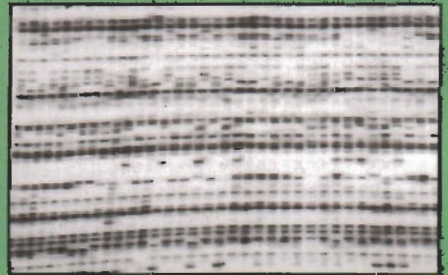


RESEARCH HIGHLIGHTS

[Till March 2005]



TROPICAL FOREST RESEARCH INSTITUTE

(Indian Council of Forestry Research & Education)

P.O. RFRC, Mandla Road, Jabalpur - 482 021, India

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Remarks

Tropical Forest Research Institute is a premier organization, which is engaged with innovative research and technological advancement for improvement of productivity and quality of various forests of central India, viz., Chhattisgarh, Madhya Pradesh, Maharashtra and Orissa. During its existence for more than two decades, the institute has tremendously contributed towards diverse aspects of research and successful implementation of several technologies. However, these efforts are scattered and need to be consolidated for benefit of SFDs, NGOs, forest based industries, policy makers, etc. With this aim, the present document has been prepared, taking inputs from various subject experts of the institute and include four chapters, which eloquently summarize information for users. It is believed that the contents will stimulate in understanding of research findings and adoption of technologies being developed at the institute. As a result, the document will help establish a direct dialogue between end users and subject experts for enhancing forest cover and productivity, sustainable forest resource utilization and policy making besides ensuring socio-economic upliftment of tribals and rurals as well as amelioration of environment.

In the end, it may be reiterated that we have taken utmost care while preparing of the document, but discrepancies, if any, may be brought to the notice for further improvement of such document in future.

Dr. A. K. MANDAL
Director

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BASIC SCIENTIFIC INFORMATION

Agroforestry

- Database prepared for market rates of forest products such as round timbers, sawn timbers and fuel wood (*Shorea robusta*, *Tectona grandis*, *Eucalyptus* spp. and bamboo spp.) from Nagpur, Raipur and Jabalpur depot, and trends of dependence of tribal people on forests.

Biodiversity

- Removal of ground flora promoted regeneration of principal species and opening of canopy resulted in changes in the distribution of major species in preservation plots and national parks. Two wild species of paddy *Oryza officinalis* and *O. perennis* have been recorded in Tadoba national park.
- Preservation plots promoted diversity index of plant species and stability of plant communities.
- Density of species increased to maximum during rainy season and became minimum in summer. Importance value index was found to be the highest during summer. Ground flora was influenced by changes in soil pH, available phosphorus and soil texture.
- Diversity index of herbaceous layer and the concentration of dominance were 3.85 and 0.038 at < 1000 m and 2.57 and 0.059 at elevation 1100-1352 m respectively.
- 150 ligneous resources of TFRRI campus and 83 tree species, 64 shrubs, 10 climbers and 51 herbs from Bandhavgarh national park were identified with the latest nomenclature, family, habit and uses.
- The flowering, fruiting and best time for seed collection of neem trees from Jabalpur (MP) were worked out. The best neem seed sources of central India identified to be Sagar (MP), Ballarshah (MH) and Gunupur (Orissa).
- The fruit maturity and ripening of neem seeds occurred from second half of June to first week of July and of teak during the month of January to December.

- Maximum diversity of ground flora was observed under *Gmelina arborea*, Eucalyptus hybrid, *Tamarindus indica*, *Buchanania lanzan*, *Mitrgyna parviflora* and *Dalbergia sissoo* plantation in bhataland area. Diversity index of species corresponded to the duration of protection.
- Diversity of tree species was high in Nauradehi WLS, Shingpur range. Regeneration of *Tectona grandis* was more in the Sarra range. Mohli range had the highest number, density and regeneration of tree species.
- Diversity of tree species of more than 30 cm/gbh recorded to be higher in core area than buffer area of Nauradehi WLS and that of ground flora, in buffer area than core area.
- The traditional uses of plants of forest origin, including five new ones by Baiga, Bhariya, Gond and Hill Korwa tribes of MP and CG were documented.
- The diversity of ground flora got enhanced in all six preservation plots viz. Allapali, Koena, Waghotre, Bhimashakar, Semadoh and Chikhaldara.

Ecology

- Dominant species like *Hyptis*, *Aristida*, *Eragrostis*, *Argemone* etc in coal mines, *Celosia*, *Tridax*, *Crotolaria* etc in copper mines and *Aristida*, *Eragrostis*, *Calotropis*, *Tephrosia* etc in iron mines exhibited natural succession.
- Emission from thermal power plant, Korba Industrial Complex (Chhattisgarh) decreased organic carbon, sulphur and available potassium, and increased pH, total and available nitrogen and phosphorus in the surrounding soil samples. Thermal power plant emission caused chlorosis and necrosis in the plant leaves and reduced foliar N, P and K.
- Natural succession in flyash dykes of Chachai (MP) steadily increased number of plant species from 3 in six months old to 33 in sixty months old dykes.
- Bacteria and actinomycetes in flyash dykes steadily increased with the age of the dykes and vegetation development.
- Foliar protein, polyphenols, N, K, total carbohydrates, moisture, P, Ca, Mg and chlorophyll were responsible for resistance against defoliators in *Tectona grandis*, *Albizia procera*, *Dalbergia sissoo* and bamboos.

- Phenotypically superior trees of neem with high azadirachtin and oil contents were selected from MP, Chhattisgarh and Orissa.
- Significant provenance variations were observed in seed characteristics, germination behaviour and growth parameters of neem collected from 18 agroclimatic zones of MP, Chhattisgarh and Orissa.
- Protection of degraded forests through JFM significantly increased the number of plant species, enhanced soil fertility and uplifted the socio-economic status of forest dependents in MP, Chhattisgarh and Orissa.
- Significant growth increment of teak was recorded in monoculture compared to mixed plantations.

Entomology

- Ten species of seed borers, 29 species of defoliators, 11 species of shoot borers and 6 species of sapsuckers recorded on *Albizia procera* and *A. lebbek* in central India.
- Developmental stages of *Eurema* spp. and *Rhesala* spp. defoliating leaves of *Albizia* spp. were studied for the first time.
- The habit, habitat, biology and control measures of a major pest (*Bruchus bilineatopygus*) were studied for the first time.
- Life cycle of seed borer, *Bruchus bilineatopygus* investigated to be complete in a year.
- The biology of bamboo leafroller, *Crypsiptya coclesalis* investigated.
- The bionomics of *Albizia* foliage feeder, *Spirama retorta* studied for the first time.
- Leaf extract of *Annona squamosa*, *Lantana camara*, *Calotropis procera* and *Ipomoea carnea*, seed extract of *Azadirachta indica* and a neem based commercial product 'Amrutguard' at the concentration of 1.0 percent inhibited feeding behaviour of teak defoliator and skeletonizer.
- 18 teak clones viz., ORANR3, ORANP-7, ORANP4 (Orissa), MHSC-A3, MHAL-P5, MHAL-P9, MHSC-J2, MHWYK-1 (Maharashtra), PT-46 (MP), MYHV-3, ST-6, ST-14, ST-17 (Karnataka), TNT-3, TNT-17 (Tamil Nadu), UP-D AND UP-N (UP) were identified resistant against defoliator and leaf skeletonizer.

- Among bamboos, *Bambusa vulgaris* (green) and *Melocanna bambusoides* exhibited resistance against leafroller (*C. coclesalis*).
- A white crystalline compound separated from ethanol extract of sal bark recrystallized in benzene acted as kairomone against sal borer beetles.
- New method for direct killing of sal borers developed by spraying of 0.05% water emulsion of endosulfan on beaten sal logs which were used as trap to attract beetles
- 53 species of butterflies, 127 species of moths, 23 species of beetles, 7 species of hymenopterans, 8 species of grasshoppers, 4 species of crickets, 6 species of bugs, 4 species of mantids, 1 species of termite and 1 species of earwig including three threatened species of insect viz. *Hypolimnas misippus*, *Kallima* and *Actias selene* were identified from Kanha National Park.

Pathology

- 346 diseases together with 32 new records of diseases from 118 hosts were registered from MP, MS, CG and Orissa. 26 foliage, 6 root rot and 5 heart-rot diseases were recorded from different nurseries, plantations and natural forest. Taxonomy of 12 new species of fungi were described and their records maintained in the division.
- Strains of different biofertilizers (VAM, Rhizobia, Azotobacter, PSB) were collected from MP, MS, CG and Orissa and the efficient strains isolated by field and laboratory experiments.
- Application of VAM in combination with *Azotobacter* and *Azospirillum* facilitated growth of teak and bamboo significantly.
- Decline of sandal by heart-rot incidence caused by *Phellinus caryophylli* in Seoni (MP) was recorded. Protection of sandal areas from fire, grazing and inducing natural regenerations through plantations of suitable host was recommended.
- Application of VAM fungi alone or in combination with *Rhizobium* produced significantly higher dry biomass and seedling volume.
- VAM fungi when inoculated with *Rhizobium* enhanced root colonization in *Dalbergia sissoo* and *Pongamia pinnata* seedlings.
- VAM application increased growth and survival of neem seedlings.
- Application of biofertilizers in nursery increased growth of teak seedlings.

Genetics

- Teak of Maharashtra origin exhibited existence of significant amount of genetic variation. Both additive and non-additive gene actions controlled growth characters (height, girth and basal area). Twelve elite clones of teak with high general combining ability were screened.
- Growth characters (height, girth and basal area) of south Indian teak were moderately to strongly inherited. Eleven elite clones of teak were identified
- Genetic estimates at an early (juvenile) age using teak of Orissa origin reflected the pattern of mature stage. Sixteen parents with positive general combining ability (elite clones) were identified.
- 39 phenotypically superior trees of *Albizia procera* were selected. Significant genetic variation existed amongst the trees for pod traits (pod and seed length, pod and seed width, seed weight) and germination traits (germination percent, germination velocity index and vigour index). Seed and germination parameters were strongly inherited and were mostly under the influence of additive gene action.
- 25 new phenotypically superior trees of teak were selected with desirable traits. Significant variation existed among trees for important fruit traits (fruit length, breadth, weight, number of filled locules and seed weight). Fruit size constituted as an important criterion of quality (healthy) seeds. Heritabilities and genetic gain for wood traits (heart wood percent, sap wood percent, bark thickness and specific gravity) were estimated to have moderate to strong values. 12 parents with positive general combining ability were identified.
- Carbonic anhydrase activity fluctuated with the season, age, leaf position and genotypes. A single isozyme of the enzyme was noticed in teak. Carbonic anhydrase activity significantly and positively correlated with photosynthesis in 47.6 % half-sib families.

NWFP

- Nutritional parameters ranged 2.0-48.0% carbohydrates, 3.20-30.81% protein, and 0.1-0.71% minerals in different parts (shoots, leaves, seeds, flowers, fruits and flower buds) of 15 forest species, including *Babusa vulgaris*, *Bambusa polymorpha*, *Bambusa nutans*, *Bambusa arundinacea*, *Melocana bacifera*, *Dendrocalamus strictus*, *Dendrocalamus longispathus*, *Sterculia urens* etc.
- Non-nutritional constituents ranged 3.04-6.82% tannins and 0.019-0.522% phenols in *Sterculia foetida*, *Cassia fistula*, *Acacia catechu* and *Garuga pinnata*.
- The performance of Motinala provenances of bamboo (*Dendrocalamus strictus*) followed by Bilaspur and Moiyana was found superior in terms of height, collar diameter, inter-nodal length and number of new culms produced in a growing season.
- *Dendrocalamus longispathus* (Sinduri bamboo) was recorded and collected from Shankargarh range of north Sarguja district, Chhattisgarh for the first time.
- The tendu (*Diospyros melanoxylon*) germplasm Kolkas-1550, Lamni-1440 and Tadoba-1430 found superior in respect of number of seeds per fruit.
- Seeds of tendu germplasm from Korba exhibited the highest (57%) germination. Tendu was found difficult to root.
- Twenty two germplasms of *Cymbopogon martini* from MP, CG, MS, Orissa, Karnataka, Kerala and Tamilnadu were collected. Germplasm from Bastar (0.65%) followed by Jhabua had high oil contents.
- Germplasms of bael (*Aegle marmelos*) from Korba and Raysen were superior in respect of height and diameter growth. Highest germination percentage (98%) was recorded in germplasm from Sagar.
- Growth performance of germplasm of Aonla (*Phyllanthus emblica*) from Gwalior and Panna was superior with the highest germination (92%) from Gwalior.
- Sugar and oil percentage of Mahua (*Madhuca longifolia* var. *latifolia*) germplasm from MP, CG, Orissa, MS and UP varied from 59.82-71.86% and 37.13-44.61%, respectively.
- Germplasm of Chironji (*Buchanania lanzan*) from Multai (Betul) and Badbhal (Sundargarh) exhibited 48.50% oil and 19% protein.

- *Jatropha curcas* seed oil had anti-termite and anti-fungal properties on wood of *Mangifera indica* with 75-90% reduction in weight loss.
- Parthenin isolated from aerial parts of *Parthenium hysterophorus* possessed pesticidal activities.
- The harvesting in second fortnight of January yielded the highest quality of starch in *Curcuma angustifolia*.
- Mucilage of *Hyptis suaveolens* was found to be good binder for agarbattis.
- Saponin glycosides ranged 1.09-1.78% in *Chlorophytum borivillianum* (tubers), 1.20-3.68% in *Asparagus racemosus* (roots), 6.89-8.92% in seeds/pulp of *Madhuca indica*, 11.23-14.69% in *Sapindus mukrossi* (pulp) and 2.19-3.55% in *Jatropha curcas*.
- Saponins from *Sapindus mukrossi*, *M. indica* and *Jatropha curcas* exhibited phagodeterrency/ mortality and provided protection up to eight months to rice crop against *T. castaneum*.
- Decrease in pH, viscosity and carbohydrate content was observed with ageing of gums from *Acacia nilotica*, *Anogessius latifolia* and *Sterculia urens*. Vinegary odour increased with ageing of *S. urens* gums.

Silviculture & JFM

- Maximum root nodules (46.6/plant) were formed in *Acacia nilotica* on combined application of 12.5 ppm N, 50 ppm P and 50 ppm K.
- Relative suitability index was prepared for species successful in degraded soil. *Albizia. procera* scoring 100% was emerged to be the most suitable species followed by *Dalbergia sissoo* and *D. latifolia*.
- Three MPTS species namely *Gmelina arborea*, *Azadirachta indica*, *Leucenia leucocephala* were found suitable for growing in semi arid region of central India. Significant variation between different provenances was observed with respect to seed germination and growth parameters. Seed sources i.e. Umaria, Shahdol (M.P.), Balaghat, Seoni (M.P.) and Shakti (MP) exhibited good growth performance and recommended for plantations.

- Three clones of *Populus deltoids* (G-48, S7 C1 and 65/27) were found suitable for Jabalpur area. The highly productive clone 65/27 was recommended for cultivation in farmer's field at Chhindwara and Jabalpur.
- The rate of carbon sequestration was more in clear felling than in selection cum improvement silviculture system.
- Regeneration was better in areas of selection cum improvement system as compared to clear felled areas. In case of selection cum improvement trees were almost uniformly distributed over all gbh classes.
- In case of clear felling, soil pH, percentage of organic carbon and available NPK showed a decreasing trend.
- No significant reduction in viability was observed in *Acacia catechu* (Khair) seeds stored at 2% moisture content at 0°C and 5°C for one year.
- Better germination was observed in *Pterocarpus marsupium* (Bijasal) seeds stored at 0°C and 5°C for one year.

Ecology

- Tree species like *Pithecellobium dulce*, *Simaruba glauca* and *Acacia mangium* for coal; *Gmelina arborea*, *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* for copper and *Leucaena leucocephala*, *E. tereticornis* and *Albizia procera* for iron mines were found suitable to reclaim mined out areas.
- 2000 ppm of IBA with 30 seconds dip time was found as the best treatment for vegetative propagation of neem.

Entomology

- Out of 29 identified Trichogrammatid egg parasitoids, *Trichogramma raoi* recorded as potential egg parasitoids for the control of teak pests. The multiplication technique of this parasitoid developed.

Pathology

- Twelve mycorrhizae forming fungi were recorded from sal forests, tropical pines and eucalypts plantations located at Amarkantak, Pachmarhi (MP), Jagadapur (CG) Koraput (Orissa). *Scleroderma verrucosum* was isolated, multiplied and applied in nurseries.
- Technique for cultivation of 3 edible mushrooms viz., *Volvariella volvacea*, *Agaricus bisporus* and *Pleurotus* species were standardized and demonstrated to the user groups, viz., Gram panchayats, Gram Samiti, SFDs.
- Effective strains of VAM fungi and rhizobia were isolated from bamboo, teak, *Albizia procera*, *A. lebeck* cultured and supplied to user groups including SFDs, NGOs, farmers.
- Application of VAM along with N - fixing bacteria and PSBs enhanced the growth and productivity of safed musli (*Chlorophytum borivillianum*).
- Techniques were developed for mass production of tree species-specific biofertilizers.

Genetics

- An improved method for establishment of seed production areas (SPAs) was developed.
- The adsorption/desorption of nitrite by roots indicating their surface area, provided basis for development of method for root surface area measurement.
- In *Dalbergia sissoo*, induction of adventitious roots exhibited the pattern: young cuttings > thin cuttings > thick cuttings. Administration of 800 or 50 ppm IAA for 24 h to semi-hardwood cuttings of 12 or 6-year-old trees, respectively induced >70-90% adventitious roots. In *Pongamia pinnata*, 800 ppm IBA resulted in significantly superior adventitious rhizogenesis to the tune of 100%.
- Adventitious rhizogenesis was season-specific and the cutting size and IAA treatment helped in optimizing rooting behaviour during responsive warm season of the year. Double/triple nodal culm branch cuttings collected in April and given immersion treatment for 24 h with 100 ppm IAA in *Bambusa vulgaris* var. yellow and double nodal cuttings collected in February and given immersion treatment for 24 h with 100 ppm IAA in *Dendrocalamus strictus* was suitable for their large-scale vegetative propagation.
- In juvenile shoot cuttings of *Albizia procera*, treatment of 2 mM KMnO_4 , a non-auxin economic inorganic salt, significantly enhanced adventitious rooting by 27.3% over the control.
- Dose-response curve exhibited root characteristics to be a binomial function of KMnO_4 doses. Quick dipping of shoot cuttings of *Azadiractha indica* in 1000 ppm IBA resulted in 100% rooting and superior root biomass.
- Bud break and sprout emergence coinciding April-June was the best period for adventitious rhizogenesis in teak. Adventitious root induction and growth needed long photoperiod and low irradiance. Administration of 1000 ppm IBA + 800 ppm thiamine for 18 h as basal dip treatment ensured induction of upto 60% adventitious roots under natural condition. Administration of 12 mM ascorbic acid stimulated induction and growth of adventitious roots in leafy juvenile cuttings.

- The non-harmonal air layering method for production of clonal plantlets from mature trees of *Albizia procera* was developed. 100 ppm IBA also enhanced induction and growth of adventitious roots by 68% in juvenile shoot cuttings. IBA influenced heritability of adventitious root characteristics in juvenile shoot cuttings of half-sib families.
- Resumption of active growth marked with emergence of sprouts in donor trees coincided with the best rhizogenesis and moderate water stress favoured adventitious rooting. The potential of the five species for adventitious rhizogenesis was recorded as: *D. sissoo*>*G. arborea*>*D. latifolia*>*B. serrata*> *A. latifolia*. Successful development of cloning procedures for *Gmelina arborea* through (a) sprout cuttings (93% rooting) and (b) semi-hardwood cuttings (75% rooting). Air-layering procedures for clonal propagation of *Boswellia serrata* (100 % success) and *Dalbergia sissoo* (83 % success) were standardized.
- Shoot multiplication rate of 16-17 folds was obtained for *Dendrocalamus asper* on MS liquid medium supplemented with 3mg/l BA and 95-98% rooting on MS liquid medium with 0.1mg/l IBA or 3mg/l NAA.
- In *Bambusa bambos*, shoot multiplication rate of 5 folds was obtained on MS liquid medium supplemented with 3mg/l BA and 80-85% rooting on MS medium supplemented with 3mg/l NAA. 80-90% plant survival was obtained after transplantation.
- Shoot multiplication rate of 15 folds was obtained on MS liquid medium supplemented with 2mg/l BA and 90-95% rooting on MS liquid medium with 2mg/l NAA in *Dendrocalamus membranaceas*. Shoot multiplication rate of 5 folds was obtained in *Bambusa nutans* on MS liquid medium supplemented with 2.25mg/l BA+ 0.175mg/l IAA and 62% rooting on MS liquid medium with 3mg/l IBA+0.125mg/l BA+3.65mg/l coumarin.
- In *Dendrocalamus giganteus*, shoot multiplication rate of 5 folds was obtained on MS medium supplemented with 4.5mg/l BA and 90% rooting on MS medium with with 0.9-4.6mg/l NAA+1.85mg/l-2.25mg/l IBA. Shoot multiplication rate of 4.56 folds was obtained on MS medium supplemented with 3mg/l BA+0.5ml/l vipul and 56.66%rooting on ½ MS medium with 2.5ml/l alcoholic rice bran extract +3mg/l NAA in *Dendrocalamus strictus*.

- A shoot multiplication rate of 4-5 fold was obtained on MS medium supplemented with 2.25mg/l BA +0.185mg/l NAA and about 60% rooting on MS medium with NAA in *Bambusa vulgaris*. Thirteen fold plantlet production was obtained on MS semisolid medium supplemented with 2.7mg/l BA +0.56mg/l NAA in *Kaempferia galanga*.
- Shoot multiplication rate of 4-5 fold was achieved on MS medium supplemented with 2.25 mg/l BA and 0.186 mg/l NAA and about 60 % rooting on MS medium supplemented with 2.7 mg NAA in *Tectona grandis*. Shoot multiplication rate of 7 fold was achieved on MS medium supplemented with 0.225mg/l BA and 0.0215mg/l Kn and about 86% rooting was on ½ WPM medium supplemented with 10µMIBA in *Gmelina arborea*.

NWFP

- Composite wood prepared from NWFP wastes had equal or better mechanical properties compared to *Sachharum spontanum* and was suitable for manufacture of hard board.
- An improved method developed for extraction and optimum yield of starch in *Curcuma angtifoloa* (Tikhur).
- Thirty different shades developed for dyeing textile material using natural colour extracted from *Butea monosperma*.

Silviculture & JFM

- Techniques for production of rooted cuttings in neem and babul by IAA application developed.
- Containerized seedling production system developed for *Albizia procera* and *Acacia nilotica*.
- The method for treatment of seeds before sowing for control of seed borne diseases was standardized.

- Root trainer seedling production system developed for production of superior quality planting stock of *Aadirachta indica*, *Acacia catechu*, *Emblica officinalis*, *Pongamia pinnata*, *Albizia lebbek*, *Pterocarpus marsupium*, *Gmelina arborea*, *Bombax ceiba*, *Dalbergia latifolia*, *Pongamia pinnata* and *Acacia catechu*.
- Improved compost production system using forest wastes was standardized.
- Seed technology criteria with respect to storage, germination and viability developed for *Albizia. procera* and *Gmelina arborea*.

PACKAGE OF PRACTICES

Agroforestry

- The improved agroforestry models with tree species, medicinal plants, perennial pigeon pea, grasses and vegetable as important tree-crop combinations developed.
- Babul based site specific agroforestry models for Chhattisgarh region developed.
- The agroforestry models in relation to allelopathic effect, root growth pattern and plantation geometry, alley crop combinations and buch-paddy combination developed.
- Silvi-medicinal system of agroforestry models with teak and safed musli developed and economics worked out.

Ecology

- Application of synthetic fertilizers, viz., urea, single super phosphate, ammonium sulphate, ammonium chloride and murate of potash and biofertilizers, viz., natrin, phosphin and bactin significantly enhanced growth of tree species like *P. dulce*, *Albizia procera* and *Dalbergia sissoo* in coal, copper and iron mine overburden dumps respectively.
- Leaf litter and husk mulches influenced nutrients uptake, growth and biomass production in *Albizia procera* and *Dalbergia sissoo* in coal, copper and iron mined out areas in a positive way over stone/gravel and grass mulches.

Entomology

- Cypermethrin @ 0.03% proved highly effective to protect the tendu leaves from the damage caused by gall insect.
- Cypermethrin @ 0.005% proved most effective followed by deltamethorin @ 0.005% and monocrotophos 0.03% against *Leucaena psyllid*, *Heteropsylla cubana*.

- Foliar spraying of monocrotophos 0.04% proved highly effective to kill the larvae of *Eurema* spp. and *Rhesala* sp. damaging *Albizia* leaves.
- Cypermethrin proved to be 18 times more toxic than malathion against the larvae of *Ailanthus* defoliator, (*Atteva fabriciella*). Fenvalerate found next to cypermethrin in its relative toxicity.
- Foliar spraying of 0.0038% cypermethrin proved highly effective against the larvae of *A. fabriciella*.
- Foliar spraying of Cypermethrin 0.005% or fenvalerate 0.01% or deltamethrin 0.03% proved highly effective against the Kullu (*Sterculia urens*) leaf defoliator.
- Deltamethrin and alphamethrin proved 22.11 and 21.83 times as toxic as malathion against the larvae of sissoo defoliator.
- Foliar spraying of 0.04% monocrotophos proved highly effective against the larvae of moringa leaf defoliator.
- Foliar spraying of monocrotophos 0.05% in mid September was effective for the control of the seed borer, *B. bilineatopygus*.
- Storing sal seeds below 10°C (in cold storage) protect them from further deterioration by seed borer.
- Insect pests damaging 8 medicinal plants, viz., *Cassia fistula*, *Solanum indicum*, *S. khasianum*, *Operculina turpenthum*, *Psoralea corylifolia*, *Abelmoschus crinitus*, *Nyctanthus arbortristis arbortristis*, *Tylophora asthamatica*, *Urginea India* were identified and their control measures investigated.
- Water seasoning of logs for 10 days prevents the attack of powder post beetles.
- Foliar spraying of 1.0% *Bacillus thuringiensis* var. kurstaki (BTK) was highly effective against teak defoliator and other major insect pests in nurseries and young plantations.
- Two fungi, viz., *Beauveria barsiana* and *Metarhizium anisopliae* @1.7 x 10⁷ and 1.5 x 10⁷ spores/ml with a small quantity of neem oil respectively was found effective against the highly resistant larvae of teak defoliator and skeletonizer.
- The exotic polyphagous egg parasitoid *Trichogramma brasiliensis* @ 1.5 lakhs/ha suppressed the incidence of teak leaf skeletonizer.

- Relative toxicity of 6 insecticides against the larvae of *Hyblaea puera* (Deltamethrin proved best followed by Alphamethrin), 11 insecticides against the larvae of *Entectona machaeralis* (Deltamethrin proved best followed by Alphamethrin), 12 insecticides against the larvae of *Spirama retorta* (Cypermethrin proved best followed by Deltamethrin) and 2 insecticides against the larvae of *Crypsiptya coclesalis* (Endosulfan proved best followed Monocrotophos) was screened.
- Spraying of 0.001% Deltamethrin, 0.002% Cypermethrin and 0.08% monocrotophos proved best for the control of larvae of teak pests (*Hyblaea puera* and *Entectona machaeralis*) *Albizia* foliage feeder, *Spirama retorta* and bamboo leaf roller, *Crypsiptya coclesalis* respectively.
- Spore concentrations of entomo-pathogenic fungi, *Beauveria bassiana* @ 1.7x10 spores/ml proved highly effective to kill the grubs of sal borer, *Hoplocerambyx spinicornis* within 6 days of spray.
- A new method of direct killing of sal borers developed by spraying 0.05% water emulsion of Endosulfan on beaten sal logs as trap without loosing its effectiveness.
- Application of *Trichogramma raoi* @ 1.25 lakh/ha found effective in minimizing at least 50% loss in annual growth caused by the attack of these pests.

Pathology

- Nine foliar pathogens of *Sterculia urens*, 4 pathogens each of *Rauvolfia serpentina* and tropical pines were recorded from forest nurseries and plantations. Fortnightly spray of Bavistin 0.2% or Dithane M-45 0.2% during July and August successfully controlled the diseases.
- *Fusarium pallidoroseum*, *Aspergillus niger*, *A. flavus*, *Alternaria alternata* and *Penicillium* species were found common in succession of seed mycoflora of *Tectona grandis*, *Albizia procera*, *A. lebeck*, *Acacia nilotica*, *Gmelina arborea*, bamboo, *Pongamia pinnata* and *Azadirachta indica*. Fungicides viz., Dithane M-45, Fytolon, Bavistin and Captaf 0.2% as seed paletting were found effective in controlling mycoflora.

- Root rot diseases caused by *Fusarium* sp. in forest nurseries of *Pongamia pinnata*, *Azadirachta indica*, *Tectona grandis*, *Acacia nilotica*, *Dalbergia sissoo*, *Albizia procera* etc. was effectively controlled with application of Bavistin 0.2% at fortnightly intervals during the month of May-June.
- Root rot caused by *Ganoderma* in *D. sissoo*, *A. procera*, *Acacia* sp. and salfi palm was noticed as the most damaging disease of MP., CG., MS. and Orissa. Soil drenching of Bordeaux mixture @ 1 lit. /tree at 3 month intervals and digging of isolation trenches (45 cm deep, 30 cm wide) was effective to control root rot spread in plantations.
- *Sarocladium oryzae* caused severe blight disease in *Bambusa nutans* at Orissa. Disease incidence was minimized by light burning of litter during March and April, mounding of clumps and application of rotten *Azadirachta indica* oil cakes during first week of July.
- *Macrophomina phaseolina* caused charcoal root rot in tropical pines and *Casuarina* plantations. Root rot infection was minimized by application of Bavistin 0.2% as soil drench in April-June.
- *Heplosporella* caused die back in young plantation of *Acacia nilotica* and *A. procera*. Fungicidal spray with Dithane M-45 0.2% at monthly intervals during August-September was found very effective.
- Low cost treatment for production of consortium was developed.

NWFP

- Agro-techniques of *Alastonia scholaris*, *Gmelina arborea* and *Crateva magna* were standardized.
- A database management package was developed for NWFP species. The package was tested successfully for over 75 species, retrieving information in an interactive way with simple key strokes like local name, botanical name, trade name, active ingredients, soil type, family and propagation method.

Silviculture & JFM

- Nursery techniques for *Boswellia serrata*, *Lagerstroemia parviflora*, *Pterocarpus marsupium* and *Stereoculia urens* developed by standardizing depth of sowing and nutrient supply, which enhanced seed germination and seedling growth significantly.
- Improved plantation techniques developed for *Cassia siamea* and *Dalbergia sissoo* for degraded soil which increased survival and growth of plants by standardizing pit size, doses and type of fertilizer.
- An improved package of practices developed for *Pongamia pinnata*, *Albizia procera*, *Albizia lebbek*, *Dalbergia sissoo*, *Dalbergia latifolia*, *Gmelina arborea*, *Acacia nilotica*, *Acacia benthamii*, *Acacia catechu* which enhanced seed germination, growth and quality of seedlings by manipulating depth of sowing, potting mixture and types and doses of fertilizer.
- Optimum spacing and doses of fertilizers for better survival and growth of *A. procera*, *A. lebbek* and *D. sissoo* were standardized.
- Dose response to fertilizer application was standardized with respect to survival and growth of *A. procera*, *A. lebbek*, *P. pinnata*, *D. sissoo*.
- Growth promoting substances including application of fertilizer boosted seedling growth of *Albizia lebbek*, *A. procera* and *Acacia nilotica* in nursery.
- Combined application of VAM and rhizobium was found to be highly effective in enhancing growth of seedlings at nursery stage.

GERMPLASMS AND PRODUCTION POPULATIONS

- A botanical garden was established with 120 species belonging to 80 genera and 40 families of forest origin of central India including 17 species of bamboo.
- Species-specific germplasm bank of biofertilizers (VAM fungi, *Azospirillum*, PSB, Azotobacter, Rhizobium) developed for important tree species.
- Germplasms of the following species collected from different states of India:

Species	Number of germplasm collected from different states						
	MP	MS	CG	Orissa	UP	Goa	Assam
<i>Aegle marmelos</i> (bael)	10	07	01	01	-	-	-
<i>Phyllanthus emblica</i> (aonla)	09	02	04	01	-	-	-
<i>Madhuca longifolia</i> var <i>latifolia</i> (mahua)	25	04	15	08	01	-	-
<i>Buchanania lanzan</i> (chironji)	04	-	05	06	-	-	-
Harra	09	03	04	-	-	-	-
Malkangni	04	-	01	-	-	-	-
Guggal	02	-	-	-	-	-	-
Kusum	08	-	09	01	-	-	-
Koka	04	-	-	-	-	01	-
Nagkeshar	-	01	-	01	-	-	01
Pisa	-	01	-	-	-	-	-

- The following production populations were established.

Type	Species	Area (ha)
Seed Production Areas	<i>Tectona grandis</i> <i>Casuarina equisetifolia</i>	500
Clonal Seed Orchards	<i>Tectona grandis</i> <i>Casuarina equisetifolia</i> <i>Albizia procera</i>	44
Seedling Seed Orchards	<i>Tectona grandis</i> <i>Albizia procera</i>	90
Vegetative Multiplication Garden	<i>Tectona grandis</i> <i>Albizia procera</i> <i>Casuarina equisetifolia</i>	10