

2.7 Forest Protection

2.7.1 Overview

Research on Forest Protection is focused on activities envisaged under different ongoing and completed projects funded by ICFRE and various external funding agencies by ICFRE institutes. The important aspects are identification of insect pests, pathogens, beneficial microbes and protection of forest seeds, seedlings, saplings, trees in plantation, and stored wood by developing Integrated Pest Management strategies for the key pests of important tree species, seed pests of selective indigenous tree species and their management, assessment of disease problems of fast growing tree species, screening of eucalyptus clones for the gall insect, pest-host plant interactions, exploring natural enemies of insect pests, identification and testing of efficacy and effect of ecto- and endo-mycorrhizal fungi and PGPRs on rooting and growth improvement of indigenous trees, identification of salt tolerant AM fungi and PGPRs, studies on association of AM fungi in heavy metal contaminated soil, and field evaluation of superior strains of *Frankia* in casuarinas, exploration of scope of microbes in bioremediation and biofertilization and DNA finger printing of pathogenic and useful fungi. Under changing environmental conditions, the forest health is a matter of serious concerns under changing climatic conditions especially temperature, erratic rainfall, receding glaciers in hills and drought like conditions interfere with the growth and development of tree. They also influence the population dynamics and development of insect and pathogens, which negatively impact the sustainability of ecosystem and its services.

2.7.1.1 Summary of the Achievements under the Theme

Insect/Marine Pests

- Gas chromatography coupled electro-antennogram detector studies on *Leptocybe invasa* and its

parasitoids showed significant variation in acceptance and deterrence to volatiles extracted from resistant and susceptible eucalyptus clones.

- Twelve bacterial isolates, obtained from *Ailanthus* and *Casuarina* insect pests were characterized (morphological and biochemical) and all 12 isolates identified as *Bacillus* spp. Two effective bacterial isolates identified, using nucleotide sequencing, as *Bacillus thuringiensis* and *B. sphaericus*.
- Host specificity studies, using four prioritized insects species i.e., *Anomalococcus indicus*, *Isturgia disputeria*, *Dereodus denticollis*, and *Physita* sp. on 9 species of Australian and Asian acacias were completed.
- Screening of 238 clones of eucalyptus raised in field trials and maintained at VMG at Satyavedu, Panampally and Bharathiar University campus for gall insect attack was continued and the status of the clones for the attack of the pest was categorized into resistant/tolerant, less susceptible, moderately susceptible and highly susceptible.
- Standardized low cost non-chemical and chemical control measures to contain the eucalyptus gall wasp problem in nurseries.
- Effective concentrations of chemicals and botanicals, earlier studied in the lab bioassay studies, were field tested for their effectiveness against the following targeted insect pests: *Eupterote geminata*, *Tingis beesooni*, *Myllocerous discolour*, *M. viridanus*, *Atteva fabriciella* and *Eligma narcissus*.
- Bio-assayed two species of potential entomopathogenic fungi (*Beauveria* sp. and *Metarhizium* sp.) and two Bacteria (*Bacillus* spp.) against the following targeted insect pests: *Atteva fabriciella*, *Eligma narcissus* and *Lymantria ampla*.



- Infestation of *Indarbela quadrinotata*, a pest of *Casuarina equisetifolia*, was the highest in the North Eastern agroclimatic zone of Tamil Nadu. Data on growth parameters of the trees and pest incidence were periodically collected at plantation raised in 2006, at T.S. Pettai. It was found that there was no significant growth reduction due to the pest attack, though the infestation led to mortality of a few trees due to the invasion of wound by pathogens.
- Bioactive compounds responsible for biopesticidal properties have been identified from the ethnobotanical extracts against teak defoliator and *Ailanthus* defoliators through bioassays.
- Mealy bug survey was conducted in various tree plantations, agroforestry plantations and horticulture crops in southern districts of Tamil Nadu. Leaves were sequentially extracted with solvents to screen the bio-efficacy against papaya mealy bug.
- Sandal dominated ecosystems of Karnataka revealed the presence of 25 coccinellid spp. in selected provenances. A new coccid viz *Coccus viridis* was found attacking Sandal and Aonla. *Tectona grandis* was found to be severely attacked by an unidentified coccid.
- Seed insect pests of *Acacia nilotica*, *Ailanthus excelsa*, *Prosopis cineraria*, *Salvadora persica*, *Salvadora oleoides*, *Tectona grandis* and *Azadirachta indica* were studied.
- Rearing of different larval instars of *Acanthophorus serraticornis* on artificial diet/wood was observed.
- A native strain of baculovirus was extracted from infected larvae of *Lymantria obfuscata*,
- Life cycle and biology of predatory social spider *Stegodyphus sarasinorum* was studied in the nursery. The result indicated that each female produced on 1-2 egg-case containing about 100-150 eggs in each. These eggs hatch in 20-25 days and spiderlings emerge out of the egg-case in 30 days. There are 12 instars of the spiderlings to become adult and only at the end of 12th instar, the sex can be determined.
- A new mite species has been found infesting the stored seeds. The data on different treatments applied against various attacks have been taken and analyzed for developing suitable control measures to protect the stored Chilgoza seeds for longer period.
- During the surveys in Jharkhand, *Psylla*, black weevil, leaf miner, green bug, and trunk borer, aphid have been observed from sal, gamhar trees and cow bug and plant hopper from sissoo trees.

Diseases and Useful Microbes

- Screening for resistant clones of *Dalbergia sissoo* against *Fusarium solani* and *Ganoderma lucidum* using direct inoculation technique was done. Clones were also tested in a sick plot with four virulent strains of *Fusarium solani* f. sp. *dalbergiae*.
- Diseased samples were collected from Uttar Pradesh for *Cylindrocladium quinqueseptatum* leaf spots and blight disease and after the DNA finger printing of 26 isolates, by nrDNA amplification, sequencing and BLAST search, Haplotype analysis was conducted and different lineages identified.
- Four primers were designed for Eucalyptus pathogens *Pestalotiopsis* spp. which will be helpful in quickly detecting and identifying the isolates.
- Isolates of *Alternaria alternata* from FRI, Rudrapur and Paniyala have been collected on poplar genotypes. Relative growth study and toxin extraction of the pathogen done.
- A new stem canker disease on *Dalbergia sissoo* caused by *Lasiodiplodia* sp. from Sirsa, Haryana; wilt disease in *Uraria picta* by *Fusarium solani* and leaf spots disease in *Piper longum* by *Botrytis cinerea* from Dehradun were reported.
- Qualitative and quantitative solubilisation efficiency and HCN and siderophore production of isolates of *Pseudomonas fluorescens* collected from FRI (UK), Kalka (Haryana) and Hoshiyarpur (Punjab) have been carried out.
- Seven different fungal pathogens viz., species of *Alternaria*, *Cercospora*, *Coniella*,



Cylindrocladium, *Pestalotiopsis*, *Corticium* and *Lasiodiplodia* were recorded causing leaf and stem diseases. There was a variation in the incidence and distribution of these diseases caused by different pathogens in various locations during two years period of observations.

- Foliar diseases such as leaf spot, leaf blight and powdery mildew on *Ailanthus excelsa*, *Gmelina arborea*, *Melia dubia* and *Pongamia pinnata* caused by *Alternaria alternata*, *Colletotrichum* spp. and *Oidium* sp. were recorded from TCPL nurseries and plantations in Tamil Nadu.
- A field trial with 36 resistant clones of *Casuarina equisetifolia* identified for blister bark disease-through controlled condition studies has been established to test the consistency of resistant nature in the field.
- The distribution, nature and intensity of damage of bamboo blight disease were recorded.
- Surveys were conducted in seven different *Khasi* pine inhabiting areas of Meghalaya to assess the status of pine mortality and maximum of 40% disease incidence recorded in NEHU Campus, Shillong.
- Four isolates of *Ganoderma lucidum* were collected from western Rajasthan for pathogenicity test and effective control measurement.
- A nematode *Bursaphelenchus* sp. was collected and identified from the soil of infested *Prosopis cineraria* trees.
- Through Koch's postulate it was established that *Lasiodiplodia theobromae* and *Acremonium* sp. caused canker in *Tecomella undulata*.
- The total protein content in infected seedlings increased as the days of inoculation of the pathogen (*L. theobromae*) increased, i.e. concentration of protein was more after 90 days of inoculation as compared to after 15 days of infection.
- In composting the major litter decomposing mycoflora reported isolated and identified were *Aspergillus niger*, *A. flavus*, *Trichoderma* sp. and *Fusarium* sp.
- Anaerobic composting in pits by using Farm Yard Manure + Dried leaves + Niprovat (containing *Trichoderma viride*) with mulching has taken 120 days in winter season; it was due to slow microbial activity in low temperature.
- Molecular and RAPD markers analysis done for 3 isolates (Panampally, Tuticorin and Rameswaram) of *Casuarina* blister bark pathogen *Subramanianospora vesiculosa*, showed same genotypic characters.
- Under elevated CO₂ *Frankia* inoculated rooted stem cuttings of *Casuarina* responded significantly and produced root nodules within 25 days.
- A total 94 isolates of PGPRs were isolated from the rhizosphere of 18 different shola tree species in the Nilgiri hills, Tamil Nadu and species level identification was done.
- Efficient PGPR isolates were short listed based on the efficacy of IAA production and phosphate solubilization under *in-vitro* conditions.
- A total 51 isolates of PGPRs were isolated from different salt affected sites in Tamil Nadu and Puducherry.
- Efficacy of PGPRs isolated from different salt affected sites was screened for the production of plant growth hormone (IAA) and Phosphate solubilization under *in-vitro* condition.
- Rhizospheric soil samples were collected from two ranges i.e. Umtasor (five compartments) and Nongpoh (Lc. Colony, Morok, Diphu-Sydang & Tower point) and screened for endomycorrhizal qualitative and quantitative analysis.
- Different strains of species of *Acaulospora*, *Glomus* and *Gigaspora* were isolated and inoculum production and mass multiplication through trap culture and pot/plot culture worked out.
- Diversity of mycorrhizal associations with *Dipterocarpus* and *Shorea* species in Assam was documented.



- In association with *Acacia nilotica* and *Ailanthus excelsa*, important genera of AM fungi viz. *Acaulospora*, *Gigaspora*, *Glomus* and *Sclerocystis* were identified. *Glomus* occurred most frequently.
- The different species of *Glomus* were recorded as *G. aggregatum*, *G. fasciculatum*, *G. mosseae*, *G. macrocarpum*, *G. microcarpum* and *G. constrictum*. *G. fasciculatum* was dominant species in all the sites of nurseries as well as in plantations of *A. nilotica* and *A. excelsa*.
- The spore population varied from site to site and ranged between 163 to 480 propagules per 100 g soil from the rhizosphere of *Acacia nilotica* and 195 to 670 propagules per 100 g from the rhizosphere soil of *Ailanthus excelsa*.
- Antifungal properties of selected plant parts (flower bud of *Datura stramonium*; leaf and root of *Tribulus terrestris*; root, flower and fruit of *Argemone mexicana*) were evaluated against fungal pathogens *Alternaria alternate*, *Fusarium solani*, *F. verticilloides*, *Rhizoctonia solani* and *R. bataticola*.

Dendrocalamus strictus, *Dendrocalamus calostachyus* and *Gigantochloa atroviolacea*. Average attack percentage on these species was recorded from 1.63 to 51.29 % with maximum attack of 51.29 % in *Bambusa wamin*.

Insect Pests of Selected Bamboo Species in Assam and their Management

Surveys were conducted in the SFD, JFM and homestead bamboo plantations and nurseries in the district of Nagaon, Sonitpur, Sivasagar, Kamrup, Golaghat and Jorhat District. Thirty one insect species belonging to various orders were recorded. Based on the incidence and intensity of insect pest attack, the insect *Antonia* sp., *Psara licarsisalis*, *Crocidophora* sp., *Pyrausta coclesalis*, *Oxya nitidula* were categorized as major pests. Two new hosts were recorded as *Discophora sondiaca* and *Nemetis chandica* on *Bambusa pallida*. During survey, the natural enemies of four different predatory spiders *Oxyopes* sp. and *O. refisternum* on the larvae of *Crocidophora* sp. and *Psara licarsisali*, *Argiope catenulate* on *Pyrausta coclesalis* and *Crocidophora* sp. were recorded.

Field Manual of Insect Pests and their Control in Plantations

Literature and field data have been sorted out and finally compiled for preparation of field manuals of *Populus deltoides*, *Dalbergia sissoo* and *Bamboo*. During collection of data, six new insect pests have also been recorded from the field. Regular surveys are being conducted in field for collection of photographs that are not available in the literature.

Thrips of Forests and Medicinal Plants and their Management in Uttarakhand

A new species *Streothrips anshumani* has been described from Dehra Dun, Uttarakhand, India. It was collected from flowers of pear tree, *Pyrus communis*, growing in the FRI, Dehradun. The genus *Streothrips* Bhatti is known to pertain three species, of which two species have been recorded from India and 1 species (*Streothrips alaris* Reyes) reported from Philippines. Both Indian species have been collected from Doon

Project under the Theme			
Projects	Completed Projects	Ongoing Projects	New Projects Initiated During the Year
Plan	15	27	17
Externally Aided	05	05	07
Total	20	32	24

2.7.2 Insects Pests, Diseases and Control

Insect Pests

Insect Pest Surveys, Incidence and Biology *Phloeobius crassicollis* – a New Insect Pest

P. crassicollis was reported as new pest on the following ten bamboos species in and around Dehradun: *Bambusa bambos*, *Bambusa nutans*, *Bambusa polymorpha*, *Bambusa tulda*, *Bambusa vulgaris*, *Bambusa wamin*, *Dendrocalamus giganteus*,



valley. Apart from one new species other thrips species, *Lefryothrips lefroyi*, *Scirtothrips dorsalis* Hood, *Thrips flavus* Schrank have also been collected and identified. One more species of genus *Lefryothrips* has been collected, which is yet to be identified up to species level.

Status of Sal Heartwood Borer, *Hoplocerambyx spinicornis* and its Management

Sal forest areas of Madhya Pradesh and Chhattisgarh were surveyed for monitoring of sal borer, collection of information on borer incidence, natural enemies and abiotic and biotic factors. Natural enemies were identified and sample plots were laid out in sal forest areas of Mandla, Dindori and Anuppur Forest Divisions. Sal borer problem was investigated in Chhattisgarh and a training programme on sal borer and its management was conducted.

Seed Insect Pests

The seed samples have been collected from eight selected tree species recommended by Gujarat Forest Department to study the insect pest incidence. The sites selected for the seed collection of respective tree species were - Nadiad Social Forestry Division (*Acacia nilotica*), Mehsana Social Forestry Division (*Ailanthus excelsa*), Palanpur (Banas Kantha division) (*Boswellia serrata*), Bhuj (Kutch), Sorastra, Jamnagar (*Prosopis cineraria*, *Salvadora persica*, *Salvadora oleoides*), Gandhinagar Division (*Azadirachta indica*), Rajpipla, Valsad and Dang (*Tectona grandis*) and Rajkot (grass species). Seeds of *Acacia nilotica*, *Ailanthus excelsa*, *Prosopis cineraria*, *Salvadora persica*, *Salvadora*

oleoides, *Tectona grandis* and *Azadirachta indica* have been collected and kept in laboratory for further studies related to the identification of emerged insect pest and their incidence of attack. The rearing of insects was conducted in laboratory under control conditions.

Insect Pests of *Dysoxylum malabaricum*, *Garcinia gummigatta*, *Myristica malabarica*, *Vateria indica*

Studies on insect pest problems and their management were made for the seedlings of eight forestry species viz., *Dysoxylum malabaricum* Bedd., *Garcinia gummigatta* (L.) Robson, *Myristica malabarica* Lam., *Vateria indica* L. *Azadirachta indica* A. Juss, *Pongamia pinnata* L., *Emblica officinalis* Gaertn. and *Sapindus emarginatus* Valph raised in forest nurseries. Insect population varied with location and season. Hebbal nursery possessed 46%, followed by Sulikere, 32%, and Udane 12%, and Medinadka 9%. Total 12 different species of insects were found associated in different nurseries. Infestation was more severe in plains when as compared to nurseries of Western Ghat area. Control measures were carried out and it was found that Chlorophyriphos was more effective.

Flower and Seed Pests of *Neolamarkia cadamba*, *Ailanthus excelsa*, *Pongamia pinnata*, *Thespesia populnea* and *Melia dubia*

Many Coleopteran and Lepidopteran species of seed pests were collected but no serious pest was recorded during pre harvest and during storage in *N. cadamba*, *A. excelsa*, *P. pinnata*, *T. populnea* and *M. dubia* seeds. Damage assessment in terms of nature and intensity of attack by pests in *P. pinnata* during post harvest storage by an unidentified Lepidopteran species caused loss of 250g/kg of seeds and an unidentified bruchid beetle resulted in damage of 15g/kg of seeds during storage. Monitoring pests during storage using TNAU traps carried showed that significant number of coleopteran species could be trapped in *P. pinnata* seeds during storage. Four species of hymenopterans were collected from *P. pinnata* seeds.



Infested Pods of *Acacia nilotica*

Infested Seed of *Acacia nilotica*



Insect Pests in Selected Silvi-horticultural Models in Karnataka

Model -1: At Bevanahalli, *Tectona grandis* (Teak) and *Grevillea robusta* (Silver oak) with *Mangifera indica* (mango); Sandal and silver oak with Mango, Pomegranate and guava combinations had very high coccid infestations as compared to the other insects present. Bark feeding termites were also high on sandal and silver oak.

Model-2: At Mudelahalli, Sandal with amla and tamarind; *Tectona grandis* with Mango combinations, both Sandal and Amla had dominant infestation by bark eating caterpillar, *Indarbela quadrinotata*. A new coccid viz *Coccus viridis* was found attacking Sandal and Aonla. *Tectona grandis* was found to be severely attacked by an unidentified coccid and Mango was found to be severely attacked by Black Band Rot disease. This disease was affecting flowering and fruiting of Mango.

Model-3: At Kolar, *Tectona grandis*, *Terminalia arjuna*, *Dalbergia latifolia*, *Pterocarpus santalinus*, *Eucalyptus*, *Grevillea robusta* grown along with *Mangifera indica* (Mango), *Achras zapota* (Sapota), *Citrus maxima*, Pomegranate, *Citrus limonia* and guava). *Pterocarpus santalinus* was heavily infested by an unidentified membracid, and unidentified weevils. *Tectona grandis* was infested by the teak defoliator and skeletonizer. *Dalbergia latifolia* was also heavily infested by unidentified weevils. *Grevillea robusta* showed severe termite infestation with gummosis and *Tectona grandis*. *Psidium guajava* (Guava) was severely affected by white flies (*Aleurodicus dispersus*). The leaf gall wasp *Leptocybe invasa* was observed on the *Eucalyptus hybrid* trees.

Model-4: At Devanahalli, in Teak with Mango and sapota combination, termite infestation was severe on the most of the trees of *Tectona grandis*.

Fouling Organism

During studies on macro wood detriogens at Kakinada port and Narsapur Greenfield port, Andhra Pradesh, test ladders of wooden panels exposed at the three test sites, viz, deep water port and fishing harbour

at Kakinada and test site at Narsapur. Monthly observations on fouling and wood boring organisms carried out, test panels retrieved and replaced, water samples analyzed for various parameters. Data on fouling and wood boring forms have been recorded.

Control

Chemical

Eucalyptus Gall Wasp, *Leptocybe invasa*

Soil application of Acetamaprid significantly controlled the gall formation. On the other hand, plant based extracts and foliar applications of various pesticides did not significantly controlled gall formation.

Seed Pests of *Pongamia pinnata*

Seed treatments with 3 pesticides, 2 plant based extracts to study protection of seeds during storage against two sp. of pests in *Pongamia* seeds showed that plant based extracts like Neem powder and neem based extracts and pesticides like Dichlorvos and Monocrotophos protected seeds for a longer period and pest mortality was higher than plant based extract treated seed lots. Persistence of protection in terms of number of days for each treatment was also studied.

Control of *Eupterote geminata*, *Tingis beesooni*, *Myllocerous discolor*, *M. Viridanus*, *Atteva fabriciella* and *Eligma narcissus*

The effective concentrations of 5 chemicals (Quinalphos, Monocrotophos, Chlorpyriphos, Imidacloprid and Dimethoate) and 5 botanicals (Neem oil, Jatropha oil and *Pongamia* oil, *Hydnocarpus* seed oil and Neem azal 1%) determined in the lab bioassay studies were tested for their field efficacy against the targeted pests. The chemical Monocrotophos @ 0.025% was found effective for all the pests, whereas, the efficacy was found to vary between 0.05% to 0.075% with the species with the other chemicals. In the case of botanicals, the product Neem azal 1% at 30 ppm was able to cause mortality (50-60%) in respect of defoliators and good repellency for both the defoliators and sap suckers. Cultural and mechanical control methods were also devised and practiced for the targeted pests.



Management of Khejri Mortality in Rajasthan

Trials were laid out at six sites in five districts: Surani (Balesar Road, Jodhpur), Raghunathpura (Didwana in Nagaur), Jhareli (Jayal in Nagaur), Goshala (Fatehpur in Sikar), Churu (Churu) and Sultana (Jhunjhunu). The treatments T-1 = Bavistin (0.1%) + chlorapyrophos (0.05%) + powermin @2ml/l and applied around two feet of trees trunk root treatment of 20 litre solution, T-2 = 20 g phorate granules at the base of the pit, covered with 8-10 inches layer of soil + 50 g *Trichoderma* in talc mixed with 5 kg FYM, applied above the layer of phorate and another layer of soil over it, T-3 = chlorpyriphos (20 EC) 15 ml + carbandazium (50 WP) 20 g + copper oxychloride (50 WP 40 g / tree. T-4 = as control using soil work and drenching with 20 litres water /tree. First round of treatments were conducted during February-March, 2011 and data pertaining to infestation caused by pests/diseases were collected after six months of treatment to evaluate the effectiveness of different treatments in the various experimental sites. It was observed that the treated trees exhibited a significant effect on recovery ranging from 25 to 35% as compared to the control, wherein percentage of infected trees remained 100%. Observation was also recorded to study the impact of good rainfall during last two years on present scenario of Khejri mortality. A significant increase in foliage production in Khejri tree has been observed after good rains experienced since past two years, but the percentage of infestation caused by the root borer, *Acanthophorus serraticornis* and disease *Ganoderma lucidum*, in Khejri remained unchanged, ranging between 90-100% of trees in the farmer's field. The second treatment was given during December, 2011 – January, 2012. The observations on the effect of second treatment have been recorded in June-July, 2012, six months after the treatment.

Phloeobius crassicollis

Phloeobius crassicollis is a major pest of bamboos. Newly emerged beetle feed on the outer surface of the bamboo culm, preferably at the nodes during May-June and damages the new culm. Chlorpyriphos at 0.04% and 0.05% concentration gave 78.16 and 80.94% control, respectively.

Oak Stem Borer, *Aphrodisium hardwickianum* White (Coleoptera: Cerambycidae)

Monocrotophos (36 EC) and dimethoate (30 EC) at concentrations of 0.4% each and 5-10 ml of of fumigant (saturated solution of para-dichlorobenzene in kerosene oil / emergence hole) were found to be most effective measure. Mechanical control by hammering stone into the exit hole for adult was also effective.

Biocontrol

Eucalyptus gall wasp, *Leptocybe invasa*

Considering the adverse impacts of chemical pesticides, difficulties in application in vast areas of plantations and concealed nature of the pest inside the gall, integrated management measures were attempted in nurseries involving traps, plant based extracts, pesticides, classical biological control and utilization of gall resistant germplasm of eucalypts. Trap methods (Light trap, colour traps, sticky traps) did not reduce the gall wasp population in nursery beds. Significant reduction in gall wasp population was observed when gall tolerant clones were deployed along with release of natural enemies *Quadrastichus mendeli* and *Megastigmus* sp. Results show that deployment of these two methods helped in reducing the high cost of containing the pest in outbreak situations and avoid loss of planting material.

Through a classical biological control programme, natural enemies *Quadrastichus mendeli* and *Megastigmus* sp. were introduced from Israel for the management of gall wasp. Parasitisation efficiency of natural enemies to galls on different species/clones of Eucalypts was studied. Host preference by the natural enemies of *L. invasa* in relation to the variation in gall incidence on different Eucalypts germplasm was also studied. More individuals of parasite and reduced gall induction was observed in susceptible eucalyptus clones in nursery beds. Gall tolerant clones showed less gall induction and less population wasp population. Gas chromatography coupled electro-antennogram detector studies of eucalyptus gall wasp and its parasites response to various eucalyptus germplasm showed significant results. Response of gall wasp to volatile



profiles of resistant clones showed absence of key compounds necessary for eliciting acceptance reaction by gall wasp, whereas those of susceptible clones revealed several compounds which are known as attractants or deterrents. These results will go a long way in tailoring gall tolerant/resistant clones with pest deterrent chemoprofiles.

Acacias

Host specificity studies with four species of prioritized insects (*Anomalococcus indicus*, *Isturgia disputeria*, *Dereodus denticollis*, *physita* sp.) were continued on live hosts of 9 species of Australian and Asian Acacias. The studies revealed that the scale insect, *A. indicus* survived on *Acacia planiferans* and *A. tortilis*. The defoliator *I. disputeria* survived and completed lifecycle on 3 species of Acacias viz., *A. planiferans*, *A. leucophila* and *A. tortilis*. The weevil *D. denticollis* survived only on *A. nilotica* ssp. *indica* and *A. nilotica* ssp. *tomentosa*. Further studies on this line are in progress.

Insect Pests of *Ailanthus* and *Casuarina*

Pathogenicity studies were carried out with 5 isolates of *Bacillus* and 2 species of entomopathogenic fungi on targeted pests. It was found that 2 isolates of bacteria, *Bacillus thuringiensis* and *B. sphericus* and 2 species of fungi, *Metarhizium anisopliae* and *Beauveria bassiana* were pathogenic. Further laboratory bioassay studies, with these potential bio-agents against the targeted pests, *Atteva fabriciella*, *Eligma narcissus* and *Lymantria ampla*, expressed that the bacteria at the concentration 1×10^8 cells/ml and the fungus *B. bassiana* at the concentration of 2×10^8 spores/ml were effective resulting 100% larval mortality over a period of 72hrs and 5days, respectively.

Coccinellids Based Biocontrol of Sandal Scales and Mealy Bugs

The study aimed to identify more potential coccinellids in sandal dominated ecosystems of Karnataka revealed the presence of 25 coccinellids in selected provenances of sandal in Karnataka. The non outbreak of insect pests on sandal is attributed to the prevalence of these coccinellids in the natural habitats

of sandal. Five species of coccinellids which were active on sandal plantations in areas outside forests were collected in association with scales and mealy bugs infesting sandal.

Field Evaluation of Indigenous Species of *Trichogramma* against Teak Skeletonizer *Eutectona machaeralis*

Population of teak skeletonizer, *Eutectona machaeralis* was observed in experimental areas. *Trichogramma* species was released against teak skeletonizer, *Eutectona machaeralis* in the field condition. Field evaluation have been initiated in three different localities Moiyanal, Udaipur and Tikariya in Mandla Forest Division, Mandla and observations recorded.

Biocontrol Potential of Native Isolates of Entomopathogenic Nematodes for the Management of Insect Pests of Teak

Biocontrol potential of 6 native isolates has been determined against the teak skeletonizer using the laboratory culture of one exotic and six unidentified (native) populations of EPNs native to central India, maintained *in-vivo*, round the year. The improved method for field applications of entomopathogenic nematodes and related parameters affecting field applications were also experimented. The determination of best effective formulation of the selected EPN and its efficacy with regards to the stages and time of application against the target pests was investigated. The work is still in progress.

Biological Control of Teak Leaf Skeletonizer *Eutectona machaeralis*

A total of 2.5 crores of egg parasitoid, *Trichogramma raoi* were released for management of teak defoliator and skeletonizer in selected sites (300 hectares in plantation and 300 hectares in natural forests of teak) at Maharajpur range of Mandla Forest Division, Madhya Pradesh. To assess and demonstrate the biological potential of *T. raoi* in field, observations on damage impact (defoliation intensity) of target insect pests and tree growth in released and non released sites are being recorded.



Biological Control of Insect Pests of Medicinal Plants- *Abelmoschus moschatus*, *Gloriosa superba* and *Withania somnifera*

Target species of medicinal plants were raised in experimental plot in Forest Entomology Division. Multiplication of *Trichogramma* and *Chrysoperla* was done. Seasonal history of key insect pests was worked out. Sampling of natural enemies was done. Different doses of biopesticides were tested in laboratory conditions. The insect pests of target species of medicinal plants were identified in different localities, egg parasitoid, *Trichogramma* and predator, *Chrysoperla* was tested against key insect pests (Defoliator & shoot borer). The work is in progress.

Studies on Larval Parasitoids, *Apanteles* spp. (Hymenoptera: Braconidae) of Major Defoliators of Teak and Sal Forests of Odisha

Surveyed teak and sal forests of five districts of Odisha (Bargarh, Bolangir, Boudh, Sambalpur and Sonepur) for the collection of larvae and pupae of insects defoliating teak and sal forests. Collected 152 samples of larvae and pupae of teak and sal defoliators from field and by laboratory rearing recovered 34 specimens belonging to *Apanteles* spp. Identified 10 species of *Apanteles* (*A. asmeadi*, *A. coleman*, *A. delioidis*, *A. endymion*, *A. erionotae*, *A. hyblaea*, *A. lakhaensis*, *A. philoempus*, *A. prodinae*, *A. rudius*) on defoliators of teak and sal. All these *Apanteles* spp. are indigenous and are being recorded for the first time from Odisha. Worked out natural field parasitisation of these 10 species of *Apanteles*, parasitising the defoliators of teak and sal. Studied biology of *Apanteles machaeralis* on teak skeletonizer.

Efficacy of *Beauveria bassiana* Against Bamboo Pests

Beauveria bassiana was evaluated on bamboo insect pest viz. *Pyrausta coclesalis*, *P. licarsialis* and *Crocidophora* species in lab condition and found effective on these pests.

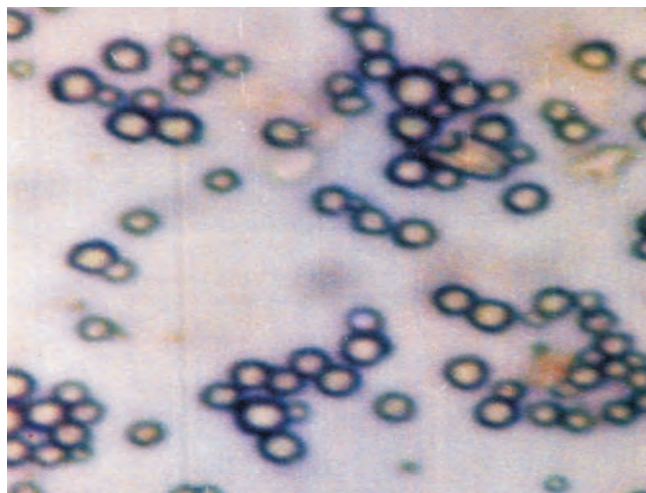
Oak Stem Borer, *Aphrodisium hardwickianum*, White (Coleoptera: Cerambycidae)

Following natural enemies of the borer were recorded (a) Insects: an undetermined Elatrid beetle (b) Birds

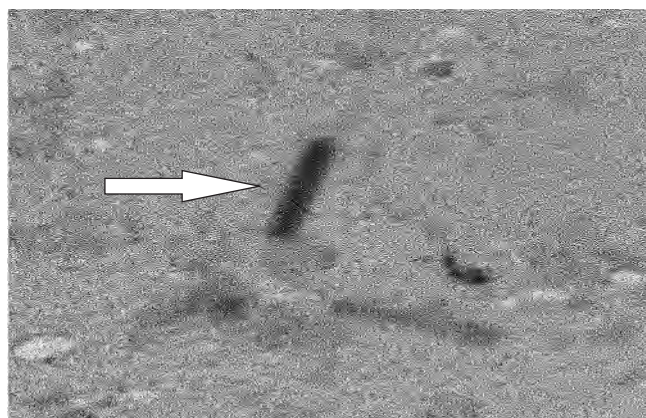
- (i) Himalayan Woodpecker, *Dendrocopos himalayensis*,
- (ii) Brown-fronted Woodpecker, *Dendrocopos auriceps*,
- (iii) Scaly-bellied Woodpecker, *Picus squamatus* and
- (iv) Greater Yellowthroat, *Picus flavinucha*.

Management of Indian Gypsy Moth (*Lymantria obfusca*) in Himachal Pradesh

Laboratory Rearing Technique of Indian Gypsy Moth (IGM) has been standardized. Through continuous rearing of IGM in the laboratory condition for past consecutive 5 years, the methodology of rearing neonate larvae and its subsequent development to adulthood have been finalized. Moreover, as IGM overwinter in egg form, rearing of egg-mass for 7-8 months, in very specific ambient environment without



Baculoviral (LONPV) Occluded Bodies



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S3
Print Mag : 144000X@7. in
14:54 01/12/10
TEM Mode : Imaging

100 nm
HV = 100Kv
Direct Mag : 66000X
AMT Camera System

TEM image of single virion of LONPV



interference of parasitic microhymenopteran parasitoids, in the laboratory was done. One native strain of baculovirus extracted from infected larvae of *Lymantria obfuscata*, was purified.

Management of Insect Pests of seeds of *Pinus gerardiana* in Storage

Chilgoza seeds which are economically important are heavily infested by insect borer. The seed borer identified as *Cateremna tuberculosa* Meyrick (*Plodia interpunctella* Hübner) is reported for the first time infesting the Chilgoza seeds. The seeds were stored in different containers such as Cotton bag and airtight containers for observations

It was observed that the seeds stored in the cotton bags were least effected by insect. Four insecticide/ biopesticides i.e. 1) Praghat (Antifeedant: *Nerium odorum* + *Bombax malabaricum* 1ml/lt.) 2 sprays/4days intervals, 2) Farsa, 10%EC (Alphamethrin (EC)-129, contact & stomach poison), 3) Robust: Chloropyriphos, 205EC, and 4) Neem Manure: product of *Neem (Azadirachta indica)* were applied to protect the seeds from different attacks. New mite species have been found



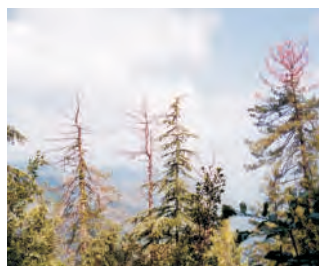
Mite Infestation on Chilgoza Seeds

infesting the stored seeds. The data on different treatments applied against various attacks have been taken and analyzed for developing suitable control measures to protect the stored Chilgoza seeds for longer period.

Bionomics of *Pityogenes scitus* in Himachal Pradesh

Five forest areas viz. D-91 Bhawan Ki Dhar under Solan Forest Range, D-73 Mashobra under Mashobra

Forest Range, Jamunda Forest Under Kotgarh Forest Range, Jangi Forest Under Akpa Forest Range and Brundhar Forest Under Manali Forest Range were selected for this study and climatological data were collected. The male adults of *P. scitus* bore the first tunnel down to the sapwood and eat out the pairing chambers. The female beetle enters through the same tunnel or eats out the separate tunnel, which meet the lower part of the male tunnel or pairing chamber directly. About five female enter the pairing chamber and pair with a single male. The single female lays 10-15 eggs in each gallery. The larvae on hatching out bore away from the mother galleries curving in irregular manner. The larvae feed chiefly in the bast layer and their



Symptoms of Attack of *P. scitus*



P. scitus Blanford (colepetra: Scolytidae)



Stellate Appearance of Galleries Formation on the Bast Layer – Polygamus Galleries

galleries do not get into the sapwood. Full grown larvae eat out a depression at the end of their galleries in sapwood and pupate. The number of 4-5 adult beetles/ 20 cm² on infested tree was found.

Botanicals

Flora Evaluation for Pesticidal Properties: Phenol and phenolics extracted from ten plant species have been



screened for allelochemical effects against *Ailanthus* defoliators (*Atteva fabriciella* and *Eligma narcissus* in plantations at Kurumbapatti, Salem) and teak defoliator (Kerala Forest Research Institute, Research station at Nilambur).

Anti-insect Secondary Metabolites from Fungal Endophytes: The endophytic fungi viz., *Colletotrichum*, *Phomopsis*, *Lasiodiplodia*, *Pestalotiopsis*, *Phyllosticta*, and *Fusarium* were recorded from the leaf samples (*Tectona grandis* and *Ailanthus excelsa* leaves were collected for isolation and taxonomic confirmation of

endophytic fungi. Variation in distribution and occurrence of different endophytic fungi was observed in different leaf segments of young and mature leaves). Pure cultures of endophytes such as *Phoma* sp., *Phomopsis* sp., *Colletotrichum gloeosporioides*, *Botryodiplodia theobromae* and *Fusarium* were maintained in the laboratory and mass cultured using Potato Dextrose broth medium. Isolation and characterization of secondary metabolites from *C. gloeosporioides* and their bioefficacy on teak and ailanthus defoliators are in progress.

Biopesticide against Papaya Mealy Bug

Extracts from plant viz., *Adhatoda vasica*, *Melia dubia*, *Vitex negundo*, *Aristolochia bracteata* and *Pongamia pinnata* were processed with organic solvent extraction and stored at 20 °C for their bioassay against exotic papaya mealy bug.

Insecticidal Properties of Extracts from Leaves and Flowers/Seeds of *Lobelia* sp. and Seeds of *A. concinna*

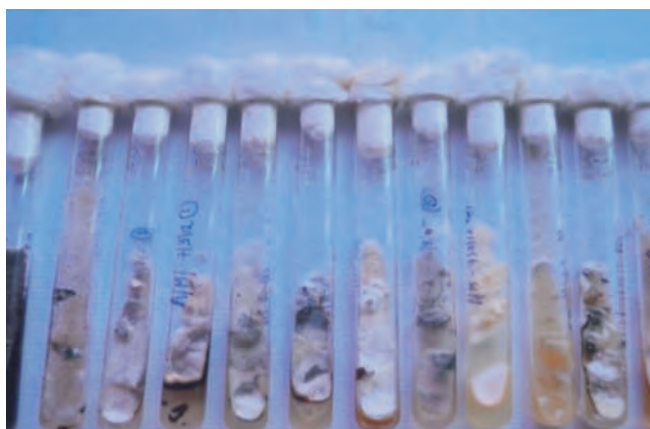
Bioassays were conducted on the 3rd instar larvae of *S. litura*. The formulated products were tested against laboratory hosts and on arboreal termites and pests of Teak, *Mangifera indica*, Neem, *Pongamia pinnata*, *Syzygium cumini* in the field conditions.

Extractives from *Lantana camara*, *Ageratum conyzoides*, *Parthenium hysterophorus* and *Croton bonplandianum* Against Marine Wood Borers

Herbage of 4 plant species were collected and extracted with acetone, ethanol and water. Extractives were complexed with copper and chrome and with these formulations timber panels were treated. These treated panels were exposed in harbour waters and observations on the performance of treated panels taken.

Methanol Extract of *Acorus calamus* Against Bamboo Pests

Extract was evaluated against *Parasa* sp. in lab condition. The higher conc. 3 and 4% caused 64 and 76% of larval mortality respectively after 48 hours. NSKE (Neem Seed Kernel Extract) was evaluated against the I, II, III instars larvae of *Crocidophora* sp. The



Fungal Endophytes Isolated from Teak Leaves



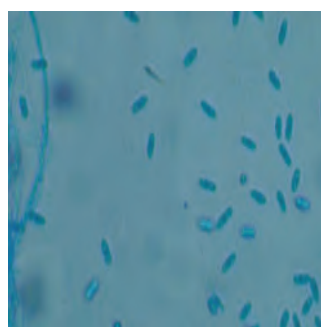
Fusarium sp.



Phomopsis sp.



Colletotrichum gloeosporioides



Spores of *Colletotrichum gloeosporioides*



concentration of 10% caused the highest larval mortality of 76% after 48 hours.

Insect Resistant Germplasms

Screening for Eucalyptus gall resistant clones:

Screening of 238 clones of eucalyptus raised in field trials and maintained at VMG at Satyavedu (AP), Panampally (KL) and Bharathiar University campus (TN) for parameters like -incidence of the pest, oviposition damage, gall formation, intensity of attack, was done. On the basis of data collected quarterly for two years on these parameters, clones were categorized as resistant/tolerant (20 clones), less susceptible (70 clones), moderately susceptible (48 clones) and highly susceptible (100 clones).

Others

Management of Insect Borer Complex in Chir Pine Forests

A) Tree Trap:

To evaluate the effectiveness of **tree trap** for entrapping the beetles of *Polygraphus longifolia* and other, billets of two sizes (80 cm L X 70 cm GBH and 100 cm L X 90 cm GBH) were kept at 5 experimental sites and the data on insect activity and population abundance of *P. longifolia* and *Cryptorhynchus rufescens* and *Sphaenoptera aterrima* were recorded along with moisture content of the logs. Trees falling into the girth range of 90-180cm were found to be highly susceptible to infestation in comparison with young (below 90 cm) and mature (above 180 cm)



Tree Trap to Attract Bark and Wood Borers In Chir-pine Forest

stands. Trap with 95 – 110 cm L X 90 - 100 cm GBH and 25 to 35 % moisture content was found to be effective to attract the beetles.

B) Pheromone:

Pheromone, Ipsdienol ($C_{10}H_{16}O$) at 1mg, 2mg, 4 mg and 8mg loading/ concentration in four types of pheromones Traps viz. Fero-TTM, Del-TaTM, Wot-TTM and Fligh-TTM by following factorial RBD design is being evaluated at Platto Chir-pine forest in Barsar Forest



Some Pheromones Traps in Chir-pine Forests

Range under Hamirpur Forest Division to manage bark and wood borers in chir pine forest especially *Ips longifolia* (Steb.) (Coleoptera: Scolytidae) under factorial RBD, design, two factors (4 Types of Pheromones traps and 4 loading/ doses of pheromone) with 3 replications. Combination of higher loadings (4 and 8mg with Fero-TTM trapped significantly higher beetle catches as compared to low loadings with other traps in the experiment during first year of observations.



Diseases And Their Control

Screening for Resistant Clones of *Dalbergia sissoo*

Screening for resistant clones of *Dalbergia sissoo* against *Fusarium solani* and *Ganoderma lucidum* using direct inoculation technique was done. Sick plot has been developed and being monitored for population of *F. solani*. Nine clones have been put to pathogenicity testing in the sick plot and Clone No. 9093 and 375 were found susceptible to wilt disease. Clone No. 2, 6, 10, 11, 16, 23 and 24 were found susceptible to *G. lucidum*.

Natural Decay Resistance of Imported Woods

Twenty one species of imported woods were tested for natural decay resistance using accelerated laboratory tests, using two white rot and two brown rot fungi. Seven woods were found in decay resistant Class-I while seven each in Class-II and III. Most resistant wood sample was of Padauk (*Pterocarpus soyauxii*) from Cameroon followed by teak (*Tectona grandis*) wood sample from Ghana, whereas, least resistant wood was of Beech wood (*Fagus sylvatica*) from Belgium followed by Maple (*Acer pseudoplatanus*) wood sample from France. White rot fungi caused more weight loss than brown rot fungi and *Pycnoporus sanguineus* caused more weight loss in wood blocks than other test fungi.

Screening of Eucalyptus germplasm for Disease Resistance Against *Cylindrocladium* leaf and Seedling Blight

Diseased samples were collected from Uttar Pradesh and after the DNA finger printing 26 isolates by nrDNA amplification, sequencing and BLAST search. Haplotype analysis was conducted and different lineages were identified. All the 26 annotated gene sequences were deposited in NCBI, Genbank, USA and accession number was obtained. Highly virulent isolates of *Cylindrocladium quinqueseptatum* were identified. The disease resistance testing of eucalyptus germplasm for clones from industries and FRI germplasm has been done.

Development of Molecular Diagnostic Kits for Identification and Early Detection of Nursery and Plantation Pathogens of Eucalyptus

ITS region of nrDNA of *Pestalotiopsis* spp. isolates from eucalyptus leaves were amplified, sequenced and BLAST searched to authenticate their taxonomic identity. Four primers were designed for *Eucalyptus* pathogens *Pestalotiopsis theae*, *P. foedans*, *P. oxyanthi* and *P. disseminata* which will be helpful in quickly detecting and identifying the collected isolates.



Treatment of Trees at Ta Prohm Temple, Cambodia



Trainees with the Director General Dr. V. K. Bahuguna at Ta Prohm



Screening of Poplar Genotypes Against *Alternaria alternata* toxin(s)

Isolates of *Alternaria alternata* from FRI, Rudrapur and Paniyala have been collected and maintained. Relative growth study of 20 isolates of *A. alternata* was completed and Toxin extraction of 4 isolates done.

Treatment of Heritage Trees

Thirty trees were treated at Ta Prohm temple, Cambodia with training to Cambodian officials. One Cambodian was given exposure training at FRI. Bodhivriksha at Bodhgaya was examined for its health status and given treatment.

New Disease of *Dalbergia sissoo*

A new disease of *Dalbergia sissoo*, caused by *Lasiodiplodia* sp. and responsible for stem canker disease has been reported from Sirsa, Haryana. The



Canker in *D. sissoo* by *Lasiodiplodia* sp.

disease is causing wet spots on the bark initially which turn into oozing of sap and splitting of bark and exhibits typical canker symptoms. The cankers are seen causing girdling and death of the severely affected trees. About 10 per cent trees were noticed affected by this disease which appears to be progressing in Haryana and Punjab.

Fungal Diseases in Forest Nurseries of Bangalore and Western Ghats

Leaf spot disease was very severe in *Pongamia pinnata* in Bangalore nursery and blight was common in

Western-Ghats nurseries with 100% severity. In Bangalore area, seedlings were free from diseases in March-June. Diseases start manifesting from July onwards and reaches peak in October- November and starts receding from December onwards; whereas, in Western Ghats area, blight was common in all seasons. Causal organisms viz. *Fusarium*, *Pestalotiopsis*, *Colletotricum gloeosporioides* and *Alternaria* species were identified from infected seedlings. Pathogenicity of *Colletotricum gloeosporioides* on *P. pinnata* was confirmed. Botanicals like *Cleistanthus collinus* and *Prosopis juliflora* leaf and bark extract and one standard fungicide Indofil-M45 was used for controlling disease incidence for *P. pinnata*, *Vateria indica* and *Sapindus emarginatus*. It is observed that disease was controlled up to 80%.

Diseases of Important Medicinal Plants and Their Biocontrol

Disease survey on medicinal plants was conducted in Madhya Pradesh and Chhattisgarh forest nurseries, plantations and farmers' fields. The disease incidences in various localities were assessed. The study revealed that *Rauvolfia serpentina* infected from leaf spot, inflorescence top dying and wilt diseases caused by *Alternaria alternata*, *A. tenuis*, *A. tenuissima*, *Cercospora rauvolfiae*, *Cladosporium oxysporum*, *Colletotrichum dematium*, *Corynespora cassicola*, *Fusarium oxysporum* f. sp. *Ruavolfiae*, *Lasiodiplodia theobromae*, *Macrophomina phaseolina*, *Mycosphaerella rauvolfiae*, *Phoma jolyana* and *Phomopsis sethii*. Similarly different pathogens viz. *Cladosporium cladosporioides*, *Fusarium oxysporum*, *Pseudocercospora withaniae*, *Sclerotium rolfsii* and *Meloidogyne incognita*, were recorded from *Withania somnifera*. The leaves of *Chlorophytum borivillianum* were found to be infected with *Colletotrichum capsici*, *C. chlorophytum*, *C. graminicola*, *Macrophomina phaseolina* and root rot disease caused by *Fusarium oxysporum*. The *in-vitro* test showed that the antagonistic activity of *Bacillus amyloliquefaciens* and *Streptomyces* sp. was very effective against the



pathogens. Field experiment for management of *R. serpentina* revealed that Bavistin 0.05% + *Streptomyces* sp. (10^6 spores/ml) was significant treatment among the other treatments, while *Streptomyces* sp. (10^6 spores/ml) was best for the control of leaf spot and root rot disease of *C. borivillianum*. Root knot disease of *W. somnifera* caused by *Meloidogyne incognita* was effectively managed by adding 50% neem cake in the potting mixture.

Integrated Management of Vascular Wilt Disease in Forest Nurseries

Occurrence of wilt disease of Aonla, Neem and Khamer in different forest Research and Extension nurseries of Betul, Chhindwara, Seoni, Balaghat and Pandarkaura have been recorded. Wilt causing pathogens viz. *Fusarium solani*, *F. oxysporum*, *F. concolor*, *Verticillium* sp. and *Rhizoctonia solani* have been isolated and identified. The disease predominated during the month of Jul- Aug. The average incidence of the disease ranged between 3.75 to 26%. Out of ten provenances of neem, provenance from Bargi was found more susceptible as compared to other provenances, while Shahdol and Raigarh provenances showed resistance to disease. The Kanchan variety of aonla was found more susceptible in nurseries at Balaghat and Seoni. The grafted saplings of Kanchan, Chakaiya, Francis and Desi (wild) varieties at Balaghat nursery have shown comparatively more incidence of disease, may be due to shade effect of broad leaved tree cover over the agronet shade of the nursery. Ridomil (carbendazim 4% + mancozeb 64%) was found more effective against *Fusarium solani* in nursery.

Wood Decay and its Control in Stored Tropical Timber

Forest wood depots of Madhya Pradesh (18), Chhattisgarh (13) Maharashtra (12) and Orissa (25) were surveyed for collection of wood decay fungi and 1159 specimens of wood decay fungi were collected on 34 hosts (timber). The wood decay fungi belong to 83 species of 47 genera distributed in 15 families. Four species were reported for the first time from India, namely, *Australohydnum dregeanum*,

Hapalopilus nidulans, *Hjortstamia friesii*, and *Schizopora flavipora*. Three wood species namely bijasal, teak and sal were treated with 2% mix of 4:3:1 combinations of K_2CO_3 , $KHCO_3$ and K_2CrO_7 . After incubation period of 8 to 16 week the decay fungi caused wood decay ranging from 16 -37 per cent in control, whereas, the treatment reduced the rate of decay up to 5 per cent. Experiment was laid out by using two biocontrol agent *Aspergillus niger* and *Trichoderma viride* against ten white rot and one brown rot fungus by dual culture technique. Both *A. niger* and *T. viride* inhibited the growth of all decay fungi tested. Although the percentage inhibition of radial growth values of *T. viride* and *A. niger* are almost the same (ranging from 29.2 to 66.7%) but the average mean value of *T. viride* was 51.7% and for *A. niger* it was 45.5%.

Taxonomy and Documentation of Wood Decay Fungi of Chhattisgarh

Three hundred forty three specimens were collected from Kawardha, Bilashpur, Marwahi, Dhamtari, Ambikapur, Manendragarh and East Raipur of Chhattisgarh region. Out of 343 specimen, 31 genera and 41 species of wood decaying fungi, collected from 35 host tree species were identified. Taxonomy and documentation of 38 wood decaying fungi were done, in which 25 new documents for fungi were prepared and 13 already prepared documents were amended.

Root rot and Stem Decay Diseases in *Acacia catechu* and Their Control

The following fungi were identified from samples of *Acacia catechu* collected from MP and HP: *Auricularia*, *Daedalea*, *Flavodon flavus*, *Ganoderma lucidum*, *Lenzites palisoti*, *Monodictys*, *Phellinus badius*, *P. gilvus*, *P. pachyphloeus*, *Stachylidium*, *Schizophyllum commune*, *Torula herbarum* and *Tremetes cingulata*. Nine fungi namely, *Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *A. fumigatus*, *Cladosporium cladosporioides*, *Curvularia* sp., *Fusarium concolor*, *F. solani* and *F. verticilloides* were isolated from seeds of *A. catechu*. Out of four tested fungicides, Bavistin 0.2% was proved successful to control the growth of *Ganoderma lucidum*.



Potential Pathogens Responsible for the Low seed Production in Teak Seed Orchards

Spermiophyte mycoflora of *Tectona grandis* were recorded from the inflorescence, young fruits and mature fruits collected from Mandla and Jabalpur Forest Divisions. The fungi associated with inflorescence and immature fruits were recorded as *Absidia* sp., *Alternaria raphani*, *Ampulliferina fagi*, *Aspergillus flavus*, *A. niger*, *Cladosporium cladosporioides*, *Curvularia lunata*, *Fusarium oxysporum*, *Helminthosporium* sp., *Humicola grisea*, *Phialophora lagerbergii*, *Rhizoctonia solani*, *R. bataticola*, *Septonema* sp., *Trichoderma harzianum* and *T. pseudokoningii*. The fungal flora associated with weathered seeds was also recorded as *Aspergillus flavus*, *Fusarium oxysporum* and *Rhizopus stolonifer*, while the unweathered seeds have shown the presence of *A. flavus*, *Fusarium equiseti* and *F. solani*. *Bacillus amyloliquefaciens* an antagonistic bacterium isolated from the rhizosphere soil of *Rauvolfia serpentina* from nursery of Institute campus inhibited the mycelial growth of spermiophyte mycoflora of teak. The teak seeds extracted from the hard nuts treated with 11 days old broth culture of *B. amyloliquefaciens* showed inhibition of the seed borne fungal flora.

Incidence and Management of Culm Rot and Bamboo Blight Disease in Assam

Representative sites of six agroclimatic zones of Assam were surveyed to assess the culm rot and bamboo blight disease. The distribution, nature and intensity of damage of bamboo blight disease were recorded and climatic data and diseased samples collected. The pathogenicity tests were conducted on three bamboo species viz., *Bambusa tulda*, *B. balcooa* and *B. nutans* in laboratory as well as in nursery. Field trials were carried out in Marigaon district on *Bambusa tulda*, with 4 fungicides (Trade name Indofil m-45, Bavistin, Stuff, Result) were tested and except result all were found effective.

Incidence and Management of Pine Mortality in Manipur

Surveys were conducted in seven different Khasi pine inhabiting areas of Meghalaya to assess the status of

pine mortality and maximum of 40% disease incidence was recorded in NEHU Campus, Shillong. Diseased samples were collected and brought to the laboratory for further investigation. Analysis of rhizosphere soil samples revealed nine different fungal genera. Soil samples were also analyzed for physico-chemical properties.

Broad Spectrum Antifungal Compound from Selected Tree/Shrubs/Weeds of Indian Arid Region

Antifungal properties of selected plant parts (flower bud of *Datura stramonium*; leaf and root of *Tribulus terrestris*; root, flower and fruit of *Argemone mexicana*) were evaluated against fungal pathogens. Alcoholic extract of *Argemone mexicana* root showed good antifungal activity against *Fusarium solani*. Aqueous and ethanolic extract of *Tribulus terrestris* leaves showed mild antifungal activity against selected fungi. Alcoholic extract of *Datura stramonium* bud showed good antifungal activity against *Alternaria alternata*.



Inhibition Zone by Alcoholic Extract of *Argemone mexicana* Root Against *Fusarium solani*



Inhibition Zone by Alcoholic Extract of *Datura stramonium* Flower bud Against *Rhizoctonia solani*



Alcoholic extract of *Datura stramonium* bud showed good antifungal activity against *Rhizoctonia solani*.

2.7.3 Mycorrhizae, Rhizobia and Other Useful Microbes

Salt tolerance ability of different Arbuscular Mycorrhizal (AM) (*Glomus* spp., *Acaulospora* spp. and *Gigaspora* spp. and ectomycorrhizal (ECM) fungi (*Pisolithus albus* and *Suillus brevipes*) was tested against three different sodium salts, such as, sodium chloride, sodium citrate and sodium sulphate under *in-vitro* condition and selected and short listed the potential salt tolerant AM and ECM fungi for nursery application.

Selected shola tree species were inoculated with different bio-inoculants (AM fungi and PGPRs) and it was observed that the bio-inoculants applied seedlings had better seedling health and growth parameters over uninoculated (control) seedlings. Field trials were established in 2 locations in the Nilgiri Hills, Tamil Nadu and it was recorded that the bio-inoculants applied saplings had significantly better survival and establishment.

Attempts were made to study the population density of AM fungi from heavy metal contaminated sites in Tirupur, Tamil Nadu and it was observed that



Effect of Inoculation of PGPR and AM Fungi on Growth Enhancement of *Gmelina arborea* Seedlings



Azospirillum

Azotobacter

large amount of AM spore population was noticed in Kasipalayam area (132/g soil).

Dynamics of Litter Decomposition in Sal Forest of Central India

Litter decomposition in five different sites of sal forests of Madhya Pradesh Chhattishgarh and Odisha was studied. Overall, 63 different fungal species involved in litter decomposition were recorded. The influence of carbon flux, nitrogen, phosphorous, and potassium at different stages of decomposition were estimated.

Total five potentially beneficial fungi were screened for their ability to enhance the decomposition rate and nutrient release. Nine mycorrhizae forming fungi (*Astraeus hygrometricus*, *Geastrum triplex*, *Boletus* sp., *Boletus fallax*, *Mycena* sp., *Russula* sp., *Scleroderma bovista*, *S. geaster*, *S. verrucosum*) were identified from different sites of sal forest. Two ectomycorrhizal fungi were multiplied for their capability of mycorrhization. Experimentation on sal seed germination have been carried out, which revealed that nursery beds containing solarised soil + FYM + mycorrhizae infested soil shown 47% germination, whereas, in case of unsolarised soil with same treatment germination was 20.50 %. Eleven documents of important litter decomposing as well as mycorrhizae contributing fungi have been prepared. A new species, *Asterostomella shoreae* collected from Achanakmar Biosphere Reserve in Chhattishgarh, on fresh fallen leaves of *Shorea robusta* has been reported. Two new fungal records *Helicosporium phragmitis* and



Boletus fallax have been recorded from India and the latter is a new mycorrhizal record for sal.

Microbial Inoculants for Application in Forest Nurseries and Plantations

For product development of different microbial inoculants, microbes including *Azotobacter*, *Azospirillum*, *Rhizobium*, AM fungi (*Glomus mosseae*, *Acaulospora scrobiculata*, *Gigaspora* sp.) were isolated from Madhya Pradesh (adjoining areas of Chitrakut, Sanawad, Badvaah and Khandwa) and Chhattisgarh (Bilaspur). Microbial samples of bel, tinsa, mahua and beeja-sal are maintained in pot cultures. Pot experiments on bel has been conducted by using combination of AM fungi, *Azotobacter* and *Azospirillum*. After 3 months biomass production was found superior in the treatment of *Azospirillum* + AM fungi.

Utilization of Vesicular Arbuscular Mycorrhizal Diversity for the Quality Stock Production in Meghalaya

Surveys were conducted to visit two ranges i.e. Umtasor (five compartments) and Nongpoh (Lc. Colony, Morok, Diphu-Sydang & Tower point) in Meghalaya and two ranges of Titabor and Borhola, Joypur Reserve Forest, Kaziranga National Park, Amsoi Reserve Forest for the collection of rhizospheric soil samples. The collected rhizospheric soil samples were screened for endomycorrhizal qualitative and quantitative analysis. Two dominant and efficient strains (*Glomus* sp. and *Gigaspora* sp.) which were prevalent in the forest soil were isolated and inoculum production and mass multiplication through trap culture and pot/plot culture completed. The seedlings of two selected plant species (*Mesua ferrea* and *Aquilaria agallocha*) are being raised by inoculation experiment with VAM fungi.

Diversity of Mycorrhizal Associations with *Dipterocarpus* and *Shorea* species in Assam

The seeds of *Dipterocarpus retusus* and *Shorea robusta* were collected from forests and sown in fumigated soil in nursery bags. Mass inoculum of

ectomycorrhizal and endomycorrhizal fungi had been raised *in-vitro* and *in-vivo* respectively and the seedlings of selected tree species were inoculated at the time of sowing. The results revealed a better root and shoot biomass in the inoculated seedlings in comparison to the control. After six months, the inoculated and control seedlings were transplanted to field and it has been observed that the inoculated seedlings in comparison to control performed better for their establishment and on growth characteristics.

Augmentation of Composting and Biofertilizer in Hot Arid Regions

Litter decomposition mycoflora i.e., *Aspergillus niger*, *Aspergillus flavus*, *Trichoderma* sp, and *Fusarium* sp were isolated and identified. Mass multiplication of indigenous consortium inoculum with dominance of *Glomus fasciculatum* of AM fungi of *Prosopis cineraia*



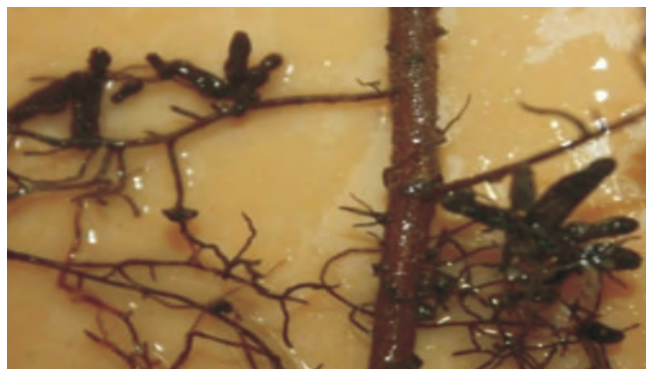
Anaerobic Composting (FYM + Dried Leaves + Niprovat (*T. viride*))



Mulching with PVC Sheet of Anaerobic Composting



VAM Multiplication in Beds



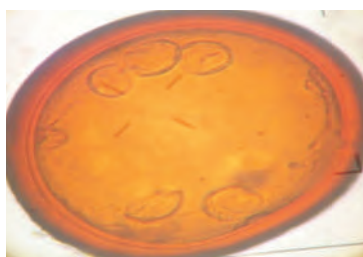
Rhizobium Nodules in Roots of *Acacia nilotica*

(Khejri), *Azadirachta indica* (Neem) and *Acacia nilotica* (babul) in pots have been prepared at AFRI Model Nursery, Jodhpur. Anaerobic composting in pits by using Farm Yard Manure + Dried leaves + Niprovat (containing *Trichoderma viride*) with mulching.

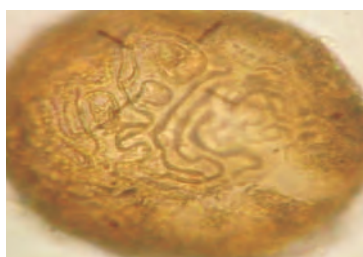
Efficient Strains of AM Fungi and *Rhizobium* for *Acacia nilotica* and *Ailanthus excelsa*

Rhizosphere soil and root samples of *Acacia nilotica* and *Ailanthus excelsa* were collected from various forest nurseries in Rajasthan. Soil samples were

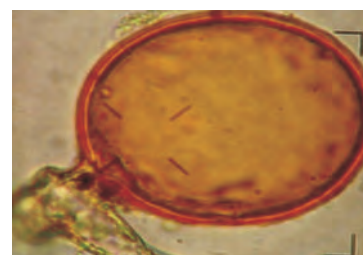
analyzed for pH, EC, (%) organic carbon (% OC) and phosphorous (P). The isolation of AM fungi was carried out and the important genera identified were; *Acaulospora*, *Gigaspora*, *Glomus* and *Sclerocystis*. The different species of *Glomus* were recorded as *G. aggregatum*, *G. fasciculatum*, *G. mosseae*, *G. macrocarpum*, *G. microcarpum* and *G. constrictum*. Out of which, *G. fasciculatum* was dominant species in all the sites of nurseries as well as in plantations. The spore population was varied from site to site and ranged between 163 to 480 propagules per 100 gm soil of



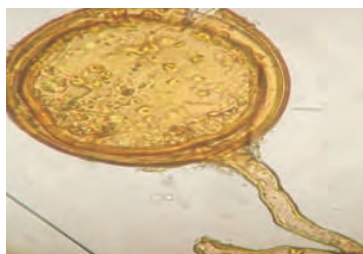
Glomus sp. Collected from *A. nilotica* from Barmer



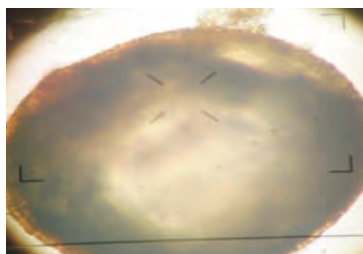
Acaulospora sp. Collected from *A. nilotic a* from Barmer



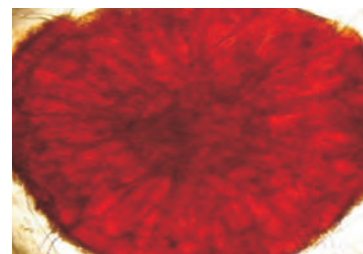
Glomus sp. Collected from *A. nilotica* from Barmer



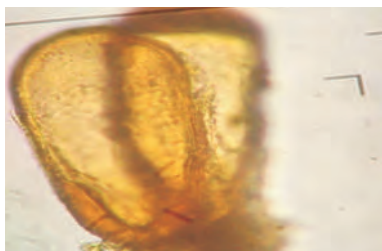
Glomus sp. Collected from *A. nilotica* from Pali



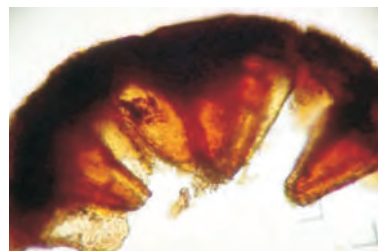
Gigaspora sp. Collected from *A. nilotica* from Barmer



Sclerocystis sp. Collected from *A. nilotica* from Pali



Sclerocystis sp. Collected from
A. nilotica from Pali



Sclerocystis sp. Collected from
A. nilotica at Pali

Acacia nilotica and 195 to 670 propagules per 100 gm rhizosphere soil of *Ailanthus excelsa*.

Plant Growth Promoting Rhizobacteria (PGPR)

Qualitative solubilisation efficiency of 64 isolates of *Pseudomonas fluorescens* on *Dendrocalamus strictus* collected from FRI, Dehradun (Uttarakhand), Kalka (Haryana) and Hoshiyarpur (Punjab) was assessed besides quantitative estimation of P solubilisation of 14 isolates from these places; these and 105 more isolates were also qualitatively assessed for HCN and siderophore production for knowing their biocontrol properties. The physico-chemical characteristics of the soil from these sites were worked out to draw relationship between soil and bacterial samples.

A total of 94 isolates of PGPRs (PSB 42, *Azotobacter* 26 and *Azospirillum* 26 isolates) were isolated from the rhizosphere of 18 different shola trees and 51 isolates [18 isolates of Phosphate Solubilizing Bacteria (PSB), 16 isolates of *Azotobacter* sp. and 17 isolates of *Azospirillum* sp.] were obtained from the rhizosphere of *Casuarina equisetifolia*, *Eucalyptus tereticornis* and *Prosopis juliflora* in salt affected areas in Tamil Nadu and Puducherry.

Salt tolerance ability of *Azospirillum*, *Azotobacter* and PSB was tested using 3 different salts viz., sodium chloride, sodium citrate and sodium sulphate under *in-vitro* condition and selected and short listed the potential salt tolerant microbes for nursery application. Fifteen different clones of *Casuarina equisetifolia* were applied with the selected salt tolerant microbes (PGPRs, AM and ECM fungi, Frankia) and it was found that most of the clones inoculated with these microbes had better growth performance over control.

Seedlings of *Ailanthus excelsa*, *A. triphysa*, *Neolamarckia cadamba*, *Gmelina arborea* *Melia dubia* and *Dalbergia latifolia* raised in sterile soil + sand as potting medium were inoculated with selected PGPR isolates and AM fungal biofertilizers (single and multiple inoculations) and maintained in the experimental nursery. It was observed that the seedlings inoculated with PGPR or AM fungi (both single and multiple inoculation) showed significant growth over uninoculated control with respect to shoot and root height, shoot and root biomass, total biomass, volume index, sturdiness quotient, absolute growth rate, relative growth rate and Microbial inoculation effect after 90 and 180DAI. The results also indicated that multiple inoculation of different PGPR and AM fungi showed better growth performance over single inoculation and control.

PGPR isolates (55 No.) were isolated from heavy metal contaminated soil samples and maximum population density of beneficial microbes was recorded in Sarkarperiyapalayam (Tirupur district) soil sample in Tamil Nadu.

Six bacterial strains viz., two species of *Bacillus*, two species of *Klebsiella* viz., *Klebsiella pneumoniae* subsp. *pneumoniae* and *Klebsiella oxytoca*, one species each of *Planococcus* sp. and *Micrococcus luteus* were isolated. The best two dye degraders viz., *Planococcus* sp. and *Bacillus* sp. were further studied for optimization studies for the effect of carbon source, nitrogen source, pH, temperature and percentage of inoculum under *in-vitro*.

16S rDNA Nucleotide sequence of Phosphate Solubilizing Bacterium (*Bacillus cereus*) isolated from the saline soil, Tamil Nadu submitted to European



Molecular Biology laboratory (EMBL) Database and Accession number obtained as Fr878075.

Based on the research findings, a biofertilizer product named “IFGTB Tree Growth Booster - VAM Biofertilizer” was developed and made available to user groups for application in nursery and field.

Frankia

A field trial has been established at Karaikal with Frankia inoculated seedlings of *Casuarina equisetifolia* and *C. junghuhniana* with 4500 seedlings inoculated with 10 different Frankia strains. Frankia inoculated seedlings and cuttings of *C. equisetifolia* and *C. junghuhniana* showed higher

growth (150-300 cm height) than the uninoculated control seedlings.

Rooted stem cuttings of *C. equisetifolia* and *C. junghuhniana* inoculated with Frankia were exposed to 600ppm of elevated CO₂ in Open Top Chambers (OTC). Frankia inoculated rooted stem cuttings were responded significantly and produced root nodules within 25 days. The growth and biomass of the rooted stem cuttings were also higher than the ambient level CO₂ conditions. Whereas, the Frankia inoculated rooted stem cuttings maintained in the open conditions did not show any nodulation even after 30 days.



Root Nodule Formation in *C. junghuhniana* Cuttings Inoculated with *Frankia* at OTC.