nilgiri Biosphere Reserve (NBR) is the first and most popular Biosphere Reserve, established in 1986, in the Nilgiri Hills Range of South India. The NBR has a remarkable topographic diversity varying from 80 m to above 2600 m above MSL and have a wide range of rainfall between 500 to 7000 mm annually. Orthoptera is one of the largest order of the class insect, and includes the grasshoppers locusts, crickets and katydids. About 20,000 species are known from all over the world, out of which 900 species are present in India. In total 52 species of Orthoptera belonging to 45 genera, 3 families and 17 subfamilies were recorded from various land escape in NBR. Grasslands harboured greater number of Orthoptera, followed by deciduous forests, scrub jungle, evergreen forests, shoal forests, and finally plantation of teak, eucalyptus and wattle. Studies revealed that there is little and strong change in the assemblage of Orthopteran insects in the disturbed grassland and forest land, respectively.

Scientific findings and contents

Present study provides the information on diversity of orthopteran insects in different habitat types in NBR. 52 species of Orthoptera belonging to 45 genera and 3 families were recorded in different habitats. The family Acrididae has the largest species representations (33 species) followed by Tettigoniidae (12 species) and Gryllidae (7 species). Latitude and altitude have a significant influence on distribution and density of species. Most widely distributed species in NBR are *Conocephalus maculates*, *Phlaeoba infumata* and *Xenocatantops humilis*, recorded from all the habitats.

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

The study provides information on diversity of orthopteran insects in different habitat types in Nilgiri Biosphere Reserve (NBR). The assemblages of grasshopper in the ecosystem will be the indication of ecosystem health because they are the primary consumers in the food web. Information generated on the diversity of othoptera will help in stakeholders for management and conservation of ecosystem. Assessment on the impact of anthropogenic disturbance provides vital information on the stress encountered by the indicator species in the ecosystem.



43. Screening of High Yielding and Seed Sources of Eucalyptus spp. for Gall Insect Pest, *Leptocybe invasa* Fisher & La Salle

Principal Investigator: Dr. A. Balu

Duration: 2012

Critical Analysis of research Theme and Summary of the study

Eucalyptus is one of the most widely planted pulpwood species in the world and covering an area of about 80 lakhs ha, in India. While efforts are being made to enhance biomass production from plantations through quality seed and productive clones, a new exotic pest problem has been encountered in recent times in India. This exotic pest is *Letocybe invasa*, native to Australia and reported from coastal plantation of Eucalyptus in Tamil Nadu (India). Considering the increasing invasion of *L. invasa* (Gall-inducing wasp), in Eucalyptus plantations, attempt has been made to screen the resistance genotype for its effective control in the field. The resistant candidate identified for gall wasp would serve as a base material for the plant breeders to develop new clones and hybrids.

Scientific findings and contents

221 high yielding clones of Eucalyptus collected from 10 different organizations were screened for gall insect, *L. invasa*. Based on the recorded data, the status of 221 Eucalyptus clones for the attack of the pest was categorized into resistant, susceptible, highly susceptible etc. categorization of 221 clones of Eucalyptus revealed the existence of 10 resistant clone, 43 very less susceptible, 62 Less susceptible, 54 moderately susceptible and 54 highly susceptible clones. Clones from IFG&TB come under the category of Very less susceptible (C 7 and C 196) and less susceptible (C10, C111 and C 186).

As these clones qualify for both the parameters of productivity and gall resistance, have been short listed and recommended to the variety release committee.

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

The 105 clones categorized on the basis of their degree of resistance, including 5 clones from IFG&TB, Coimbatore. Clones from IFG&TB come under the category of Very less susceptible (C 7 and C 196) and less susceptible (C10, C111 and C 186). These clones are found productively higher as par the ruling commercial clones in the market. The level of resistance is varied from site to site. Under the tree Improvement programme, these clones should also be evaluated at multi-locations for the pest and disease problems.

The knowledge gained through this project, will facilitate to test the gall tolerant and very less susceptible clones further in multi-locations in order to select the best clones which can tolerate the pest at varied agro-climatic zones.





44. Bioassay of some selected plant extracts against major defoliators of Poplar and Shisham

Principal Investigator: Dr. K.P. Singh

Duration: 2012

Critical Analysis of research Theme and Summary of the study

Dalbergia sissoo (Shisham) and Poplar (Poplar spp.) are among the primary group of multipurpose trees, well accepted and extensively planted under afforestation and a variety of agroforestry systems. Defoliating insects removes the photosynthesizing tissue from the tree and reduce carbohydrates production and the immediate effect of defoliation is a reduction in the vigour and growth of the tree. Botanical insecticides have been recognized as attractive alternatives to synthetic chemical insecticides for pest management as they reputedly pose little threat to the environment or to human health.

Plecoptera reflexa and *Clostera cupreata* are the major defoliators of shisham and poplar, caused moderate to heavy leaf defoliation in plantations raised under various programmes. Bio-efficacy of 4 promising plants viz. *Adina cordifolia*, *Calotropis procera*, *Plumbago zeylanica* and *Tagetes minuta* on destructive stage of the pest at various concentrations with different solvents were tested in the laboratory for their effective control under field conditions. Out of 4 tested plants, only 3 plant species (*A. cordifolia*, *C. procera* and *P. zeylanica*) extracts have been considered effective and can be used in Integrated Pest management and have potential to control serious defoliators of Shisham and Poplar.

Scientific findings and contents

Screening of methanol, acetone and water extract of *Adina cordifolia*, *Calotropis procera*, *Plumbago zeylanica* and *Tagetes minuta* was done on the larval stage of *P. reflexa* and *C. cupreata*. Out of 4 plants, methanol and acetone extract of 3 plants viz. *A. cordifolia*, *C. procera* and *P. zeylanica* caused 55 to 70 mortality under laboratory conditions. The presence of phytochemicals in the extracts might be the reason for insecticidal activities of these plants and they can be used as a source of novel insecticide.

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

The extract of *A. cordifolia*, *C. procera* and *P. zeylanica* showed potent insecticidal activities against *Plecoptera reflexa* and *Clostera cupreata*, serious defoliators of shisham and poplar, respectively.



45. The termite diversity of northern India with special reference to species composition in relation to different tree species (Insecta: Isoptera)

Principal Investigator: Dr. R. K Thakur

Duration: 2009

Critical Analysis of research Theme and Summary of the study

The project was carried out to explore termite diversity in the seven states of Northern India, viz. Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Delhi and some parts of Uttar Pradesh. Termite fauna was collected from 130 localities (DL - 14, HR - 8, HP - 35, JK - 10, PB - 10, UK - 41 and UP - 12) spread over the region. Key to the families and the genera has been provided.

The collected material was identified into 73 species, belonging to 24 genera, under five families – Termopsidae with 1 species, Kalotermitidae with 8 species, Rhinotermitidae with 4 species under two genera, Stylotermitidae with four species, and Termitidae with 56 species under 17 genera. This number of species contributes 23.7% of total Indian termite fauna. Running keys have been provided for the families, genera and species. Where ever necessary, relevant discussions have been incorporated with regards to the taxonomic status. In a similar manner, relevant notes have been provided under each species in respect of collection data, biology and distribution. At the beginning, a review has been given concerning the literature of the termite fauna of India and Northern India in particular and the present position of the termite fauna is discussed. The systematic account has been arranged phylogenetically under each family and sub-family. The distribution of the genera found in Northern India: is discussed under each of the five families. Under each genus its important literature and number of species described has been given. The comparisons are based on the examination of type specimens of closely allied species, with which they have been compared for authentic validity of species. All the species reported have been illustrated with Camera Lucida diagrams. New species are described in details with morphometric data and Camera Leucida diagrams.

Out of these 73 species, seven species are described new to science: *Neotermes sensarmai*, *Glyptotermes roonwali*, *Eurytermes punjabensis*, *Angulitermes bhagsunagensis*, *Pericapritermes chichrauliensis*, *Macrotermes vikaspurensis* and *Nasutitermes saharanpurensis*. For new species, various categories of type specimens have been separated out in different vials and deposited in the Termite wet collection of National Forest Insect Collection, Forest Research Institute, Dehradun.

Many species have been recorded for the first time from this region while for other known species recorded earlier by previous workers; it gives an extension of range of distribution.

Host plants and nature and extent of damage caused by these species have been tabulated for all the 73 identified species.

Scientific findings and contents

In Northern India out of these 73 species, seven species are described new to science: *Neotermes sensarmai*, *Glyptotermes roonwali*, *Eurytermes punjabensis*, *Angulitermes bhagsunagensis*, *Pericapritermes chichrauliensis*, *Macrotermes vikaspurensis* and *Nasutitermes saharanpurensis*.

Many of the species are new records from the Northern States: two new records from Jammu & Kashmir; 10 new records from Himachal Pradesh; 13 new records from Punjab; 11 new records from Haryana; 7 new records from Uttarakhand; 8 new records from Delhi and 13 new records from Uttar Pradesh are reported here.





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

There is no scope of patenting for discovery of natural biological material – new species, new records.

46. Relative resistance of neem provenance to insect pests and mites and their bio-management in arid areas

Principal Investigator: Dr. S.I. Ahmed

Duration: 2009

Critical Analysis of research Theme and Summary of the study

The present study was conducted in national neem provenances raised at Forest Protection field, AFRI, Jodhpur. The 39 (thirty nine) provenances - P1 Lodpur (Kota), P2 Indore, P3 Triveni (Ujjain), P4 Sonu (Jaisalmer), P5 Bikaner, P6 Jhalamand (Jodhpur), P7 Pune, P8 Satara, P9 Solapur, P10 Sawaimadhopur, P11 Nagpur, P12 Jhansi, P13 KanpurPN 28, P14 Kanpur PN48, P15 Kanpur P46, P16 Kanpur P27, P17 Rajkopt, P18 Palanpur, P19 Ghandinagar, P20, Pali, P21 New Delhi, P22 Sikar, P23 Mathura, P24 Gurgaon, P25 Amravati, P26 Ravinagar, P27, Ranchi, P28 Muzzafarpur, P29 Mulag, P30, Bankara, P31 Raipur, P32 N. Bilaspur, P33 Jabalpur, P34 Hoshangabad, P35 Shivpuri, P36 Maihar, P37 Soghagi Range, P38 Katni, and P39 Kuthalia, Rewa - were screened out and studied for relative resistance against insect pest. Neem has a wide spectrum of Insect pests of different orders of insects. and from the studied area 27 species of insects, 2 species of mollusk and 5 species of mites, infesting neem have been identified . Five species of mites are recorded from Neem viz., *Eutetranychus orientalis* (Klein), *E. maximae* Nassar and Ghai, *E. phaseoli* Nassar and Ghai, *E. bilobatus* Nassar and Ghai and Red spider mite, *Tetranychus* spp. These mites basically damage nursery stock due to sap sucking mechanism.

In the study *Myllocerus tenuicornis* has been identified as most serious pest. Therefore, bio-ecology and management of this pest have been studied in details in the project.

Bioecology of *Myllocerus tenuicornis* have been studied in details including effect of larval crowding on development and reproduction of *Myllocerus tenuicornis*, its population dynamics, overwintering and relative preference of hibernating sites. Management of the weevil incorporates phytochemical and microbial control.

Scientific findings and contents

Pest management is an essential part of tree planting programmes, including those in which neem is a component. The approach has to be integrated to make the afforestation programmes successful. 27 species of insects (termites, thrips, bugs, butterflies and moths, beetles), 2 species of mollusks and 5 species of mites, infesting neem in 39 provenances, has been recorded.

Myllocerus tenuicornis was recorded as most destructive and serious defoliator to young and matured trees of *A. indica* throughout the tract of its distribution in arid and semi-arid areas. The provenance from Mulag was found to be the most favoured or susceptible host as the leaf area consumed by larvae was comparatively much more as being 3.11 cm sq.

Integrated pest management of *Myllocerus tenuicornis* with microbial, phytochemical and biological controvert control components has been suggested as chemical control is not much useful. Proper doses have been recommended after standardization.



Five species of mites are recorded from Neem viz., *Eutetranychus orientalis* (Klein), *E. maximae* Nassar and Ghai, *E. phaseoli* Nassar and Ghai, *E. bilobatus* Nassar and Ghai and Red spider mite, *Tetranychus* spp. These mites basically damage nursery stock due to sap sucking mechanism.

Detailed Bioecology study of *Myllocerus tenuicornis* has been carried in the project. *Bioecology*: *M. tenuicornis* undergoes five generations annually and all the generations overlap considerably and the same phenomenon may be due to the overcrowding of individuals in various generations. A complete life cycle during different generations took an average period of 43.76 ± 2.65 days. The pre-oviposition, incubation, larval and pupal periods are recorded as being 5.96 ± 1.22 days, 18.60 ± 1.75 days, 2.95 ± 0.45 days, 13.67 ± 1.82 days, 11.92 ± 0.15 days respectively. The sex proportions between males and females during different generations were noted as 46.90 ± 4.71 and 53.10 ± 4.77 , respectively, i.e., 1 : 1.12.

Effect of larval crowding on development and reproduction of *Myllocerus tenuicornis*: The larval survival varied among different levels of the larval densities. Its range decreases between 100 percent (single isolated larva) to 57.0% (40 larvae/cage). The different larval densities had a significant effect on the weight of the growing larvae. Individually isolated reared larva was 0.091 ± 0.001 mg, whereas the one which was reared under the highest crowding stress (40 larvae/cage) weighed 0.053 ± 0.002 mg.

Population dynamics: The eggs, larvae, pupae and adults of *M. tenuicornis* were most abundant during July to September due to the optimum ecological conditions of temperature and relative humidity. The population is recorded to be the lowest during the months from March to June and again noticed to be progressively declined from October to February in each year. A significant negative relationship was faced between the population size and the temperature but there was direct relationship between population size and relative humidity.

Overwintering and relative preference of hibernating sites: Hibernation of adult weevils of *M. tenuicornis* takes place in the middle or late December at Jodhpur when the temperature falls below 27.4°C . Natural hibernating sites in the neem provenance trials, comprised of loose barks of Acacia species, thatched roof of huts, folded and dry leaves on the forest floor, Thick grasses in the plantations, debris and litter, dead standing trees with holes, cracks and crevices of fallen trees.

Management of *Myllocerus tenuicornis*: (a) Phytochemical control: The average percentage mortality in *M. tenuicornis* larvae was recorded highest (87.50%) in case of the treatment using root decoction of Dhatura whereas root decoction of *Calotropis procera* caused the lowest mortality (53.7%) after 48 hours of the treatment. Larval mortality was highest when treated with Dhatura followed by Euphorbia (66.00%) and Calotropis and the least mortality was recorded in case of check as being 08.50%.

(b) Microbial control agent of neem weevil: During the survey of natural enemy-complex of *Myllocerus tenuicornis*, it was observed that some adult weevils were found infected by the fungal pathogen *Beauveria bassiana*. All weevils at the lowest spore concentration 3.5×10^4 were killed after 11 days. Mortality of adult weevils exposed with 3.5×10^7 spore concentration in the out-door cages started from the 4th day after spraying. The weevils developed disease symptoms and the mycelium of *B. bassiana* appeared on the 6th day after spraying. The deaths of inoculated weevils proved the most effective nature of *B. bassiana* against *M. tenuicornis*.

New Pest Record: *Myllocerus laetivirens* Marshall has infested neem as an alternative host plant. Its primary existence in abundance is horticultural orchard crops. Spray of monocrotophos @ 0.03% is





effective in case of severe infestation. The presence of this pest species is indicative of its sprawling effects in future on the growth factor of this tree species in this region. *Aehaea janata* Linn is a new pest record on neem and its management can be successfully done through its Nuclear Polyhedrosis Virus.

Ten species of common insect predatory birds were observed in the neem provenance trial and its vicinity. They are acting as biological controlling agents to regulate the insect population.

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

Monitoring of neem against insect pests should be continued in light of its recently acclaimed importance for use of its seed oil for neem coated urea. In last few years outbreaks of geometrid defoliators like *Ascotis selenaria* and *Cleora cornaria* have taken place in Uttar Pradesh, Haryana and Punjab. Screening of provenances against these pests should also be carried out systematically.

47. Studies on taxonomy of braconid parasitoides (Hymenoptera: Braconidae) from central India

Principal Investigator: Dr. Mohd. Yousuf

Duration: 2010

Critical Analysis of research Theme and Summary of the study

Project envisaged to study the diversity of family Braconidae taxonomically. During the study from 605 sweeping samples (from three Ecological/ Agro-climatic zones covering 185 localities in 16 districts of Chhattisgarh and nine Ecological/ Agro-climatic zones covering 385 localities under 34 districts of Maharashtra), 2606 Braconid parasitoids were sorted out.

Apart from sweep samples 424 samples of host-insects were collected and reared in the laboratory for parasitoid emergence.

As a whole 56 Braconid parasitoids have been identified from the sweep and rearing samples.

Scientific findings and contents

During the project period following 56 Braconid parasitoids have been identified: *Apanteles agilis*, *Apanteles antipoda*, *Apanteles bambusae*, *Apanteles belippae*, *Apanteles cajani*, *Apanteles caniae*, *Apanteles creatonoti*, *Apanteles detrectans*, *Apanteles effrenus*, *Apanteles eriimotae*, *Apanteles expulsus*, *Apanteles hyblaeae*, *Apanteles javensis*, *Apanteles lamprosemae*, *Apanteles leptothecus*, *Apanteles machaeralis*, *Apanteles platyedrae*, *Apanteles prodeniae*, *Apanteles signifians*, *Apanteles tachardiae*, *Apanteles tiraeholae*, *Cassidibracon castus*, *Chelonus (Chelonus) deogiri*, *Chelonus (Chelonus) dwibindus*, *Chelonus (Chelonus) gastrus*, *Chelonus (Chelonus) nr. indicus*, *Chelonus (Chelonus) narayani*, *Chelonus (Chelonus) shafeei*, *Chelonus (Microchelonus) notaulii*, *Chelonus (Microchelonus) scutellatus*, *Cremnops desertor*, *Doryctobracon areolatus*, *Eutropobracon granulatus*, *Fopius arisanus*, *Habrobracon brevicornis*, *Helcon tardator*, *Hormius lamidae*, *Hormius orientalis*, *Parahormius absonus*, *Parahormius deiphobus*, *Parahormius stom*, *Parahormius zonus*, *Protomicroplitis rugulosus* and *Trioxys soporensis*.

Twelve species have been discovered as new to science whose names are: *Apanteles lakhaensis*, *Apanteles neoeajani*, *Apanteles neohyblaeae*, *Apanteles neotaeniaticornis* and *Rogas jalnaensis* *Anisocyrtia gilvieorpa sp.n.*, *Bracon jalgaonensis sp. n.*, *Chelonus (Chelonus) wardhaensis sp. n.*, *Chelonus (Microchelonus) hingoliensis sp. n.*, *Doryctes indicus sp. n.*, *Parahormius longicarpus sp. n.*, and *Parahormius longiflagellatus sp. n.* Descriptions and illustrations of all the new species and



27 important known species have been carried out.

Key to 11 sub families of the family Braconidae along with 17 genera has been prepared. Keys to Indian species for 12 genera (*Apanteles* Foerster, *Cassidibracon* Quicke, *Chelonus* Panzer, *Eutropobracon* Ayyar, *Habrobracon* Ashmead, *Hormius* Nees, *Parahormius* Nixon, *Protomicroplitis* Ashmead, *Rogas* Nees *Yon* Esenbeck, *Trioxys* Haliday, *Bracon* Fabricius and *Doryctes* Haliday) have been prepared. Keys to species of five genera (*Cremnops* Foerster, *Doryctobracon* Enderlein, *Fopius* Wharton, *Helcon* Nees, *Anisocyrta* Foerster) have not been prepared, as these genera are being recorded for the first time from India with representing one species from India, in each genus. All presently recorded 56 Braconid species, from Chhattisgarh and Maharashtra, have been accommodated in these keys.

In order to have a consolidated account of host-record of Indian species of Braconids, complete list of host- record of Indian Braconid species has been prepared, after careful consultation of literature.

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

Braconids are important biological control agents especially in the forestry eco systems, they keep the check on population of insects. More studies should be carried out on the host-range and natural field parasitization by braconids. Work on biology of important *Apanteles* species should also been carried out.

Species belonging to the genus *Apanteles* Foerster are the important parasitoids of key insect pests of forest tree species, as they have shown their excellent natural field parasitization, during present study. Therefore more studies on the host-range/ host preference of *Apanteles* species should be carried out, mainly on the *Apanteles* species attacking teak defoliators, teak skeletonizer and sal defoliators.

More studies should be carried out on the host-range and natural field parasitization of Microgastrine Braconids, attacking the key insect-pests of forest tree species.

Work on biology and laboratory rearing techniques of important species should be carried out.

Laboratory rearing techniques should also be evolved for some important *Apanteles* species which are showing good natural field parasitization on key insect pests of forest tree species, so that their laboratory culture can be maintained.

After developing the laboratory rearing technique for *Apanteles* species, their laboratory efficacy should also be carried out against key insect-pests like teak defoliator, *Hyblaea puera*; teak skeletonizer, *Euteetona maehaeralis*; sal defoliators: *Aseotis selenaria* & *Paeetes subapiealis* & *Ailanthus* webworm, *Atteva fabriciella* etc.

After getting perfection in laboratory rearing techniques, some *Apanteles* species should be taken in field release programmes of "Applied biological control" of key insect pests of forest tree species.





48. Investigations on Microsporidia affecting forest Lepidoptera of South India and their prospects as biocontrol agents

Principal Investigator: Dr. O. K. Remadevi

Duration: 2010

Critical Analysis of research Theme and Summary of the study: The phylum Microspora consists of approximately 143 genera and over 1200 described species, which infect all major animal lineages. Insects in all taxonomic orders are susceptible to this pathogen, but over half of the susceptible insect hosts occur principally in two orders, Lepidoptera and Diptera. Most entomopathogenic microsporidia cause chronic infections in insects, impairing their growth, development and reproductive ability. Many species exhibit a unique mode of vertical transmission in which the infecting stages of the organism pass from the mother to the progeny through the eggs. This feature makes them remarkably efficient in regulating insect populations. Studies on infection of Microsporidia in forest insects have been very limited in India. Interestingly, these organisms assume importance from two contrasting angles, one from the point of view of their possible utility for insect pest control and the other because of their severe harmful impact on beneficial insects including the silkworm, honey bee and also the many aesthetic and charismatic butterfly species.

Explorative survey resulted in collection of 71 species of butterflies from different forest types and screened for presence of microsporidia. 31 species were found to be infected out of which 25 species were found to be infected with microsporidia for the first time.

For the first time a highly virulent micro sporidium was isolated from the defoliator pest of teak, *Hyblaea puera* Cramer. Microsporidian isolates from defoliator pest of teak, *Hyblaea puera*, three butterfly species, viz., *Papilio demoleus*, *Papilio polytes* and *Catopsilia pyranthe* were studied. Among the butterfly species tested, the highest prevalence of infection, both in captive bred and natural population, was observed in *Catopsilia pyranthe*, followed by *Papilio demoleus*.

Scientific findings and contents

For the first time a highly virulent micro sporidium was isolated from the defoliator pest of teak, *Hyblaea puera* Cramer. The spores of the microsporidium were observed to be ovoocylindrical in shape with a mean size of $5.2 \pm 0.18 \mu\text{m} \times 2.8 \pm 0.06 \mu\text{m}$. Inoculation of the microsporidium resulted in a cumulative mortality ranging from 37.5 to 100% concurrent with spore loads inoculated. The LC₅₀ of the microsporidium estimated for *Hyblaea puera* was 5.44×10^3 spores/larva. The microsporidium induced severe adverse effect on the growth and development of the larvae. The parasite sequentially infected the different body tissues in the order of mid gut - fat body - tracheal membrane - malpighian tubule and gonad. The sporulation in the whole body, mid gut and fat body increased proportionately with the concentration of inoculum and age of the insect. The increasing rate of sporulation with advancing age of the infected host suggested the parasite's tendency to complete the cycle and transform into mature spores as the nutrient level of the host is reduced with advancing age. Laboratory experiments revealed high transmission potential of the microsporidium, both horizontal (>90%) and vertical (88.67%). The high rate of spore excretion by the infected larvae also could result in the easy spread of infection among the pest population in the field.

The observations indicated prospect of the micro sporidium as a bio-control agent against the defoliator pest, if exploited properly. The life cycle of Hp microsporidium showed close similarity to the silk moth microsporidium, *Nosema bombycis*, suggesting it to be a member of the *Nosema*



genus. SSU rRNA gene sequence analysis also revealed this microsporidium to be a closely related strain of *Nosema bombycis*, from which it differed by only two nucleotides. This implied the likelihood of host switching by the parasite.

The *Hyblaea puera* micro sporidium also showed high degree of cross infectivity to the teak skeletonizer, *Paliga machoeralis*, *Sylepta derogata* and *Eupterote geminata* with LC₅₀ values of 8.11×10^2 , 5.79×10^2 and 1.48×10^3 respectively. This suggests that this microsporidium can be used to target simultaneously both the species of teak defoliators which are sympatric and share the same ecological niche.

Comparison of the prevalence of micro sporidia in natural and captive bred populations of ten species of butterflies showed higher prevalence of microsporidia in captive bred populations. Among the butterfly species tested, the highest prevalence of infection, both in captive bred and natural population, was observed in *Catopsilia pyranthe*, followed by *Papilio demoleus*. This indicated the high potential of transmission of the parasites when the infected host insects were reared in closed and restricted areas. Poor hygiene and sanitation in the rearing place might have contributed to the higher prevalence in the captive bred populations, due to horizontal transmission.

Microsporidian isolates from three butterfly species, viz., *Papilio demoleus*, *Papilio polytes* and *Catopsilia pyranthe* were studied to assess their virulence and pathogenicity against their respective hosts. The LC₅₀ of *Papilio demoleus*, *Papilio polytes* and *Catopsilia pyranthe* microsporidia against their respective hosts were 3.7×10^4 , 1.0×10^5 and 8.3×10^4 . The Pd and Cp micro sporidia were also found to be cross infective to the teak defoliators, *Hyblaea puera* and *Paliga machoeralis* suggesting their utility for biocontrol against teak pests.

Since many microsporidia are potential endoparasites, the observed association of these organisms with butterflies is indicative of their possible role in regulating the butterfly populations in nature. Laboratory experiments also resulted in very high horizontal transmission with 88% in the case of Pd microsporidium and 90% in the case of Cp microsporidium in their respective hosts. These two microsporidia also showed vertical transmission to the extent of 72 and 82% respectively. This observation tends to suggest possibility of prevalence of vertical transmission among microsporidia of many other butterfly species also. Also, due to their reported pathological effects on the hosts they could be implicated as one of the conspicuous mortality factors in butterfly farming. These observations may necessitate screening of female butterflies after egg laying to raise microsporidia free stocks in butterfly farming for eco-tourism. The findings also highlight the need for maintaining good hygiene while raising butterfly population in the parks. In depth studies on microsporidians associated with butterflies will enable us to generate more knowledge on the dynamics of these host-parasite systems which in turn would help in developing methods to eliminate microsporidiosis during butterfly rearing.

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

Exploration of these organisms should be done for the important pests of forest trees for their management.





49. Management of Insect Borer Complex in Chir-pine Forests

Principal Investigator: Dr. Ranjeet Singh

Duration: 2012

Critical Analysis of research Theme and Summary of the study

Pinus roxburghii Sargent is a large evergreen tree, some time nearly deciduous in dry localities, is a principal indigenous resin producing pine in India and is also used as timber. In total 15 species of insect stem bores belonging insect order, Coleoptera and 4 families viz. Buprestidae, Curculionidae, Platypodidae and Scolytidae were collected and identified and found to be associated with main stem of Chir-pine. *Polygraphus longifolia* appears in the chir-pine forest first and attack the susceptible tree, thereafter other insect stem borer viz. *Ips longifolia*, *Cryptorhynchus rufescens*, *Platypus biformis* and *Sphaenoptera aterrima* were seen on the tree for food, shelter, egg laying and other biological association. Fire incidence and excessive resin tapping increased the susceptibility of tree to aggressive beetle attack. Depending primarily on the moisture content of the wood, the insect borer attack in chir-pine forest follow in general, a set of ecological sequence. After the forest fire in chir-pine forest, Ambrosia and bark beetles of coleopterous families Platipodidae and Scolytidae are the first to invade and colonize the weak tree.

Scientific findings and contents

15 species of insect stem bores viz. *Ips longifolia*, *Cryphalus longifolia*, *Cryptorhynchus rufescens*, *Hylastes longifolia*, *Milenophila ignicola*, *Nothorrhina muricata*, *Polygraphus longifolia*, *Polygraphus himalayensis*, *Pityogenes scitus*, *Platypus biformis*, *Rhyncholus* sp, *Sphaenoptera aterrima*, *Stenoscelis himalayensis* *Stenoscelis longifolia*, *Stromatium barbatum* were found to be associated with main stem of Chir- pine trees. On the basis of population and nature of damage, five species of insect were graded as serious and they are *Cryptorhynchus rufescens*, *Ips longifolia* *Platypus biformis*, *Polygraphus longifolia* and *Sphaenoptera aterrima*. *Polygraphus longifolia* was recorded as first to colonize the main stem of the trees, where the moisture content is above 60 % level with a moderate flow of resin.

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

Biopesticides viz. Neem oil @ 10 %, Grownim @ 5.0 % and summer oil @ 5.0 % is proved to be effective to keep the population of *Polygraphus longifolia* (Coleoptera : Scolytidae) damaging level in Chir-pine forest.

Tree-trap with 95-110 cm L X 90-100 cm Girth size and 45 to 70 per cent moisture content was found to be effective to attract the various beetles Complex, but cannot be recommended in emergent situation against any specific insect borers.

Pheromone, Ipsdienol ((s)-2-methyl-6mehtyleneocta-2,7-dien-4-0l) with dose of 4 mg / dispenser (rubber) in Fero-TTM was found to be optimum to attract significantly greater number of beetles of *Ips longifolia* . Use of 4-5 traps per hectare for trapping the beetles was optimum to contain the pest under out-break situation.



50. Evaluation of certain flora based on ethnobotanical records for their pesticidal properties against important forestry insect pests

Principal Investigator: Dr. N Senthilkumar

Duration: 2013

Critical Analysis of research Theme and Summary of the study

Project aimed at exploitation of plant products as novel chemotherapeutants in plant protection. These plant products possess valuable potential in pest management because of their non phytotoxicity, svstemicity, easy biodegradability and stimulatory nature of host metabolism.

Ten plant species – *Adhatoda vasica*, *Aristolochia bracteata*, *Briedelia scandens*, *Cleistanthus collinus*, *Melia dubia*, *Murraya koenigii*, *Pongamia pinnata*, *Strychnos nuxvomica*, *Trichiliaconnaroides* and *Vitex negundo* have been short listed based on ethnobotanical records to identify their pesticidal properties against insect pests of forestry important. Surveys have been made in different districts of Tamil Nadu and samples were collected, processed, powdered and stored under deep freezer for further laboratory analysis. Different organic solvents such as acetone, methanol and ethyl acetate extracts of the collected leaves were sequentially performed and solvents were evaporated using vacuum evaporator, dried, lyophilised and stored at -20⁰ C till bioassays and other phytochemical analysis. Larvae of the test insects, *Hyblaea puera*, *Atteva Ibriciella* and *Eligma narcissus indica* collected from teak and *Ailanthus excelasa* were laboratory cultured. Nucleus cultures of these pests were established under laboratory for bioassay studies. The promosing chemicals were identified using GC/MS.

Scientific findings and contents

Bioassay studies of the extracts made from the selected plants (*Adhatoda vasica*, *Aristolochia bracteata*, *Briedelia scandens*, *Cleistanthus collinus*, *Melia dubia*, *Murraya koenigii*, *Pongamia pinnata*, *Strychnos nuxvomica*, *Trichilia connaroides* and *Vitex negundo*) were evaluated against teak defoliator, *Hyblaea puera*, *Atteva fabriciella* and *Eligma narcissus indica* under laboratory conditions. All the extracts were found to possess antifeedant and insecticidal property (40-80 %) at higher concentrations (500 and 1000 ppm). The extracts were subjected to spectral analysis for identification of secondary metabolites.

All the extracts were fractionated using column Chromatographic separation followed by UV Spectrum and the fractions were analysed using HPLC for phenol and phenolics, alkaloids, fatty acids, tannins and flavanoids. Further GC/MS/MS lalysis of extracts was carried out to characterize bioactive principles.

The bioefficacy of individual compounds identified showed significant results when tested against teak defoliator and ailanthus defoliators in laboratory conditions. Based on the laboratory performance the species were short listed and ranked. Five plant species showed promising results, hence the preformualtoion was made by combining all those five species and were evaluated against test insects under field conditions in teak and *Ailanthus excelsa* plantations of IFGTB's field station at Kuumbapatti, Salem, Tamilnadu. 80 to 96 percent of larval mortality was observed from filed evaluation on test insects. The same formulation was evaluated against casuarina bark eating caterpillar, *Indarbela quadrinotata* under field conditions and showed 60% insecticidal activity :against *Indarbela quadrinotata*.

Based on the results of present study, it has been concluded that organic solvent methanol is found to





yield higher amount of extract. Estimation of phenolic content in different extracts owed methanol extracts has maximum phenolic content followed by acetone. The phenolic compounds such as ferulic acid was found to be more in *Briedelia scandens* and *Vitex negundo* followed by Catechol in *P. pinnata*, *A. bracteata*; Pyrogallol in *B. scandens* and Syringic acid in *V. negundo*. Bioassay studies on *H. puera*, *A. fabriciella* and *Eligma narcissus indica* using the extract at different concentrations viz., 250, 500, 750, and 1000 ppm showed promising results with mortality range between 80-96 %. *Melia dubia* was found to be more effective followed by *Murraya koenigii*, *Briedelia scandens*, *Adhatoda vasica*, *Vitex negundo* and *Strychnos nuxvomica*.

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

A number of plant substances have been considered for use as insect antifeedants or repellents, but apart from some natural mosquito repellents, only a little commercial success has ensued for plant substances that modify arthropod behavior. Several factors appear to limit the success of botanicals, most notably regulatory barriers and the availability of competing products (newer synthetics, fermentation products, microbials) that are cost-effective and relatively safe compared with their predecessors. In the context of agricultural forestry pest management, botanical insecticides are best suited for use in organic wood production in industrialized countries besides non wood forest produce but can play a much greater role in the production forestry in developing countries.

51. Biological control of teak leaf skeletonizer, *Eutectona machaeralis*

Principal Investigator: Dr. N Roychoudhury

Duration: 2013

Critical Analysis of research Theme and Summary of the study

The project envisaged to control teak skeletonizer, *Eutectona macaeralis* by realizing *Trichogramma* spp, in the infested plantations and thereby enhancement of teak productivity. Infested teak plantations were selected in Maharajpur Forest Range of Mandla Forest Division of Madhya Pradesh. Total of 600 ha area under the plantation was selected for the study. *Trichogramma raoi* was reared in the laboratory on laboratory host, *Corcyra cephalonica*. 25 million parasitoids were released in the selected area under experimental plots in randomized block design.

Scientific findings and contents

To suppress the incidence of teak defoliator, *H. puera* and leaf skeletonizer, *E. machaeralis*, and to enhance the growth of teak trees, an indigenous egg parasitoid, *Trichogramma raoi*, was collected from natural forests and plantations of teak at Maharajpur Forest Range, Mandla Forest Division, Madhya Pradesh, during the year 2011-2012. It was reared on laboratory host, multiplied and introduced in 100 ha in natural forests and 100 ha in plantations of teak @ 1.25 lakhs/ha in 10 installments during the population outbreak of target insect pests in monsoon showers.

Releasing the wasps of parasitoid, *T. raoi*, proved significant ($P < 0.05$ - $P < 0.01$) reduction of percentage defoliation/skeletonization and incidence of pests, *H. puera* and *E. machaeralis* and subsequently significant ($P < 0.001$) enhancement of growth of teak trees occurred, both in natural forests and plantations of teak. Further, the findings on growth data trees indicate significant ($P < 0.05$) increase of growth at breast height (GBH) due to e of biocontrol agents.



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

All these findings advocate the potentiality of egg parasitoid, *T. raoi*, as a biocontrol agent for management of teak pests. This technique is ecofriendly, safer, non-toxic and pragmatic method of management of teak pests over large forest areas. The findings of the present study are consistent with the view that the release of indigenous parasitoid, *Trichogramma raoi*, @ 1.25 lakh/ha significantly ($P < 0.05$) reduced defoliation/skeletonization intensity and larval incidence of *Hyblaea puera* and *Eutectona machaeralis*, both in natural forest and plantations of teak.

Indigenous egg parasitoid, *T. raoi* may be utilized for effective use as a biocontrol agent against *H. puera* and *E. machaeralis* and as guide-lines for large scale management programme.

Similar works should be extended to other Lepidopterous pests of forest trees after exploring the *Trichogramma* fauna from the native regions and standardization of their multiplication and release techniques.

52. Screening, identification and preparation of a comprehensive check-list of the lepidopteran fauna of Sasan Gir National Park of Gujarat State

Principal Investigator: Dr. Meeta Sharma

Duration: 2014

Critical Analysis of research Theme and Summary of the study

This project was aimed at exploring the butterfly and moth diversity of the Gir National Park and Wildlife Sanctuary, Gujarat. Surveys were undertaken to catalogue the lepidopteran fauna of the park. Assessment of host range of lepidopteran on host plant use in the field was also taken up. Further rare and endangered species were also screened.

Dry Grassland, Desert Thorn Forest, Dry Acacia Forest, Southern Thorn Forest, Tropical Riverine Forest, Dry Deciduous Teak Forest, Dry Savannah Forest, Tropical Euphorbia Scrub Forest and Dry Deciduous Mixed Forest forest types were selected for survey and observations.

Life histories of some butterflies like *Danaus chrysippus* and *Acherontia atropos* have also been studied.

Survey and cataloguing of the Lepidopteron fauna associated with plant species present in Gir National Park and Sanctuary (GNPS) has been done. 220 species of lepidopteron fauna with diverse population of 105 species of butterflies and 115 species of moth has been observed, identified and their comprehensive, updated checklist had been prepared. Out of these 220 species, 65 species of butterflies and 59 species of moths are newly recorded from GNPS.

A database of species of butterflies and 65 species of moths has been tabulated with information on species name, author and year of publication, classification, distribution, locality at GNPS, status, brief description of species, identifying characters and host plants. 188 photographs of butterflies and moths are also given.

Scientific findings and contents

A diverse population of 105 species of butterflies and 115 species of moths (Lepidoptera) has been observed and identified from Gir National Park & Wildlife Sanctuary (GNPS), Gujarat.

A comprehensive, updated checklist of total 220 species of lepidopteron fauna had been prepared.





Out of them 65 species of butterflies and 59 species of moths are newly recorded from GNPS.

About sixty nectar plants have been identified as host. The interaction of host plant species with butterflies, their species abundance, richness and evenness (similarity) has been calculated for each habitat type. The disturbed forest was found as most ideal home for diverse population of lepidopteron fauna in comparison to the natural forests habitat.

The faunal diversity of butterflies was highest during monsoon to early winters and declined in winters and early summer. The flower color and size also influence the visiting insects, therefore majority of butterflies were attracted to white flowers. Also small sized flowers charmed maximum butterflies.

30 species of lepidopteron fauna have been observed as "rare" species, 14 species have been screened out as "endangered" species and 19 species were recorded as "protected" in Schedule I, II & IV of Indian Wildlife Protection Act, 1972 and the list is prepared. The above listing of important "rare" and "endangered species" of lepidopteron fauna was recorded first time from GNPS.

GNPS was found as a suitable habitat for abundance of most of the butterflies viz., *Castalius rosimon*, *Hypolimnas misippus* and *Euploea core* which are enlisted in the Indian Wildlife Protection Act, 1972. Therefore, for long term conservation of rare and endangered lepidopteran fauna, encouragement of more such unadulterated areas is need of the hour.

The host range of lepidopteron fauna has been assessed and about 60 nectar plants identified as their host plants. It was observed that the Papilionid butterflies had food preference for the plant family Rutaceae, Nymphalid butterflies preferred to feed on the plant families of Malvaceae and Acanthaceae, butterflies of Pieridae had a preference for plant families Capparaceae and Caesalpiniaceae and the butterflies of the family Lycaenidae mostly feed on plant families Mimosaceae and Fabaceae. Among the moths, family Lymantriidae were attracted to *Ficus* species, families Limacodidae and Lasiocampidae feed on fruits of *Mangifera indica*, *Psidium guava* and *Syzygium cuminii* plants. Family Sphingidae obtained their food from *Jasminum* species and *Nerium oleander* plants while Geometrid moth preferred castor plants. Top seven plant species visited by the maximum number of butterfly species were identified. *Lantana camara* (Verbenaceae) was visited by the maximum number (25) of butterfly species, followed by *Tridax procumbens*, *Celosia argentea*, *Calotropis procera*, *Acacia* sp., *Zizyphus* sp. and *Tamarindus indica*.

Checklist of host plants species provides suitable route for mass scale breeding of beautiful butterflies' species in order to develop a butterfly garden.

Top seven plant species visited by the maximum number of butterfly species were identified. *Lantana camara* (Verbenaceae) was visited by the maximum number (25) of butterfly species, followed by *Tridax procumbens*, *Celosia argentea*, *Calotropis procera*, *Acacia* sp., *Zizyphus* sp. and *Tamarindus indica*.

The faunal diversity was greatly influenced by season, monsoon to early winters (June -November) being the preferred seasons. Lycaenidae butterflies were dominant during monsoon season. Papilionidae were always encountered in all the seasons flying at heights in pair. Environmental polymorphism or polyphenism have been observed in the form of seasonal morphs (Dry & Wet forms) especially in the butterfly families of Nymphalidae and Pieridae. This proves the seasonal abundance of the species. Females are observed to be good mimics so as to protect themselves.



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

Biodiversity of the protected forest network should be taken up to assess the identity of insect species present and their abundance in the ecosystem. Insects are the biggest group of organisms on this planet and therefore has very essential role in the ecosystem, mainly in the food chain, pollination, etc. Basic information on species identity and their abundance influence existence and population of innumerable number of higher species. Therefore such studies should be taken up in all the protected forest networks for better understanding and management of these protected areas.

53. A novel approach to synergise growth and pest management in fast growing industrially important tree species

Principal Investigator: Dr. S Murugesan

Duration: 2015

Critical Analysis of research Theme and Summary of the study

Indiscriminate use and application of the synthetic' chemicals, which actually aggravates ecological backlash by way of eliminating numerous beneficial organisms. Therefore, the environmental awareness among the farming community has triggered a paradigm shift towards designing material compatible with the environment. Soil ameliorating practice is increasing in recent years because of high cost of chemical fertilizers, increased risk of environmental pollution, and need for the production of healthy plants by nursery growers.

Therefore to address these problems the project was envisaged to screen the effect of different bioinoculants along with biomanures on growth enhancement of industrially important tree species in nurseries. It also aimed at standardization of nutrient composition and to develop tree rich bioboosters.

Roots and rizosphere soils of tree species viz., Melia, Teak, Ailanthus and Neolamarckia were selected. Bioinoculants like Azospirillum, Azotobacter, AM fungi and Phosphate Solubing Bacteria were cultured. Various potting manures like vermicompost, Farm yard manure, green manure, effluent compost, etc were used in various combinations with the inoculants as potting mixture. In the present research effect of various bioinoculants comprise PGPRs, PPFM, AM fungi along with vermi-compost, decomposed coir pith/vermiculite, effluent biocompost, soil potting mixture, decomposed green manure, neem seed kernel cake, aegle seed cake etc., were critically examined at different mixing ratio as an integrated bio- nutrient management for the quality production of the selected forest tree species viz., *Ailanthus excelsa*, *Casuarina equisetifolia*, *Eucalyptus tereticornis*, *Gmelina arborea*, *Neolamarckia cadamba* and *Tectona grandis*.

Scientific findings and contents

It was demonstrated that some of the bioinoculant application appreciably improved the germination behaviour i.e. 24 -100% in nursery experiments as supplement the primary/ micronutrients like protein, chlorophyll, Ca, N, Ph, Mg, K and organic carbon, and thus reducing the need for fertilizers.

The inoculated seedlings have shown better performance of biomass with reference to seedling survival, shoot length, collar dia meter at 30- 60 days after application. Increase in growth was the result of cumulative effect of increased phosphate and other mineral uptake, improved water holding capacity of the biomixture due to the added nitrogen and optimum level of physicochemical properties like pH, Ee, colour etc.





The results indicated that the combined application of three or more beneficial organisms exerted more complimentary effect on growth and productivity than dual or single inoculations.

The added effect of Pink Pigmented Facultative Methylophs (PPFMs) in the biomixtures influence the seed germination and seedling growth by producing plant growth regulators. Biomanure contains microorganisms which are capable of mobilizing nutritive elements from non-usable form to usable form through biological process.

Phytochemical profiling in the course of chromatographic analysis revealed that seedling grown in nutrient amended coir pith and vermiculite media elicited additional bioactive compounds which are not activated in control grown seedlings. Seedlings grown in coir pith based medium elucidated more bioactive molecules than vermiculite based medium and control. The nutrient amendments made in coir pith and vermiculite base media signaled more polyphenol compounds in seedlings which induce the seedling growth and promote plant defense against many bio factors. Therefore, the present research was directed to enhance seedling performance and to produce quality seedling for better out planting and improve its ability to survive and re-establishing capacity in the field.

The coir pith based potting medium could be considered as a promising potting media for healthy seedling production for improved out planting for the entire tree species selected, and the coir pith based medium has gained prominence as potting medium. Using coir pith based potting media is possible to cultivate plants organically, economically and environmental friendly ways.

Some of the bioactive phenolic compounds elucidated were found to be defensive, and hence no infestation was noticed in the seedlings which could ultimately lead to enhance the healthy seedlings production. This is because some of the allelochemicals are known to play a key role, where they induce defensive mechanisms as well as crop protection. Based on the promising results obtained from various experiments, efficacy on plant growth and biomass of economically important tree species in various experimental studies in the present study.

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

The product was released to the various user growers during "Farmers Mela 2013" organized at IFGTB, Coimbatore.



54. **Study on the influence of climate on bionomics of *Pityogenes scitus* Blanford (Coleoptera: Scolytidae) in Himachal Pradesh**

Principal Investigator: Dr. Ranjeet Singh

Duration: 2016

Critical Analysis of research Theme and Summary of the study

Forests of the Himalayan region are facing the paradox of climate change, which is one of the greatest environmental challenges facing the Himalayan ecosystem today. In recent years, there have been a several epidemic instances for pest outbreak causing alarming damage to the forest trees in northwest Himalayas, and one of the probable outcome can be the climate change. *Pityogenes scitus* Blanford (Coleoptera: Scolytidae) is bark and wood borer of coniferous trees viz. *Cedrus deodara*, *Picea smithiana*, *Pinus gerardiana*, *Pinus roxburghii* and *Pinus wallichiana* and distributed in northwest Himalayas and Baluchistan. Beetle is about 2.75 mm in length and made tunnel down to the sapwood and made galleries in stellate appearance. The insect passes through three generation in a year from February to October. Life cycle is completed within the period varying from 56- 72days and entered into hibernation in pupal stage. It passes about 80% of time its life cycle from egg, larval and pupal stage below bark. Larval growth index was reported to be maximum in *P. wallichiana* and minimum in *P. gerardiana*.

Scientific findings and contents

The growth and development of *P. scitus* was found to be faster at lower altitude in comparison with higher altitude. The insect beetle lives and works in association with other bark and wood borer species i.e. *Platypus bifomis*, *Ips longifolia*, *Cryptorhynchus rufescens* and *Sphaenoptera aterrma*. Pupal stage (Hibernating stage) of *P. scitus* showed statistically significant variation in their abundance and survival in different altitude, which may be due to due to the effect of particular climate conditions on the bionomics of the insect.

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

Major threat of *Pityogenes scitus* under changing climatic conditions is found to the Kail (*Pinus wallichiana*) forest ecosystem. Beetle population was recorded highest in *P. wallichiana*, where as less in *P. gerardiana* during May to September. Maximum damage was also reported kail forest in comparison with other pine species. The population abundance of larva and adult of the insect is greatly influenced by weather parameters i.e. temperature, humidity and rainfall.





55. Studies on diversity of egg parasitoid wasps *Trichogramma* spp. From punjab and haryana and their application in biological control of important forest insect pests

Principal Investigator: Dr. Mohd. Yousuf

Duration: 2016

Critical Analysis of research Theme and Summary of the study

During the present project work, screening of indigenous species of *Trichogramma* has been carried out from Punjab and Haryana. Diversity of all species, available in Punjab and Haryana has been worked out. Cultures of two indigenous species have been developed from Punjab and Haryana and these cultures have been tested in laboratory against two key insect pests of forestry importance.

As a whole 600 sweeping samples have been collected from five agroclimatic/ Ecological zones of Punjab, covering 352 localities of districts: Amritsar, Bamala, Bathinda, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Ludhiana, Moga, Nawanshahr, Patiala, Ropar, Sagrur and Tam-Taran 197 specimens belonging to *Trichogramma* spp. were sorted out from collected samples.

Ten species of *Trichogramma*: *T. achaeae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilotraeae*, *T. jlandersi*, *T. japonicum*, *T. plasseyensis*, *T. poliae* and *T. rooi* have been recorded from Punjab for the first time. Ten species of *Trichogramma*: *T. achaeae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilotraeae*, *T. jlandersi*, *T. japonicum*, *T. plasseyensis*, *T. poliae* and *T. semblidis* have been recorded from Haryana for the first time.

Detailed diagnostic characters and genitalic components have been studied for ascertaining their correct identification. Complete host range and distribution of all these *Trichogramma* spp. have also been given.

Diversity of *Trichogramma* spp. has been worked out from Punjab and Haryana for the first time, by applying diversity Indices (i) Importance Value Index (IVI), (ii) Shannon Wiener Index, (iii) Simpson's Index, (iv) Evenness and (v) Effective Number of Species (ENS).

Two species of *Trichogramma*: *T. chilonis* and *T. japonicum* were taken in culture from Punjab and Haryana. These indigenous species were multiplied and maintained in the eggs of laboratory host, *Corcyra cephalonica*.

Morphometrics of two indigenous species: *Trichogramma chilonis* and *Trichogramma japonicum* have been studied in detail by dissecting ten males and ten females of each species.

Laboratory efficacy of two indigenous *Trichogramma* spp.' has been carried out against key insect pests of Poplar and shisham.

Scientific findings and contents

As a whole 600 sweeping samples have been collected from five agroclimatic/ Ecological zones of Punjab, covering 352 localities of districts: Amritsar, Bamala, Bathinda, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Ludhiana, Moga, Nawanshahr, Patiala, Ropar, Sagrur and Tam-Taran 197 specimens belonging to *Trichogramma* spp. were sorted out from collected samples. Ten species of *Trichogramma*: *T. achaeae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilotraeae*, *T. jlandersi*, *T. japonicum*, *T. plasseyensis*, *T. poliae* and *T. rooi* have been recorded for the first time from Punjab. Similarly 480 sweeping samples have been collected from four agroclimatic/ Ecological zones of Haryana, covering 292 localities of districts: Bhiwani, Fatehabad,



Hisar, Jhajjar, Jind, Kaithal, Kamal, Kurukshetra, Mahendargarh, Panipat, Rewari, Rohtak, Sirsa, Sonapat and Yamuna Nagar.

168 specimens belonging to *Trichogramma* spp. were sorted out from collected samples. Ten species of *Trichogramma*: *T. achaeae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilotraeae*, *T. jlandersi*, *T. japonicum*, *T. plasseyensis*, *T. poliae* and *T. semblidis* have been recorded for the first time from Haryana. Eleven species of *Trichogramma*: *T. achaeae*, *T. agriae*, *T. breviciliata*, *T. chilonis*, *T. chilotraeae*, *T. flandersi*, *T. japonicum*, *T. plasseyensis*, *T. poliae*, *T. semblidis* and *T. rooi* have been identified and recorded from Punjab and Haryana. Detailed diagnostic characters and genitalic components of all eleven species have been studied.

Trichogramma spp diversity study showed that their population in Punjab was found less diverse due to the high evenness because of the higher density of *Trichogramma chilonis*, *T. achaeae* and *T. japonicum*. Shannon-Wiener Index showed that the diversity of *Trichogramma* is also low in Haryana. The dominant species are evenly distributed throughout Haryana. The species such as *T. achaeae*, *T. semblidis*, *T. breviciliata* and *T. plasseyensis* are dominating in different agro-climatic zones of Haryana. The Simpson's Reciprocal index for *Trichogramma* spp. in Punjab and Haryana clearly revealed that in Haryana, the *Trichogramma* spp. have more diversity than Punjab.

T. chilonis and *T. japonicum* were cultured from Punjab and Haryana, which were multiplied and maintained in the eggs of laboratory host, *Corcyra cephalonica*. Morphometric characters of *Trichogramma chilonis* and *Trichogramma japonicum* have been studied in detail by dissecting their ten males and ten females. Twenty morphometric characters have been studied and measured. Fifteen ratios were also calculated of selected parameters of important characters.

Laboratory efficacy of *T. chilonis* and *T. japonicum* has been studied against key insect pests of Poplar and shiahm. Both species showed good parasitization, *Trichogramma chilonis* (18.80% by one pair and 58.90% by five pairs in the eggs of *Clostera fulgurita*; while parasitisation was recorded 22.00% by one pair and 59.70% by five pairs in the eggs of *Plecoptera reflexa*). *Trichogramma japonicum* does not accept the eggs of *Clostera fulgurita*, but it showed good parasitisation in Shisham defoliator (19.20% by one pair and 44.90% by five pairs pairs in the eggs of *Plecoptera reflexa*).

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

In the forestry ecosystem biological control is the only permanent solution for tackling pest insurgent problem. Natural enemies of the insect pest should be explored and their utilization after standardization of rearing techniques in the forestry sector should be tried.





56. **Biology of hispine bamboo borer-*Estimena chinensis* Hope (Coleoptera: Chrysomelidae) damaging green standing bamboo and its management**

Principal Investigator: Dr. K P Singh

Duration: 2016

Critical Analysis of research Theme and Summary of the study: Bamboos are woody grass like fast growing species belonging to family Poaceae and subfamily Bambusoideae. Bamboo is one of the important substitute timbers in many respects because of versatile uses in construction of buildings, scaffoldings, making agricultural and industrial implements and value added products etc. Bamboos are recorded to have been damaged by 212 insect species at various stages and render them of no commercial value, They have been categorised as culm and shoot borer (12), felled and dried bamboo (44), defoliators (48), Nursery pest (5), termites (13) and sap suckers (90) belonging to insect orders Coleoptera, Lepidoptera, Isoptera, Homoptera and Thysanoptera. Among all, the hispine beetle- *Estimena chinensis* Hope. (Coleoptera: Chrysomelidae) is the most important pest of bamboos in India and Burma. Therefore, the present work was taken up to study the biology of the borer, nature of damage, incidence and intensity of attack and suitable chemical control measure.

Scientific findings and contents

During the present study, *E. chinensis* was found damaging green standing bamboo of thirteen species in natural stand viz. *Dendrocalamus longispathus*, *D. giganteus*, *D. asper*, *D. calostachyus*, *Bambusa wamin*, *B. tulda*, *B. multiplex*, *B. striata*, *B. bambos*, *B. burmanica*, *B. nutans*, *Schizostachyum pergracile*, and *D. strictus*. Out of these 13 species following eight bamboo species were observed to be attacked by the weevil for the first time: *D. longispathus*, *D. giganteus*, *D. asper*, *D. calostachyus*, *Bambusa wamin*, *B. tulda*, *B. multiplex* and *B. striata*

Biology of the beetle showed that a gravid female laid 13-20 eggs of transparent chorion with visible yellow yolk elongated with rounded end. The incubation period 24.2 ± 0.71 days, larval period 64.7 ± 0.58 days, prepupal period 7.5 ± 0.02 , pupal period 9.5 ± 0.17 days, longevity of male 5.1 ± 0.23 days and female 5.8 ± 0.20 days. The life cycle of *P. crassicollis* is 366.25 ± 1.09 days and the borer completed one generation in a year. Sex ratio of Male: Female :: 1 : 0.92 ± 0.03 .

Insecticidal control trials against the borer were conducted later using three systemic (dimethoate, monocrotophos and imidachloprid) and three contact (deltamethrin, cypermethrin, and chloropyriphos) insecticides with 0.01, 0.02, and 0.04 per cent concentrations. Among these dimethoate 0.04% was found most effective which controlled the 65.28% damage of bamboo borer- *E. chinensis*. In case of monocrotophos 0.04% concentration provided 63.57% of borer control. Imidacloprid was observed least effective amongst the systemic insecticides and yielded 51.12 of borer control at 0.04 % concentration. It is also observed that systemic insecticides performed better as compare to contact insecticides.

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

Control measures designed for the borer will be very helpful in management of this pest in the field.



57. Development of artificial diet for conservation and utilization of drying *mantids* as bio control agents

Principal Investigator: Lalji Prasad, Scientist-E

Co Principal Investigator: Dr. Neena Chauhan, Scientist-D

Duration: 2011-2017

Critical evaluation of the research theme and summary of the study

Praying *mantids* are voracious predators of insects. Adult as well as immature stages of insects are predated by them. An attempt has been made to rear the *mantids* in laboratory on artificial diet. In nature they predate on the moving insects and are known as one of the predators for biological control of insects. The *mantids* are carnivorous hence hen's egg and or meat was added to the artificial diet. Four species of *mantids*, *creobroter gemmatus*, *C. urbana*, *Hierodula westwood* and *H. venosa* were used for the experiments.

Two species of genus *creobroter*, *C. urbana* and *c. gemmatus* were collected and reared in the laboratory. Two types of artificial diets were prepared and tried on them one diet with ground meat and other without meat. During winter these *mantids* for 8-12 days on this artificial diet. Two species of genus *Hierodula*, *H. venoda* and *H. westwood* were also collected and reared in the laboratory on artificial diet, with and without grounded meat, during summer these *mantids* survive for 5-12 days on artificial diet with ground meat. The artificial diet thus prepared was found partially successful against both the genera.

Scientific findings and contents

Mantids are known for their predatory behaviour and are responsible for predated on many species of insects. They are voracious predators in the nature. An attempt has been made to rear or multiply *mantids* in the laboratory on artificial diet, mass rearing and then releasing in the field for biological control of pests. Many artificial diets were prepared in the laboratory for mass rearing of *mantids* but desirable success was not achieved *creobroter spp.* and *Hierodula spp.* adults was reared on the artificial diet with ground meat and survived for 5 to 12 days. Longevity to adult *mantids* in the nature or on natural diet is not compared. If the longevity of adult is increased, they will predate on relatively larger number of prey. As *mantids* are polyphagous their use for biological control is not ascertained. But when large number of *mantids* are released in the field for biological control, there will be a positive impact on the pest population. The present work for rearing *mantids* on artificial diet is the first step forward for mass rearing of *mantids* in laboratory.

Suggestions regarding follow up patenting possibility, utilization aspect, and prototype

Rearing of *mantids* on artificial diet was attempted for the first time. There is scope of improvement as suggested –

- Modification of artificial diets for mass rearing of *mantids*. Some new ingredients should be used & the ratio of mixing the ingredients should be rationalized.
- As the habit of *mantids* is to feed on living or moving insects attempts should be made to shape the artificial diet in the form of insect and may be fed on a moving platform.
- When perfect artificial diet is prepared it may be patented.
- *Mantids* are voracious feeders of insects. They are polyshagous and both harmful as well as beneficial insects are predated by them. If large number of laboratory reared *mantids* are produced and mass released in the field, it will suppress the pest population.





58. Survey and bioecology of potential insect pests and pathogens of conea seeds of *Pinus gerardians* wall.

Principal Investigator: Dr. Pawan Kumar

Duration: 2008-2010

Critical analysis of the research theme and summary of the study

Chilgoza pine mostly grows in valleys at 2000-3350 m MSL elevator in dry temperate forest of inner Himalayas. Seeds of the Chilgoza pine are commercially important and are known as chilgoza, neoza etc. and are used as dry fruits. Cone and seed insects and pathogen play an important role in destroying the seed which have high commercial importance. The cone and seed of chilgoza pine (*Pinus gerardiana*) are damaged by the coneworm *Droryyctria abietella* and *cateremna tuborculosa* beside ten pathogens, *C. tuberculosa* was reported for the first time damaging cone and seed of *Pinus gerardiana* from Himachal Pradesh. Both the insects damage cone & seed of chilgoza pinus simultaneously in the field and laboratory. The studies were conducted at Pangi, labrang, Jhangi, Kilba, Aka, Korathi, Bhargnour and Rispa. The seed borer, *cateremna tuberculosa* was studied in detail for her first time. The seed borer completes its life cycle in 42-53 days. All the stages in the lifecycle were described. The seed bore *C. tuberculosa* starts its life cycle in July and by August 50% of seed were damaged which increased to 94% by December. During 2008 the incidence of attack ranges from 50% in August to 94% in December. During 2009 the incidence of attack was 20% in May and increased to 84% in November. This shows considerable damage is done to the seed.

Studies on cone borer, or cone worm *Dioryctria abieteblla* were also conducted and different stages in the life cycle were described. Life cycle in the laboratory and in the field was studied. In laboratory conditions there are three generations and in field only two generation per annum were recorded. The duration of lifecycle may ranges from 42-65 days.

During 2008 percentage of damaged cones was highest in Kilba (69%) and lowest in Aksa/Janghi (47%). During 2009 there was less attack on the cones which ranges from 21.12% in Rispa to 34.7% in Kilba. The effect of temperature on the infestation by cone borer was also studied at different locations.

Seed rot by pathogens was also studied and ten pathogens were isolated from the seed. It was found that *Pencillum citrinum* was most dominant which caused 40.07% seed rot at 25°C and even 8.27% seed rot was observed at 0°C. The studies on the pathogens responsible for seed rot needs to be studied in details.

Scientific findings and contents

The studies on the seed borer, *cateremna tuborculosa* were recorded for the first time damaging seed of chilgoza pine. The description of egg, larva, pupa and adult is done. Life cycle of seed borer its generations per year and damage to the seed at different locations was also studied. Photographs of all the stages of development were given. Nature of damage to seed is also given. Moults study of different larval instars clone. The measurements of head capsule are not given which determines different instars were done.

Cone borer *Dioryctria abietetta* is a major pest of cones of conifers. It is cosmopolitan species. In India it damages the cones of fir, spruce, kail, deodar and 1st year cones of chir pine. It is also a shoot borer of chirpine and khasipine in North East. The developmental stages of *D. abietella* were described which are supported by photographs. Morphology of adult is also described. The



incidence of attack at different locations was also studied. Cone analysis is not done but seed damaged by cone borer in a cone for 2008 and 2009 was given. Effect of temperature on the incidence of attack on the cones at different locations was also studied.

Seed micro flora was cultured for the study of seed rot causing pathogens. It was observed that *Penicillium citrinum* was most virulent among the ten pathogen which were isolated. *P. citrinum* caused 40.07% seed rot at 25° C temperature and even at 0°C it causes 8.27% seed rot. Detailed studies are needed on this aspect.

Suggestions regarding follow-up patenting possibility, utilization aspect prototype

Studies on seed borer, *catermna tuberculosa* are preliminary detailed studies are needed. Identity of *C. tuberculosa* should be confirmed from experts.

Cone analysis of *Pinus geradiana* should be done with a view to ascertain healthy seed seed attached by *D. abretebla*, seed attacked by *C. tuberculosa*, pathogen attacked seed undeveloped seed etc.

The seed of chilgoza pine are commercially important. Therefore, economic loss caused by insects & pathogens should be quantified.

Environmentally suitable control measures should be evolved for the management i.e. insect behavior regulators (pheromone), insect growth regulators (Hormone analogues) etc.

59. Field evaluation of indigenous species of *Trichogramma* against teak skeletonizer, *Eutictona machatxlis*

Principal Investigator: Dr. P.B Meshram, Scientist-F

Co Principal Investigator: Dr. Mohd. Yousuf, Scientist-F

Duration: 2011-2014

Critical analysis of the research theme and summary of the study

Biological control of insect pests using parasitoid predators and pathogens is the integral part of the Integrated Pest Management (IPM). Among the parasitoids egg parasitoids are used extensively for the management of many agricultural insect pests. During the present studies attempt has been made to test the indigenous egg parasitoid of *Eutectona machaeralis*, the teak skeletonizer, *Trichogramma raoi* in the field. The egg parasitoid was mass released in the laboratory and released in the teak forest/plantations which are endemic to teak skeletonizer. The egg parasitoids are the promising parasitoid to be used against forest insect pests for. They are easy to mass rearing, easy to store for a longer period in laboratory and easy to release.

The experiment was conducted at three laboratories Udipur, Mohiyanala and Tikaria in West Mandla Forest Division (MP). Laboratory reared egg parasitoid *Trichogramma raoi* were released @1.25 lakh per ha in all the three locations. It was found that the release of *T. raoi* is very effective in minimizing the population of the teak skeletonizer, *Eutectona machaeralis*. The indigenous egg parasitoid, *Trichogramma raoi* should be released in five installments from July to November to get the maximum protection of teak leaves which in turn minimized annual loss of growth.

Scientific findings and contents

The efficacy of egg parasitoid *T. raoi* against the egg of *E. machaeralis* was tested in the laboratory. It was found that one pair of the egg parasitoid parasitizes less eggs as compare to when five pairs of





parasitoids were released on 10 eggs of teak *skeletonizer*. Age of the eggs was not mentioned when parasitoid were released on them.

Mass rearing of egg parasitoids was done in the laboratory. It is not mentioned in the report that on which host the mass production of egg parasitoids was done for field release. Mass reared egg parasitoid, *T. raoi* were released at three locations i.e. Mohiyanala, Bijadandi and Tikaria. The egg parasitoid was released in each location @1.25 lakhs per hectare. It is not mentioned how much forest area was covered. The parasitoids were released from July to November in five installments. Pre released population of the teak *skeletonizer* was not mentioned only post released larval population was mentioned and compared it to larval population of non released control areas. Parasitized eggs of *E. machaeralis* from the area were also not collected. Only decline in the larval population was studied. The status of natural egg parasitoid in the field was also not monitored. There is no need to measure GBH in released and non-released areas because teak being slow growing species and in the short period of study one cannot study the effect of released egg parasitoids on GBH.

The study revealed that there is significant reduction of larval population of *E. machaeralis* in the areas where egg parasitoid & *T. raoi* was released. The trend of reduction of of the larval population is similar in Bijadandi, Mohiyanala and Tikaria locations of West Mandla Forest Division (MP)

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

Biological control of forest insect pest is most safe and effective control measure. Once the area is augmented with the released bio-control agent, it need not be released frequently. It is suggested that this studies should be continued. The mass production of egg parasitoids should be perfected. The natural egg parasitoids of *E. machaeralis* should be discovered and attempt should be made to mass rear them in laboratory and release in deficient areas.

Exotic species of *Trichogramma* available should be tested for their efficacy against the eggs of *E. machaeralis*. The better performer may be mass reared and released in the field for biological control of the pest.

The experiment pertaining to the use of indigenous egg parasitoid of *E. machaeralis* for the biological control, should be perfected, mass reared and released. The establishment of released parasitoid in the field should be studied by recapture method.



60. **Development, augmentation of efficacy and improvement of dissemination systems of *Metarhizium* based myco insecticide for the management of major pests in forest plantations and nurseries**

Principal Investigator: Dr. T.O. Sasidharan, Scientist ATREE, Bengaluru

Co Principal Investigator: Dr. O.K. Remadevi, Scientist-F, IWST, Bengaluru

Duration: 2006-2010

Critical analysis of the research theme and summary of the study

Entomogenous fungus *Metarhizium* is found in nature to infest many insect species. During present studies various geographical strains were collected, isolated and tested against many important insect pests of forests. Attempt was also made to mass culture *Metarhizium* spp. in various media and a myco-insecticide was developed in dust formulation and liquid formulation.

Field collection and rearing of important insect pests i.e. *teak defoliator*, *teak skeletonizer*, Birar hairy caterpillar, *ailanthus webworm*, *ailanthus defoliator*, *mahogany shoot borer* and *termite* was done. Isolation of twenty five fungal isolates thus obtained were cultured and purified culture of *metarhizium* spp. and its various geographical isolates was maintained in the laboratory.

Pathogenicity tests were conducted against *Hyblaea puza* (*teak defoliator*), *Paliga machaeralis* (*teak skeletonizer*), *spileictria obliqua* (poly phagous) defoliator of many forest trees, *hypsipyla roubusta* (mahogany shoot borer), *Atteva fabriciella* (*ailanthus webworm*), *Eligma marcissus* (*ailanthus defoliator*) and *odontotermes* sp. (mound building termite). Twenty five *Metarhizium* isolates were tested against their insect pests. The concentrations used were 10^4 , 10^5 , 10^6 , 10^7 conidia ml^{-1} on third instar larvae of above insects. In case of termite testing was done on worker cast.

Morphological characteristics of different isolates of *Metarhizium* were also studied. Cultural characteristics of the isolates were studied. Effect of culture media on germination of conidia, effect of temperature effect of RH, PH, light & darkness was also studied. Radial growth of *Metarhizium* isolates, biomass, viability of culture in storage, biochemical characteristics, carbon and nitrogen source utilization, growth and sporulation in nitrogen and carbohydrate sources were also studied.

Enzyme studies using chitinase assay, protease assay & lipase assay both qualitative and quantitative were done.

Mass production of effective isolates for aerial conidia production using grains, non-synthetic solid media & agrowaste was done. Mass production of effective isolates for submerged conidia production in different liquid media was also done. Harvesting of aerial conidia and submerged conidia was perfected.

Formulation of myco-insecticide was attempted for dust formulation as well as for liquid formulation and granular formulation. For dust formulation carrier material used were tal, kaolinite (continental clay) and celite (diatomaceous earth) used. While for granular formulation attaclay was used. For liquid formulation neem, *pongam*, *eucalyptus*, *simarouba glauca*, coconut oil and diesel were used. Glycerol, Tween 80 and mineral oil were tested as adjuvants.

Augmentation of efficacy of myco insecticide was done at two stages: - Mass production stage & ii- Formulation stage. Augmentation at mass production stage on grains and solid substrates, dry silkworm pupa powder, sugar (mannose 2%) and yeast extract (2%) were used with rice and bajra. Augmentation in liquid media was done using larval/termite homogenate insect cuticle, pupal powder and acid chitin.





Augmentation of formulation stage studied with compatibility between isolates & compatibility with insecticide and chitin synthesis inhibitor. Different dissemination methods in field were tested using liquid formulation, foliar spray against insect pests already mentioned.

Detailed studies on the field application have been done and data was statistically analyzed, supported with suitable photographs.

Morphological characteristics of *Metarhizium* were studied in detail. Various media were used for the laboratory culture and effect of temperature, relative humidity and photo period was also studied.

Mass production of myco-insecticide using different ingredients for dust formulation as well as liquid formulation have been perfected. Field application using various methods against target insects have been performed successfully.

Scientific findings and contexts

Metarhizium spp. is a well known entomogenous fungus and is used for the management of many agricultural insect pests. In the present study 25 isolates of this fungus were tested against important forest insects. Among various isolate tested most virulent were MA2, MA7 and MA13 isolates. It was found that these isolates are not specific to a particular insect.

Enrich culture medium fortified with dry silk worm pupal powder is found to be highly suitable to maintain the virulence of the isolates.

Mass production of isolates on broken rice grains gave highest growth & sporulation which is improved by adding dry silkworm pupae powder. High spore yield was obtained by adding yeast extract and mannose into the media. Maximum biomass was obtained in liquid media by adding trehalose and lecithin & sporulation was increased by incorporating dry silkworm pupae powder.

Kaolinite was found best carrier for dust formulation. Synergism was best noticed in Ma2 and Ma7 for targeting multiple pests of different tree species by a single formulation followed by Ma7 and Ma13.

Dust formulation was more effective against termite treatment. When deltamethrin (0.8 ppm) is added to formulation its efficacy is increased 5-9% on target pests. Effective control was obtained when myco-insecticide is applied in the field late evening hours as cool and congenial condition during night favoured prolonged survival and better germination of spores.

Detailed protocol for multiplication, mass production and formulation of the myco insecticide is developed incorporating modifications and improvements to achieve better efficacy of the formulation against target pest species.

Suggestions regarding follow up patenting possibility, utilization, and prototype.

The present studies on the entomogenous fungus *Metarhizium* spp. open door to the possibility of microbial control of forest insect pests. As a follow up action other entomogenous fungi should be worked out and their formulation may be developed. Various isolates were tested against many forest insect pests and most virulent isolates were selected and formulated. The formulations will be more effective some sticker and spreader were used.

There is a strong possibility for patenting the formulation thus prepared. Large scale field trials of the formulation may be conducted to control the forest insect pest to ascertain the efficacy.

A prototype has been developed during the studies on how the formulation of the entomogenous fungus *Metarhizium*.



61. Insect and diseases of bamboo occurring in central India and their management

Principal Investigator: Dr. K.C. Joshi, Scientist-G

Duration: 2010

Critical analysis of the research theme and summary of the study

A. Insect pests & diseases of seed

Only two known insect damaging developing seed and stored seed were recorded. There was no detailed study on the biology and incidence of these two seed insects.

No new seed insects were recorded.

Incidence of *Ochrophara Montana* and *Sitotroga Ceralella* was not recorded.

Seed microflora was studied in detail and nine pathogens were isolated and cultured in the laboratory. Cultural characteristics of each microflora were described.

Pathogens damaging developing seed and matured seed in the field were not studied.

B. Insect pests & diseases in nurseries & plantations

Short descriptions of root feeding insect, termite and chafer grub, defoliators, grasshoppers, leaf roller, leaf miner, sap sucker, white fly, bamboo aphid, culm borers and rats were given.

The incidence of attack at TFRI, Jabalpur and Korba (Chhattisgarh) were given in separate tables.

The data pertaining to incidence of attack of bamboo insects in nurseries and plantations for TFRI, Jabalpur is for more or less two years. While the data for Korba is only for one year. It is not possible to have any conclusion from the data mentioned. Sample size is also not given.

Regarding pathogens the data have been collected from Reva, Seoni, Chhindwara, Badrwah, Bahrai in M.P and Korba & Bilaspur in Chhattisgarh. The pathogens were isolated cultured and identified. Symptoms and description was also given.

The incidence of pathogens was also given. It is not possible from the tabulated data to infer that the observations are of how many years.

C. Insect pests & diseases of bamboo in storage insects

Only three insect pests were reported. Localities were not mentioned. Incidence of attack of these species is also not given.

Pathogens-

Thirteen species were reported causing decay in stored bamboo culms. Locations and intensity of attack was tabulated.

Quantification of assessment of damage caused by insect pests and diseases is reported.

Natural enemies of the bamboo defoliators-

Two predators and one entomogenous fungus were recorded.

i. Against bamboo diseases

Field trial was conducted at Kasebaedi (Korba) in Chhattisgarh. Various designs of Streptomycin Baristin, Redomyl and Trichoderma were tested against rhizome rot & fungal diseases. The result indicates that there is no significant difference between various treatments





and untreated control.

ii. Against insect pests of bamboos

Seven field experiments were carried out to test the efficacy of various insecticides and their dilutions during 2007 and 2008. In first five trials Endosulfan and Chlorpyrifos with other insecticides were used. These two insecticides are generally not used as foliar application, but used as soil insecticides. At present Endosulfan is banned. The result also indicates that Chlorpyrifos 0.05% and Endosulfan 0.07% best to effectively control. *Cryptesia coclesalis* the bamboo leaf roller. These insecticides must not be recommended for foliar application.

Further when we test the efficacy of insecticides against any insect the active ingredient (a. i.) should be similar to all the insecticides used in the trial so that bias should not be there in the experiment and use of insecticides. In trials one of five the insecticides used have different dilutions which cannot be treated as fair comparison of the efficacy.

In trial experiment six and seven synthetic pyrethroids were tested against the bamboo leaf roller. The dilutions of the various insecticides used were correct for comparison. Best results were given by foliar spraying of fenprothion 0.01% but recently this insecticide is also banned.

The illustrations both photographs and camera lucida drawing are of good quality.

Scientific findings and contents

An attempt has been made to gather information pertaining to insect pests and pathogens damaging bamboo in Central India. Short accounts of the seed insect and diseases, nursery, plantations and stored bamboo damaged by important insects and pathogens were given in the report.

The incidence of attack of both insects and pathogens of bamboos in seed, nurseries, plantations, and stored bamboos was also given. The species of bamboo studied were *Bambusa nutans* and *Dendrocalamus strictus*. There was no or little information about *Bambusa vulgaris* and *Dendrocalamus asper*. The study area is restricted to Madhya Pradesh and Chhattisgarh. The incidence of attack was recorded for one year or two years.

Though the second objective was assessment of damage caused due to insects and disease pests. The same is given in a single paragraph. This aspect is not studied in detail.

Few natural enemies of bamboo leaf roller *Cryptesia coclesalis* which include two insect predators and one entomogenous fungus were reported which were supported by the illustrations/photographs.

For the management of insect pests and pathogens of bamboos in central India, Some experiments were conducted. For the control of pathogens causing rhizome rot and fungal diseases, streptomycin, Bevastin, Redomyl, Trichoderma sp.+ FYM were tested. The data thus collected did not show any significant difference between treated and untreated control. The experiment may be redesigned and new fungicides may be included in the experiment in future.

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

There is no possibility for patenting. The end users of the findings, particularly for the management of insect pests and diseases, may use the strategies evolved. The forest departments, forest development corporations, farmers, industries, plantation companies etc. will be benefitted by the findings. It is suggested that a follow-up experiment may be set up in the disease prevalent areas. New fungicides may be tested against important diseases of bamboos.



62. Studies on the termites of family Termitidae (Insecta; Isoptera) with special emphasis on their taxonomic status, identity & distribution

Principal Investigator: Dr. R.K. Thakur, Scientist-F

Duration: 2008-2010

Critical analysis of the research theme and summary of the study

Termites are well known for their capability to destroy wood, wood products, nursery plants, plantation and natural forest. The abundance of termite in the tropical countries is very high. Forest Research Institute (FRI) is one the pioneer Institution in India for taxonomic studies of termite. The termite taxonomy was initiated at FRI by Dr. M.L. Roonral during 1950-1951. An account of history of termite taxonomy is given. There are 5 families under the order Isoptera to which termites belong viz. 1. Termopsidae 2. Kalotermitidae 3. Rhinotermitidae 4. Stylotermitidae and 5. Termitidae. Termite under the family Termitidae are widely distributed it consists of 4 sub families viz. 1. Amitermitinae 2. Termitinae 3. Macrotermitinae and 4. Nasutitermitinae. Attempts have been made to give correct identification of the species belonging to different genera, their geographical distribution, correct nomenclature etc.

The literature available so far have some lacunae and doubts regarding determination of some species and validity of many species described from different geographical areas. Sometimes the species are separated on minor difference which may not stand when variation in these species are studied with larger collections. Concerted efforts were thus required to study large series of collections of these species and confirm the taxonomic status and identity thereby giving true picture of their geographical distributions.

The species under family Termitidae are the most destructive to forestry, agriculture, horticulture buildings etc. The family Termitidae is widely distributed throughout India. The gaps in the taxonomic status of the species was filled. Whenever required the original types were also studied to clear the doubts and taxonomic status of the species has been established with their correct identification.

While revisiting species of family Termitidae some termite species of family, Termopsidae, Kalotermitidae, Rhinotermitidae and Stylotermitidae were also studied. The description is supported by Camera lucida illustrations & some photographs.

Correct identification and updating the nomenclature of 40 termite species has been done during the present study. Out of 40 species 33 species belonging to family termitidae, 5 species to Kalotermitidae and one species each of families Rhinotermitidae and Stylotermitidae.

Scientific findings and contents

Termites are social insects, they are small delicate but most destructive. There are 337 species of termites described so far from India. These species belong to 59 genera and 7 families. The family Termitidae is the largest with 4 sub-families and 37 genera. During the present study attempts have been made to describe 40 species of termite with their synonymy geographical distribution, material (collection) examined measurement of taxonomically important parts of termite etc.

The systematic account has been arranged phylogenetically under each family and sub-family. The geographical distribution of all the species studied has been given. The comparisons are based on the examination of type specimens referred for authentic validity of species. Whenever necessary, relevant discussions have been incorporated with regards to their taxonomic status.





Redescriptions of 40 species of termites have been done. Out of which 33 species belong to the family Termitidae, 5 species of the family Kalotermitidae and one species each of the family Rhinoermitidae and Styloermitidae.

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

Forest Research Institute (FRI) is the pioneer Institute in India for taxonomic studies on termites. The scientific tools utilized during 1950-1957 are still being used for the taxonomy to termites. There is some addition pertaining to the measurement of taxonomically important body parts which are incorporated in the studies. New taxonomic tools may be searched and utilized for the study and description of new species.

The present study can be utilized for the correct identification of the 40 species of termite and their geographical distribution. This work is important for the students and scientists working on the termite taxonomy.

63. Laboratory testing for the assessment of the durability of timber against powder post beetles- standardization and evaluation

Principal Investigator: Dr. O.K. Remadevi, Scientist-G

Duration: 2006-2011

Critical analysis of the research theme and summary of the study

Wood borer play an important role in the bio-degradation of timber. None of the timber species are immun to the borer damage. During present studies some commercially important timer of southern India were subjected to the borer attack particularly powder powder post beetles belonging to the family Lyctidae and Bostrychidae. Different species of bamboo were also tested against bamboo ghoon *Dinoderus minutus*. Following are the different species of powder pest beetles which were selected for the study:

1. *Syctus africanus* Lyctidae
2. *Sinoxylon anale* Bostrychidae
3. *Sinoxylon conigerum* Bostrychidae
4. *Dinoderus minutus* Bostrychidae

Timber species selected for the experiment were *Hevea braziliensis*, *Mesopsis emini*, *Acacia auriculiformis*, *Acacia mangium*, *Eucalyptus tereticornis*, *Leucaena leucocephala*, *Ailanthus excelsa*, *Melia dubia*, *Grevelia robusta* and different species of bamboo chemical insecticides and preservatives used for the treatment of the timber species are *Biferthrin*, *Chlorpyrifos*, *imidacloprid*, *dichlorovos*, *chlorfenapyr* and *dimilin* as insecticides. Preservative used are Ammonical copper arsenac (ACA) and *Dyroxylum malabaricum* extract, Neem and pongam extracts cashew nut shell liquid (CNSL), *Cleistanthus collines* extract and extract of *Prosopis juliflora*, Plant oil i.e. *Eucalyptus* oil, *Camphor* oil, *Clove oil*, *Caster oil*, *turpentine oil*, *hongi oil*, *olive oil*, *neem oil* and *peppermint oil*. Only fumigant used was phosphine. The timber was treated by spraying, dipping and pressure impregnation.

Before treatment desired dilutions were prepared. Two methods release of beetle and larval transfer method were adopted. For this laboratory culture of test insect was maintained using Tapioca which is converted into chips.



Natural resistance of timber against powder post beetles were studied by releasing 4 pairs of *Lyctus* beetles on test blocks of each timber species. *Acacia mangium* was found relatively more naturally resistance to the lyctus attack while *Mesopsis eminii* was most susceptible. Four timber species were tested for their natural resistance against *Sinoxylon anale* out of which most susceptible was subabool and relatively more resistant was silver oak. Four species of bamboo were also tested for their natural resistance against bamboo ghoon, *Dinoderus minutus*. No significant difference was found on the susceptibility/resistance against *D. minutus*.

Evaluation of bio-efficacy of different products for the control of the powder post beetles have been carried out. For all the experiments the data thus collected was statistically analyzed. Best results were found by using Chlorpyrifos+Cypermethrin 1.0% and 0.5% Pressure/dip/spray treatment of neem/pongam seed extracts, cashew nut shell liquid *Cleistanthus collinus* extract, *Prosopis juliflora* extract and treatment by Ammoniacal copper useful against powder past beetles in varying degrees. Under laboratory conditions 100% mortality of common powder post beetles *Lyctus africanus*, *Sinoxylon anale* and *S. conigerum* was obtained. Phosphine fumigation for 24hrs using 75ppm dose resulted in 100% mortality. The fumigation by phosphine is more practical in killing the existing attack of powder post beetles for small articles as handicrafts attacked by powder past beetles. After fumigation the articles are safe for handling as there is no residue left.

Scientific findings and contents

Timber borers play an important role in biodegradation of timbers. In hard wood timber powder post beetles cause maximum damage. These beetles belongs to the family lyctidae and *Bostrychidae*. In the present study *Lyctus africanus*, *Sinoxylon anale*, *S. conigerum* were used against various hard woods while *Dinoderous minutus* was used against bamboos i.e. *Bambusa balcooa*, *B. pallida*, *Dendrocalamus strictus* & *D. stocksii*.

The study proposed a BIS standard titled laboratory testing for the assessment of the durability of timber and determining the toxic values of wood protectants against powder past beetles (adult release and larval transfer method) Ten species of timber and four species of bamboo were tested either adult release or larval transfer method. Among the hardwood *Acacia mangium* was found relatively resistant while there is no significant difference in the susceptibility of bamboo species. Though *Dendrocalamus strictus* and *D. stocksii* are relatively resistant.

The bio efficacy of insecticides, wood preservatives, fumigants and botanicals/oils were evaluated by adult release and larval transfer method. Chlorpyrifos+cypermethrin was found most effective in giving maximum adult mortality at highest dosages 1.0% & 0.5% pressure/dip/spray treatment of neem/pongam seed extract, cashew nut shell liquid (CXISL), *Cleistanthus collinus* extract, *Prosopis juliflora* extract and treatment by ammonical copper arsemate/copper boric/insecticides were found useful against powder post beetles in varying degrees. Under laboratory conditions, 100% mortality of common powder post beetles was obtained at 200ppm phosphine after exposure of 24hrs while 75ppm dose resulted in 100% mortality of larvae for the same exposure.

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

A detailed study should be done on the effect of various insecticides/preservatives/botanicals etc. separately on *Lyctus africanus* and *Sinoxylon anale* etc. Relative resistance of bamboo species against bamboo ghoon, *Dinoderus spp.* and use of different insecticide/preservatives etc. should be done in details before filing for BIS standards.





Durability of the timer species is enhanced by using different methods of treatment and use of insecticides/preservatives etc.

How long the effect of treatment persists on the treated timber is to be studied

Durability of the timber bamboo is increased by the treatment which helps the end users to adopt these treated timbers for various uses.

More species of timber, especially commercial timber and bamboo should be included for the study.

Treatment of small articles and handicrafts by closed space fumigation with other fumigants available should also be tried.

Natural resistance of timber against powder post beetles was studied. More timber species should be including in the study to help the endusers to utilize the timber for various works.

64. **Taxonomic studies of parasitoids belonging to sub-family Microgastrinae (Hymenoptera, Braconidae) of Uttarakhand & Haryana**

Principal Investigator: Dr. Neena Chauhan, Scientist-D

Duration: 2006-2011

Critical analysis of the research theme and summary of the study

Family Braconidae, order Hymenoptera consists of wasps which are used for the biological control of insect pests damaging forest crops, agricultural and horticultural crops. These wasps normally parasitise lepidopterous insects and are used for their control.

The family Braconidae containing over 15,000 species which are distributed all around the world. There are 43 subfamilies within the family Braconidae. The subfamily Microgastrinae have worldwide distribution. There are more than 1,500 species described so far from different parts of the world. Microgastrinae is the most conspicuous single group of parasitoids of lepidoptera in the world both in species richness and economic importance. More than 100 species of this group have been used in the biological control of lepidopterous pests in tropical and sub tropical ecosystems.

The species belong to the subfamily Microgastrinae generally small, inconspicuous, black to brown or orange in colour and are fully winged. There is 18 segmented antennae scutellar sulcus more or less developed. The species of this subfamily have the spiracles of the first metasomal segment situated on the lateral tergites, rather than on the median tergites and tend to have apical reduced wing venation: Vein 2-S R of fore wing connected to vein r; vein 1-SR meeting or almost meeting pterostigma; vein 2m-cu absent; pterostigma present and usually well differentiated. Hind wing has a long sub medial cell which is almost half of its length, is more than one third of the length of medial cell and several times wider, recurrent vein usually present. The second sub marginal cell of the wing usually with tergites 2 & 3 fused. For the study of the species of Microgastrinae subfamily field collection of infested larvae was done and slides of taxonomically important parts were prepared.

Scientific findings and contents

Species of parasitic wasps belonging to the family Braconidae subfamily Microgastrinae are important bio control agents which are used for the biological control of many lepidopteran pests. During the period under study attempt have been made to redescribe new accession which are incorporated in national forest insect collection (NFIC). Two species of *Apanteles* i.e. *A. galleria* and *A. plutellae*, *Microplitis mediator* and two species of the genus *Cotesia* i.e. *C. electrae* and *C.*



koebeli were rediscrined with the help of SEM microhphotographs and host insect.

An account of the distribution, host insects etc was given for 19 species of genus *Apanteles*, 3 species of genus *Dolichogendea*, 7 species of genus *Cotesia*, one species of the genus *Diocogaster*, 3 species of genus *Proapanteles*, one species of genus *Protomicroplitis*, 3 species of genus *Microgaster* and 5 species of *Microplities*.

An identification key to various genus and tribe of subfamily microgastrine was also given.

A data base of the parastiodis of subfamily Microgastrine present in National Forest Insect Collection has been prepared. The data base give the information pertaining to accession number, name of species, author, type, country, state, collection locality, date of collection, collectors name, distribution and host. This will help the students working on the taxonomy of the subfamily Microgastrine to easily locate the species in the main reference collection for their study.

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

Parasitoids belonging to family braconidae and subfamily microgastrinae are well known as bio control agents of many lepidopteron insect pests. Attempt should be made to mass rear the promising parasitoids of the subfamily microgastrine. Mass rearing can be done on the natural host. Possibility of mass rearing on artificial diet should be explored. The biological control is specific to the target insect, environmentally safe, economically feasible and is time tested technique.

65. Studies on taxonomy of braconid parasitoids (Hymenoptera; Braconidal) from Central India

Principal Investigator: Dr. Mohd. Yousuf, Scientist-F

Duration: 2007-2010

Critical analysis of the research theme and summary of the study

Wasps belonging to the family Braconidae of order Hymenoptera are well known for their ability to parasite harmful insects particularly lepidospteros larvae. Owing to this ability braconids are used as biological control agents against many insect pests and are an important component of Integrated Pest Management (IPM). The braconid parasitoids are distributed throughout India. Attempts have been made to study the paracentic braconids of Central India during the period of this study.

The parasitic braconids were collected from three agro-climatic zones of Chhattisgarh and nine agro-climatic zones of Maharashtra. During the period of the study 185 localities of 16 districts of Chhattisgarh and 385 localities of 34 districts of Maharashtra were visited for the collection of braconids and their host insects. During collection 266 braconids were collected together with 424 samples of host insect from which 22 species of braconid parasitoids emerged. A total of 618 slides of taxonomically important parts of the braconid thus collected were prepared.

During the study period 56 braconid parasitoids have been studied in detail. This include 21 species of genus *Apanteles*, one species of genus *Cassidibracon*, eight species of *Chelonus*, one species each of the genera *Cremonops*, *Doryctobracon*, *Eutropobracon*, *Fopius*, *Habrobracon* and *Heleon*. Two species of genus *Hormius*, four species of genus *Parahormius* and one species each of genera *Protomicroplitis* and *Trioxys*. There 44 species are re-described upto species level while five species (4 species of the genus *Apanteles* and one species of Rogas) have been established through National and International publications.

Seven species (*Anisocyrta gilcricorpa* sp.n., *Bracon jalgaonensis* sp.n, *Chelonus* (*Chelonus*)





wardhensis sp.n, *Chelnous (Microchelonus) hingoliensis* sp.n, *Doryctes indicus* sp.n., *Parahormius lonigcorpis* sp.n. and *Parahormiun longiflagellatus* sp.n) have been proposed as the species new to science . The description is supported by illustrations for seven new species (39 illustrations) and 120 illustrations of taxonomically important characters of 27 important species have been carried out.

Key to the families, genera and species have been prepared for 56 species. Rearing of parasitoids was done by collecting host insects from different localities. Some new hosts were also recorded. A consolidated host-parasitoid records of Indian braconids have been prepared.

Scientific findings and contents

A comprehensive account of the braconids collected from Chhattisgarh and Maharashtra is given. In all 2606 parasitoids were collected from different agro-climatic zones From 16 districts of Chhattisgarh and 34 districts of Maharashtra.

Laboratory rearing of host insects on their respective plant host was done. From these insect hosts 22 braconid parasitoid were emerged.

Detailed taxonomical studies on 56 braconids have been carried of which 44 species have been identified upto species level. Taxonomic status of five species has been established by consulting national and international publications.

Seven species of braconids were discovered and have been proposed as species new to science with illustration of taxonomically important characters (39 illustrations)

Redescription of 27 important known species have been carried out and 120 illustrations of taxonomically important parts were given.

Identification keys of 11 subfamilies and 17 genera have been prepared together with 56 braconid species collected from Chhattisgarh and Maharashtra.

Infested host insects were collected from the field and reared in the laboratory and 22 species of braconid parasitoids were emerged in laboratory. Percentage of natural field parasitization and active period of parasitization was also studied. A consolidated account host-parasitoid record of Indian species of braconid was prepared.

Suggestion regarding follow-up patenting possibility, utilization aspect and prototype

Taxonomical accounts of the members belonging to the family Braconidae in Chhattisgarh and Maharashtra together with the description of seven new braconid species have been carried out.

Apanteles spp were found more abundant in both the states. Mass rearing of *Apanteles* spp should be evolved in the laboratory for release in the deficient areas for the control of the insect pest. Mass rearing may be done on natural host or on artificial diet to be prepared in the laboratory.

Updating the nomenclature should be done regularly. New species should be published in the reputed journal of taxonomy.



66. Taxonomy, biodiversity and habitat association of noctuid moths (Lepidoptera; Noctuidae) in various conifer forests in Himachal Pradesh

Principal Investigator: Dr. Pawan Kumar, Scientist-C

Duration: 2008-2012

Critical analysis of the research theme and summary of the study

Family Noctuidae of order Lepidoptera is one of the largest family with 32 subfamilies. There are estimated 60,000 species of noctuids found in the world. The members of this family include many species of economic importance such as all armyworms and cutworms. Most of the species are recorded as stem & shoot borers, root feeders, defoliators, fruits & seeds feeders, detritus feeders and predators. Owing to the diversified feeding habits noctuids are found in all agro-climatic zones of the country. The main determining characteristic in the post-spiracular position to counter tympanal hood: an ear like structure on first also dominal segment. There are varied vegetational combinations in Himalaya from dry scrub forests at lower altitudes to alpine pastures at higher altitudes. In between distinct vegetational zones of mixed deciduos forests, bamboo chil, oaks deodar, kail, spruce and fir are found. The richness and diversity of flora supports a large number of species. Out of the total 45,000 species found in the country as many as 3,295 species (7.32%) are reported from the region. More than 95% species are endemic to the region.

Noctuid moths are collected by light traps or illuminated white sheet for chirpine forest of Hamirpur and Kangra, Kail forest of Shimla, Deodar forest of Shimla & Mandi, Chilgoza pine forest of Kinnaur and Chamba, Fir and spruce forest of Kullu & Shimla and *Juniperous macropoda* forest of Lahual & Spiti. Periodic collection was made and moths thus collected were stretched & dried. Slides of taxonomically important parts such as wings & genitalia prepared and photographs were taken. The moths were got identified from different reputed Institutions, ZSI, IARI, FRI etc. Biodiversity of the moths was also analyzed and categorized as abundant >30%, very common 20%-30%, common 10%-20%, frequent 5%-10%, occasional 1%-5% rare <1%. Shannon Winner diversity index is applied to known the threat status of the noctuid moths of coniferous forests of Himachal Pradesh.

Detailed studies on the biosystematics of 25 species belonging to 21 genera of the family Noctuidae as carried out. Their synonymy, characteristics of adult, wing venation, genitalia, wing expanse of male and female, material examined and habitat were given. It will be very helpful to the scientific community working on the taxonomy of the family Noctuidae.

A list of 107 species of the family Noctuidae is given with their food plants whenever possible. Abundance and distribution of different species in the forest of different species of conifers in Himachal Pradesh is also given.

Phyto-sociological studies of all the habitats under conifer forest were conducted and for this quadrant of 10m x 10m for trees; 3m x 3m for shrubs and 1m x 1m for herbs were laid. The vegetation data was analyzed for density, frequency and abundance. The relative values of density, frequency and dominance were summed to get importance value index (IVI) of individual species.

Summary of findings & contents

A consolidated account of the moths belonging to family Noctuidae (Lepidoptera) from conifer forest of Himachal Pradesh is given. Taxonomy, status and geographical distribution are given. A total of 107 species of moths of family Noctuidal belonging to 32 subfamilies have been collected





and identified. Taxonomically important characters such as wing venation and genitalia have been studied and illustrations were made together with the current status of the species. In the development of insect conservation lepidopteron insects are commonly known as charismatic flagship species. Wider benefits of conservation studies on single species include developing and clarifying their role as putative umbrella taxa whereby the protection as well as protection of conifer species coexist with other organisms, is documented. Potent umbrella taxa manifest many of the features of indicator and flagship taxa. Due to the drastic climate change during the last decade, different insect pests are diversifying their host preference with ease and are adapting well in changing climatic conditions which in turn cause severe damage to the vegetation and ecosystem in which they live. Biodiversity analysis of the species thus collected has been carried out to ascertain the threat status of the species. Key to the taxa such as subfamily, genus and species have been prepared for easy identification. Host plant relationship has been updated by identifying the host plant preferred by the species of noctuid moths. Faunal diversity of all the conifer habitats has been analyzed to establish the habitat association of the species.

Noctuid moths are good indicators of the environment and can be used to identify ecologically important areas for conservation purposes. Habitat is very important requisite for proliferation and conservation of Lepidoptern insects. During the present study noctuid fauna in different habitat of conifer forest of Himachal Pradesh was studied as to explore the habitat preference of different noctuid moths species so that measures for conservation of biodiversity can be established.

Concentration of dominance of trees, shrubs and herbs and index of diversity have been evaluated for chirpine forest town, chirpine forest Malan, Kail forest Theog, Kail forest Shimla, Deodar forest Narkanda, Deodar forest Jhanjholi, Chilgoza pine forest Akpa, Chilgoza pine forest Bharnampur, Silverfir spruce forest Narkanda, Juniper forest pattan valley and Juniper forest Dsrang.

Shannon-Winner diversity index analysis was carried out to know the status of biodiversity of noctuid moths in various conifer forests. It was observed that during 2009, species richness in chirpine forest was 3.32547 and species evenness was 2.6736389. The species richness in Kail forest was 2.571478 and the species evenness was 2.5038137. The species richness in deodar forest was 2.604729 and species evenness was 2.59273122. The species richness for chilgozapine forest was 2.457864 and the species evenness was 2.59273122. The species richness in silver fir forest is 3.375 and species evenness is 2.548325. the species richness for juniper forest is 1.944562 and species evenness is 2.9514416. Similarly dominance of species in different forest was also studied.

The studies carried out during 2010 indicate that in chirpine forest species richness was 3.8306 and species evenness was 2.544563. The species richness in Kail forest was 2.82843 and species evenness was 2.237715. The species richness in deodar forest was 3.20903 and evenness was 2.993098. The species richness for silver fir forest was 3.5301 and evenness was 2.197031. The species richness for juniper forest was 2.45677 and species evenness was 2.708425. Dominance of the species was also calculated for the year in different forests.

During the year 2011 species richness in chirpine forest was calculated as 2.7264 and species evenness 2.795790073. In kail forest the species richness was 2.7196 and evenness 2.543448719. The species richness in deodar forest was 2.00806 and species evenness was 3.055379468. In silver fir forest the species richness was 4.07622 and species evenness was 2.426045083. The species richness in juniper forest was 3.6366 and species evenness was 2.27851655. Species dominance was also calculated for different forests.



Suggestions regarding follow-up, patenting possibility, utilization aspect and prototype

Extensive collection of noctuid moths of different conifer habitats of Himachal Pradesh has been made with their taxonomical details and geographical distribution and status. It was possible for me to ascertain classification of noctuid moths, which were studied and redescibe 107 species belonging 32 subfamilies. It was not mentioned that classification of which authority was followed. The work will be beneficial for the students working on the taxonomy of family Noctuidae. Food plants of some of the species are not given. After studying the biodiversity, species richness, species evenness and dominance, no inference has been drawn.

Whole work is well supported by the photographs of moths, drawing of wings for study of venation and genitalia Photographs of different conifer forest with associated plant were adequately given.

67. Assessment of insect pest problems of selected bamboo species in Assam and their management

Principal Investigator: R. Raja Rishi, Scientist-C

Duration: 2010-2013

Critical analysis of the research theme and summary of the study

Importance of bamboo in forestry and their utilization is well known. North East of the country is the house of many bamboo species and is utilized by the inhabitants by various ways among other species of bamboo, *Bambusa balcooa*, *B. nutans*, *B. pallida* and *B. tulda* are getting importance. Bamboos are damaged by insects in nurseries, plantations, dried bamboo and bamboos in use. To address this problem an attempt has been made to study the insect pest problems associated with above mentioned bamboo species in the nurseries and plantations and suggest the method for their control.

In Assam nearly 32 species of insect pests of various categories were recorded during the present study on the selected bamboo species. The insect pests are categories major or minor depending on the incidence and intensity of attack. Some new records were also made. A pest calendar was prepared based on the periodicity incidence, intensity of attack and nature of damage in nurseries & plantations of bamboo in Assam. Natural enemy complex of the important pests was also recorded. Abiotic factors like temperature, humidity and rainfall recorded during the period of study were correlated with the level of pest populations. It was found that temperature tends to have positive correlation with the sap sucking insects while significant positive correlation was observed between rainfall and defoliators.

For the management of important insect pests experiments were carried out in laboratory as well as in the field using microbial pesticide, *Beauveria bassiana* and plant extracts of the rhizomes of *Acorus calamus*, leaf extract of *Adhatoda vasica*, neem seed kernel extract etc. Application of *B. bassiana* found very effective in controlling the defoliator pests. Aguous extract of rhizomes of *A. calamus* and leaf extracts of *A. vasica*, was found effective against defoliator insects whereas neem seed kernel and neem oil was found effective for controlling defoliator and sap sucking scales. Insect pests reported feeding on various bamboo species of Assam were listed with their name, systematic position, pest status and nature of damage and discription. Photographs of the insect pests were also given.





Scientific findings and contents

Insect pest damaging, *Bambusa balcooa*, *B. nutans*, *B. pallida* and *B. tulda* have been studied from seven nurseries and twenty three plantations in Assam. Periodic collection of insects was made. Incidence, intensity of attack and nature of damage was noted in all the locations. In all 32 insect pests were recorded and based on the incidence and intensity of attack these pests were categorized in major and minor pests. There are seven species of sap suckers, nineteen species of defoliators, three species of borers and three species of root feeders out of these four species of sap sucker and six defoliators were found major insects pests damaging bamboo in Assam.

Biology of the key defoliators of bamboo species was studied in the laboratory. Abundance pertaining to different seasons was also studied and a pest calendar depicting seasonal abundance of different insect pests was prepared. Natural enemy complex of the major insect pests was studied and some predators, parasitoids and pathogens were recorded acting as biotic agents for regulation of pest population. Abiotic factors, temperature, humidity and rainfall in the areas of study were noted. Analysis of correlation between all pests vs rainfall, temperature and humidity has been studied. It was found that during the months of January to March the temperature varies between 15.8° C to 23.8° C and analysis indicate that this temperature range tends to have a significant positive correlation among the sap sucking insects in Assam. Defoliators cause considerable damage to the foliage of bamboo during the months from May to August where average rainfall varies between 132.5 mm to 509.5 mm and the analysis shows that this rainfall tends to have a significant positive correlation among the defoliators of bamboo in Assam. Method of mass production of entomogeneous fungus *Beauveria bossiana* on vegetable waste rice powder and sorghum grain media has been standardized. The efficiency of *Beauveria bassiana* has been tested against defoliators of bamboo. Effective dose for the control of the defoliator was found 7.8×10^{10} and 7.8×10^{10} (spores/ml) for target insects. There was 100% control of the defoliators in the seventh day of the treatment in the field condition. Efficiency of bacteria, *Bacillus* sp. was also tested against *Pyrausta coclesalis* a well known bamboo defoliator. There was 100% mortality when treated with 2.6×10^8 CFU/ml concentrations. Methanol extract of the rhizomes of *Acorus calamus* when used at 4% concentration, caused 76% mortality of the larvae of *Parasa* sp. in laboratory and 58% larval mortality in field after 48 hrs of treatment The rhizome extract was also tested against other bamboo defoliators and was found effective in causing mortality of larvae. Aquous extract of the leaves of *Adhatoda vasica* at 4% concentration caused 60% larval mortality after 48 hrs in case of *Pyrausta coclesalis*. Neem seed kernel extract was also tested against defoliator *Crocidophora* sp and aphids at 5% and 10% concentration which caused considerable mortality. Neem oil at 2.5% concentration was effective on scale insect, *Antonina* sp. in field and caused 66% mortality in 72 hrs.

Suggestions regarding follow up, patenting possibility, utilization aspect and prototype

Bamboo plays a vital role in the livelihood and economy of North East India. Insects feeding and damaging green standing bamboo cause problem in raising bamboo plantation. The damage caused by the insect reduces the productivity of bamboo in the area. A good attempt has been made to study insects damaging bamboo and their management. It is suggested that a detailed study on the individual insect pest should be conducted and pest specific, eco friendly management methods should be evolved. An extension Hand Book has been published with the photographs, nature of damage and control of important insects of bamboo. The Hand Book will play an important role in causing awareness to the foresters, famers and other individuals growing bamboo. It is also suggested that insect damaging felled bamboo should be studied and suitable control measures evolved.



68. Natural enemy examples of key and potential pests of five *Quercus* spp. of Himachal Pradesh

Principal Investigator: Dr. S. Chakrabarti, Scientist-E

Duration: 2003-2008

Critical analysis of the research theme and summary of the study

Oaks are the important tree species in the Himalaya, and distributed in Eastern Himalaya as well as in Western Himalaya. In Western Himalaya six species of oaks are found i.e. *Quercus leucotrichophora*, *Q. Himalayana*, *Q. Semecarpifolia*, *Q. Glauca*, *Q. Lanuginosa* and *Q. Ilex*. About 90 species of insects feed on oaks, as defoliator, stemborer, acorn feeder etc. Oak forest, Sudernagar, Shimla, Kinnaur, Rampur, Chopal, Solan, and Sirmaur districts were visited and various areas/locations were selected for insect pest collections. *Quercus leucotrichophora* was damage by many insects while other 4 species were less attacked except acorn borer. After screening of the pest sprectum three insect species *Lymantria obfuscata*, *Curculio sikkimensis* and *Holotrichia longipennis* were selected for the study. Detailed studies on the life cycle of *Lymantria obfuscata* (Indian Gypsy Moth) were carried out After mating the female deposit eggs as egg masses which are covered with soft yellow hairs. One egg mass comprises of 250-300 eggs. The stage is prolonged and may last for 8-10 months. Hatching takes place in March-April. There are six laval insects and larval period is 47-65 days. The female pupa is larger than the male pupa and the pupal period is 12-17 days. Emergence of moths and egg laying is reported during the month of June. The life cycle is completed in a year. There is one generation per year (univoltine). One pathogen Baculovirus was reported to insect *L. Obfuscata* larvae and is named as *Lymantria Obfuscata* nuclear polyhydrosis virus (LONPV). Studies on other important insects infesting oaks have not been done. i.e. *Curculio sikkimensis*, oak acorn borer and *Holotrichia longipennis*, beetles of this *Holotrichia* are the polyphagous defoliator of many broad leave tree species. A data base by listing of known insect pests of oaks in India have been given in the report but it is not specified, on which *Quercus* species these insects are recorded in the past.

Scientific findings and contents

Five species of oaks, *Quercus leucotrichophora*, *Q. semecarpifolia*, *Q. floribunda = himalayana*, *Q. glauca* and *Q. ilex* were screened for insect pests and their natural enemies. *Q. leucotrichophora* was found more vulnerable as acorn borers and defoliators damage it most. *Lymantria obfuscata*, Indian Gypsy Moth (IGM) was found major defoliator of ban oak in outer Himalaya, its life cycle was studied. Three new species of *Torymus* were discovered parasitizing gall making cynipid on oak. 22 species of spiders were identified as predators of many insects feeding on oaks. A native strain of *Baculovirus* (LONPV) was discovered from the larvae of *L. obfuscata*. Some control measures were also suggested but are not carried out during the study, for the management of *Lymantria obfuscata*, the Indian Gypsy Moth (IGM).

Suggestions regarding follow up patenting possibilities, utilization aspect, and prototype

The objectives of the study are not completely addressed. Only one major defoliator of *Quercus leucotrichophora*, *Lymantria obfuscata* was studied in details. The life history of this insect is also worked out in details by many workers in the past. Other important insects damaging *Quercus* spp were not studied. A passing reference has been given for the oak acorn borer *Curculio sikkimensis* and defoliator, *Holotrichia Longipennis*. It is suggested that there are other insects which damage oaks in Western Himalaya. Some of them were reported causing out breaks, should be taken as a follow up project. I think that virus infesting insects cannot be cultured in the laboratory. As





mentioned in the report the Baculovirus names as Lymantria Obfuscata Nuclear Polyhedrosis Virus (LONPV) may be mass cultured in the laboratory, spray formulation may be developed and sprayed in the affected areas for the control is not possible. Moulting study of the larvae of *L. obfuscata* has been done in the laboratory only length and width of the larval were measured while for the correct determination of different insects of the larval measurement of head capsule is essential as indicated under Dyar's law.



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P.O. New Forest, Dehradun, Uttarakhand, India