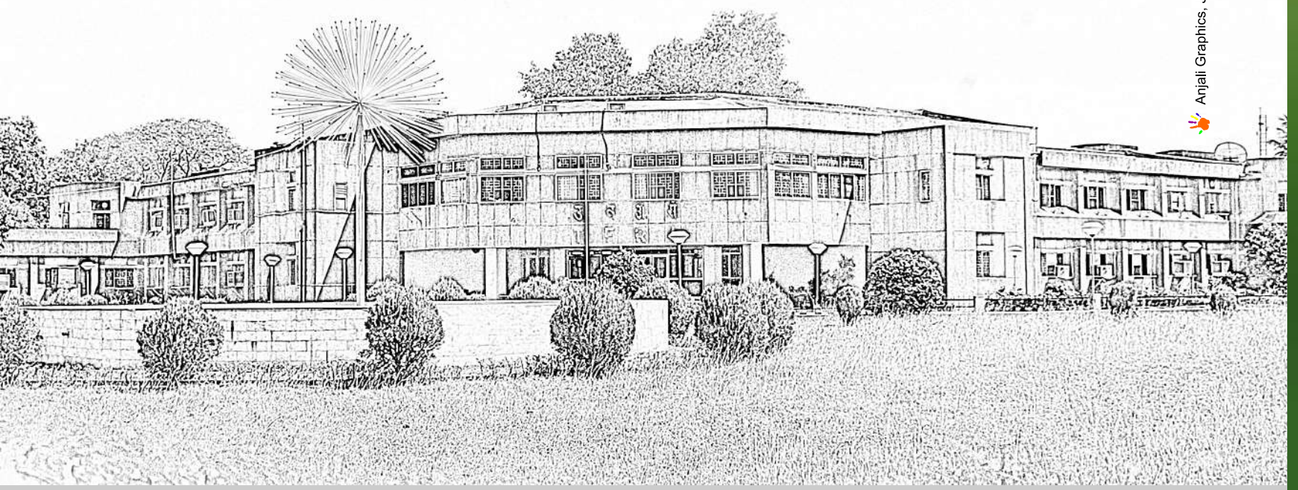
Pioneering Institute for Forestry Research in Central India

TROPICAL FOREST RESEARCH INSTITUTE, JABALPUR (M.P.)



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TFRI/Book-1/2020

COMPENDIUM OF DOABLE TECHNOLOGIES

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Foreword

Tropical Forest Research Institute, a premier forestry research institute is continuously providing strong research support for ecological stability, improved productivity, sustainable development and economic security of forests and forestry sector in central India, covering 33 agro-climatic zones and five major forest types. The institute conducts demand driven research on genetics and tree improvement, forest ecology, biodiversity and climate change, forest protection, agro-forestry and non-wood forest produce. It provides technical/ advisory services to the stakeholders like State Forest Departments, Forest Development Corporations, Minor Forest Produce Federations, farmers, forest dwellers, PSU's and corporate sectors.

The institute has been tirelessly working to fulfil the requirements of stakeholders and has published a number of technical bulletins, brochures, pamphlets. However it was always felt to have all the information readily available at one place in a usable manner. Therefore, an effort has been made to compile most promising technologies and package of practices on development of varieties, propagation of bamboo and tree species, eco-restoration of mine dumps and degraded lands, Integrated Pest Management, agroforestry models, sustainable harvesting and cultivation of NWFPs as-well-as seed and nursery protocol for important forestry species. I am sure this compendium of doable technologies would be useful to the stakeholders. I compliment Forest Extension Division for the efforts in bringing out this publication and the contributors for their inputs.

Dr. G. Rajeshwar Rao, ARS
Director

Preface

This publication has been created keeping in mind, the requirements of researchers and stakeholders, especially with reference to tropical forestry research. It provides various 'Doable Technologies', developed and standardized at Tropical Forest Research Institute (TFRI) for adoption in the field.

One of the salient features of this publication is that, it does not follow a classical textbook structure with the chapters listed in sequence. One can start reading from anywhere, based on their interests and preferences. There are 30 successful technologies and package of practices developed by TFRI which can be readily used by stakeholders. These are suitable for clonal production of quality planting material of trees and bamboos, rehabilitation of mine overburdens and fly ash dyke's, environment friendly methods for protection of forests and plantations, optimum land utilization through agroforestry and silvi-medicinal models, sustainable harvesting and value addition of medicinal plants and handling and storage of tree seeds.

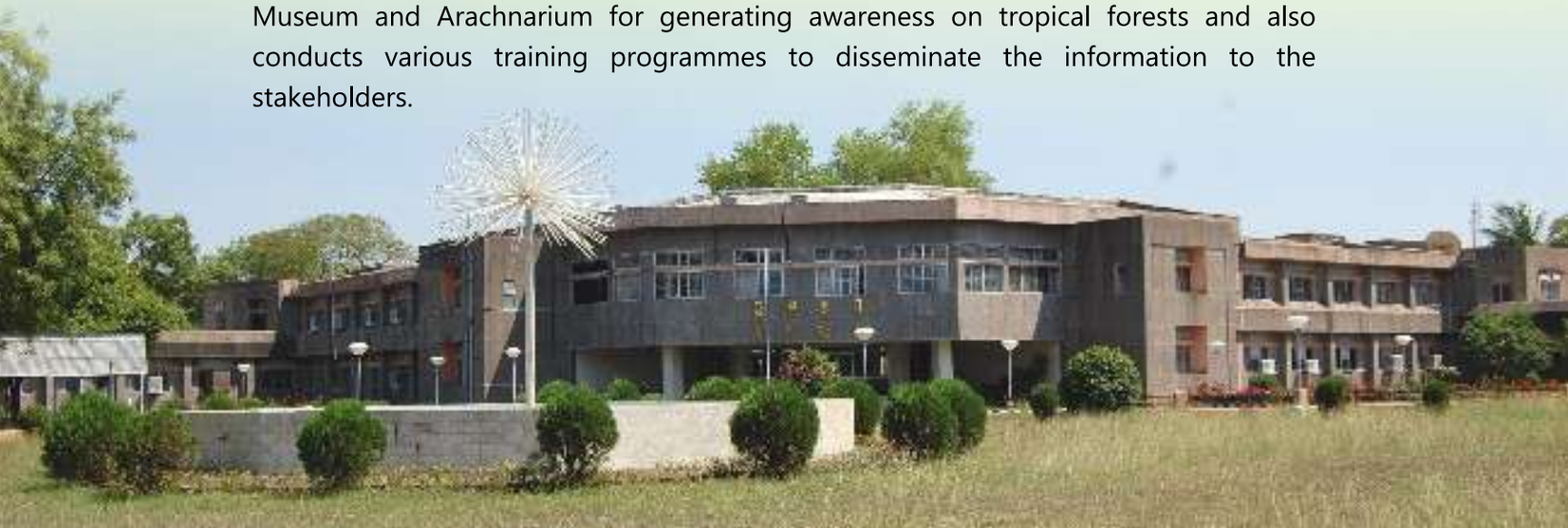
We are thankful to the committee consisting of our scientists Dr. S. Chakrabarti, Dr. Arun Kumar A. N., Dr. S. Saravanan and Shri M. Rajkumar for selection of technologies.

We acknowledge all the contributors, due to their immense support we are able to collate this information at one place. Only brief profile of technology and package of practices have been given in this handbook, the details can be obtained from concerned scientists. We hope that this handbook will be useful to our stakeholders.

About Institute

Tropical Forest Research Institute (TFRI), Jabalpur is one of the R&D institute of Indian Council of Forestry Research and Education (ICFRE), under Ministry of Environment Forest and Climate Change, Government of India. To provide research support for the problems of forest management in central India, in 1973 a Regional Centre of FRI, Dehradun was established at Jabalpur. With the formation of ICFRE, in April 1988, the Regional Centre was upgraded as Institute and renamed as TFRI. The institute conducts research on various forestry related aspects catering to the needs of State of Madhya Pradesh, Chhattisgarh and Maharashtra, and also has a Forest Research Centre and Skill Development at Chhindwara, MP. The institute has a strong team of scientists, technical personnels and support staff for conducting demand driven research, based on issues raised by forest departments, farmers, plantation companies, industries etc.

The institute has four research divisions which carry out basic as well as applied research and take up consultancy projects. The Genetics and Tree Improvement Division is engaged in research on conservation and genetic improvement of commercially important tree species of tropical forests for productivity enhancement and germ plasm conservation. Forest Ecology and Climate Change division addresses the issues related to climate change, valuation of plantations and natural forests for tangible and intangible benefits, eco-restoration of degraded lands, biodiversity assessment, wildlife conservation, management and desertification. Forest Protection Division provides support for management of insect pests and diseases in nurseries, plantations, natural forests and monitors and manages disease outbreaks through Integrated Pest Management. It also has NBA accredited insect reference collection for central India with more than 700 identified insect specimens and a mycology fungarium of forest fungi with over 3500 specimens. Silviculture and Forest Management Division work for developing site specific agroforestry models for optimum land utilization, standardizing seed and nursery protocol for important forestry species, value addition and sustainable harvesting techniques of important medicinal species. For dissemination of research findings and technologies/package of practices developed in the institute, the Forest Extension Division establishes linkages between the Institute and other organizations such as forest departments, government organizations, universities, farmers, industries and Non-Government Organizations. The division also has Forest Interpretation Centre cum Museum and Arachnarium for generating awareness on tropical forests and also conducts various training programmes to disseminate the information to the stakeholders.



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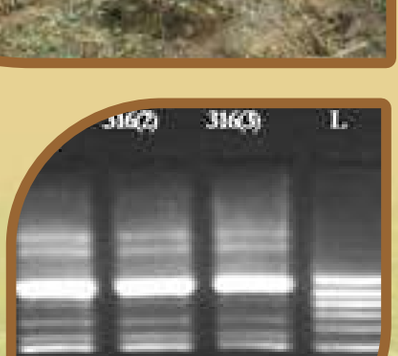
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GENETICS AND TREE IMPROVEMENT DIVISION

Development of varieties of *Rauvolfia serpentina* (Sarpagandha)

Nature of technology

Release of varieties

Brief description of technology

Rauvolfia serpentina (L.) Benth. (Family Apocynaceae) is an indigenous important medicinal plant distributed in tropical countries of Asia. The roots contain 50 indole alkaloids including the therapeutically important reserpine. Germplasm bank of Sarpagandha at TFRI has been established having collection from 11 states, *viz.,* Chhattisgarh, Madhya Pradesh, Maharashtra, Odisha, Uttar Pradesh, Kerala, Karnataka, Tamil Nadu, Goa, Himachal Pradesh and Uttrakhand. The phenotypic stability of 23 genotypes of *R. serpentina* were compared with two checks *viz.,* RS-1(JNKVV, Indore) and CIM-Sheel (CIMPP, Lucknow) for reserpine content in root and related traits in three different locations. Finally, two varieties of *R. serpentina* TFRI-RS1 and TFRI-RS2 were released by National Variety Release Committee, New Delhi in February 2017, as improved varieties for high reserpine, total alkaloid and root yield. The variety TFRI-RS1 gives high root yield whereas TFRI-RS2 contains high alkaloid and reserpine. Both the varieties are suitable for commercial cultivation.

Beneficiaries of the technology

State Forest Departments, NGOs, research organizations, farmers, pharmaceutical companies.

Impact of technology

These varieties can be planted by farmers and other end users for high in alkaloid content.

TFRI RS-I

TFRI RS-II

Varieties of *Rauvolfia serpentina*

Micropropagation of bamboo species

Nature of technology

Propagation of bamboos

Brief description of technology

TFRI has developed micropropagation protocols of nine indigenous bamboo species (*Bambusa bambos, B. nutans, B. nana, B. polymorpha, B. tulda, B. vulgaris* var. green, *Dendrocalamus giganteus, D. membranaceus,* and *D. strictus*) and one exotic edible species (*Dendrocalamus asper*) through tissue culture. Collection and sterilization of explants, culture establishment, shoot multiplication and root induction and finally hardening and acclimatization has been standardized. Single nodal segments with axillary buds collected from field growing clumps (7-10 year old) were used as explant for culture establishment. The explants were sterilized with 0.1-0.2% mercuric chloride and shoot multiplication was carried out on semi-solid or liquid culture (usually MS) medium enriched with 1-7 mgl^{-1} BA. A culture cycle of 15-30 days produced 2-15 shoots, which were induced for rooting on MS medium enriched with 3-5 mgl^{-1} IBA, NAA or coumarin. The rooting success varied from 50-90%. The plantlets were gradually hardened from culture room to shade house via mist chamber. The hardened plantlets had 80-100% field survival. Standardized micropropagation methods for some of the important bamboo species are summarized in table1 and 2.

Beneficiaries of the technology

State Forest Departments, plantation companies, research organizations, farmers, bamboo nursery owners.

Impact of technology

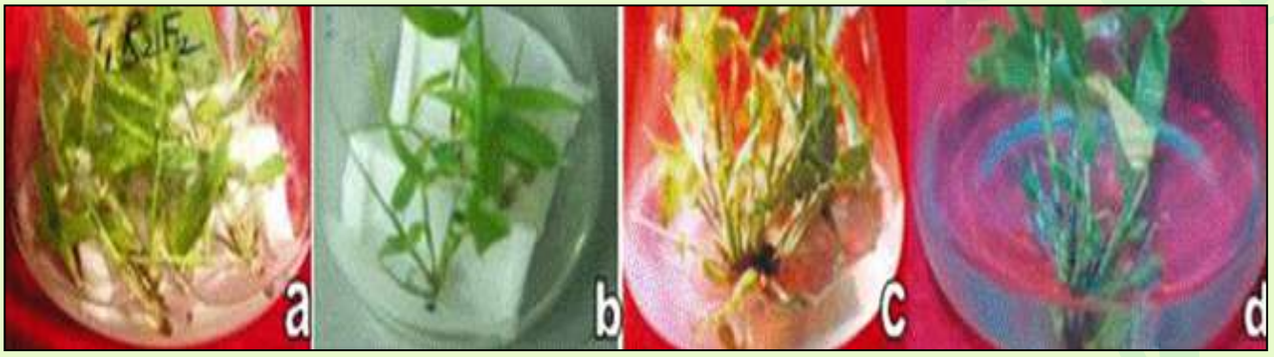
Mass production of quality planting material and supplying to stakeholders. The acclaimed work on tissue culture of bamboos resulted in award of a patent entitled "A protocol for micropropagation of bamboos from explants" (patent no. 207870) on 29.06.2007 by the Controller of Patents, Mumbai. Demonstration trial of tissue culture raised bamboos has been established at the TFRI campus.

Table 1: *In vitro* shoot multiplication in various bamboo species

Species	Medium	Phytohormones	Multiplication rate (fold)
Bambusa nutans	MS liquid	7 mgl^{-1} BA+0.5 mgl^{-1} IAA	2-3
Bambusa tulda	MS liquid	2.5 mgl^{-1} BA	2
Bambusa vulgaris var. green	MS semisolid/liquid	3 mgl^{-1} BA	3-4
Bambusa nana	MS semisolid/liquid	1 mgl^{-1} BA	2-3
Bambusa polymorpha	MS semisolid/liquid	4 mgl^{-1} BA	2-3
Bambusa bambos	MS semisolid	3 mgl^{-1} BA	4-5
Dendrocalamus strictus	MS liquid	3 mgl^{-1} BA+0.5 ml-1vipul	4-5
Dendrocalamus asper	MS semisolid/liquid	3 mgl^{-1} BA	15-20
Dendrocalamus membranaceus	MS semisolid/liquid	5 mgl^{-1} BA	10-12
Dendrocalamus giganteus	Liquid	4 mgl^{-1} BA	3-4

Table 2: *In vitro* adventitious rhizogenesis in various bamboo species

Species	Medium	Phytohormones	Rooting%
Bambusa nutans	MS liquid	5 mgl^{-1}IBA	60-70
Bambusa tulda	MS liquid	5.84 mgl^{-1} Coumarin	90-95
Bambusa vulgaris var. green	MS semisolid/ liquid	5 mgl^{-1} NAA	80-90
Bambusa nana	MS semisolid / liquid	5 mgl^{-1}IBA	70-80
Bambusa polymorpha	MS semisolid / liquid	4 mgl^{-1} NAA	70-80
Bambusa bambos	MS semisolid	3 mgl^{-1} NAA	80-85
Dendrocalamus strictus	MS liquid	3 mgl^{-1} NAA+ 2.5 mll^{-1} rice bran extract	50-60
Dendrocalamus asper	MS semisolid / liquid	3 mgl^{-1} NAA	90-95
Dendrocalamus membranaceus	MS semisolid / liquid	2 mgl^{-1} NAA	80-90
Dendrocalamus giganteus	Liquid	5 mgl^{-1} IBA+0.01 mgl^{-1}BA	70-80



***In vitro* shoot multiplication (a) *B. nutans*, (b) *B.tulda*, (c) *B. vulgaris* var. green, (d) *B. nana*.**

***In vitro* adventitious root formation; (a) *B. nutans*, (b) *B.tulda*, (c) *B. vulgaris* var. green (d) *B. nana*.**

Macropropagation of various bamboo species through culm-cuttings

Nature of technology

Propagation and mass multiplication bamboos

Technology in brief

Culm cuttings of *Bambusa vulgaris* var. green, *B. tulda*, *B. nutans* and *B. balcooa* were collected from clumps growing in the field. For *B. vulgaris, B. tulda* and *B. nutans,* smaller size cuttings of 30-40 cm length and about 1-2 cm or 2-3 cm or 3-4 cm diameter with single nodes were prepared and used for propagation. These culm cuttings were completely dipped in IBA solution (200 ppm) for 24 hours. For *B. balcooa* bigger size cuttings of 70-80 cm length and about 4-5 cm diameter with double nodes were used for propagation. Small cavities were made on the culm cuttings and 1000 ppm IBA solution was poured in these cavities. The cavities were covered with tape and the cuttings were planted in the sand bed. Sprouting was initiated after one week and optimum rooting was achieved in four weeks under controlled environmental conditions of mist chamber *i.e.,* temperature about 30°C, relative humidity 70% and intermittent misting for *B. vulgaris, B. tulda* and *B. nutans*. For *B. balcooa* sprouting initiated after two week and optimum rooting was achieved in five weeks. Rooting percentage ranged from 65% to 95% in different species and in different diameter classes as depicted in the table below . The culm cuttings produced maximum adventitious rooting when planted during the months of April-May.

Table : Adventitious rooting obtained in culm cuttings of various Bamboo species through Macropropagation

Species	Time period	Diameter of cuttings (cm)	Auxin Treatment (ppm)	Rooting (%)
Bambusa vulgaris var. green	April- May	1– 2	200	85-95
B. tulda	April	2-3	200	80-85
B. nutans	April	1-2 and 2-3	200	70-75
B. balcooa	April	4-5	1000	60-65

Beneficiaries of the technology

State Forest Departments, plantation companies, research organizations, farmers, bamboo nursery owners.

Impact of technology

Mass production of quality bamboo plants. A large number of plants have been produced and supplied to various end users, consequently earning revenue for the institute.

Macropropagation of various bamboo species through culm-cuttings

Macropropagation of *Bambusa vulgaris* var. green through culm cuttings

Macropropagation of *Bambusa balcooa* through culm cuttings

Macropropagation of *Bambusa tulda* through culm cuttings

Macropropagation of *Bambusa nutans* through culm cuttings

Propagation of *Bambusa vulgaris* var. green and *B. nutans* using mini-cuttings

Nature of technology

Propagation and mass multiplication bamboos

Technology in brief

Use of mini-cuttings for vegetative propagation of bamboo is rapid, economical and without destruction of culm. Besides, the use of mini cuttings for propagation requires comparative less space in propagation beds than the culm and culm branch cuttings and rooted cuttings can be easily transferred to polybags for hardening. Sub-branch cuttings of the size 5-10 cm and about 1.0cm diameter (mini-cuttings) with single node were used for propagation of bamboo species viz. *Bambusa vulgaris* var. green and *B. nutans*. Cuttings can be obtained from culm branches and culm sub-branches and are completely dipped in phytohormonal solution of 100 ppm IBA for 20hrs. Rooting is initiated after one week and optimum rooting is achieved in three weeks under controlled environmental conditions of mist chamber i.e. temperature about 30°C, relative humidity 70% and intermittent misting. In case of *B. nutans* up to 60% mini cuttings and in *B. vulgaris* var. green 80%-90% mini cuttings produced adventitious rooting when planted during the month of April-May.

Beneficiaries of the technology

Forest department, bamboo nursery owners, plantation companies and farmers.

Impact of the technology

Mass production of bamboo plants

Macropropagation of *Bambusa vulgaris* var green through mini-cuttings

Macro-propagation of tree species

Nature of technology

Propagation and conservation of superior germplasm

Technology in brief

Propagation of superior germplasm is one of the important constituents of the tree improvement programme. Institute developed macro-propagation packages for some of the valuable tree species through shoot cuttings. Rooting ability varies with the juvenility of tree. Standardized macro-propagation practices for some of the important species are summarized in the table below.

Table: Macro-propagation packages for tree species

Species	Age of selected tree	Treatment	Treatment duration	Rooting ability
Dalbergia sissoo	Shoot cuttings from 10-12 years trees	IAA 100ppm	24hrs basal dip	90%
Azadirachta indica	Shoot cuttings from 10-12 years trees	IBA 1000ppm	Quick basal dip	80%
Pongamia pinnata	Shoot cuttings from 10-12 years trees	IBA 800ppm	15hrs basal dip	100%
Tectona grandis	Shoot cuttings from 15-20 years trees	IBA 400ppm + Thiamine 400ppm	24hrs basal dip	40%
Gmelina arborea	Shoot cuttings from 4-5 years trees	0.5mM IBA at 5.5 pH	4hrs basal dip	50%
Dalbergia latifolia	Shoot cuttings from 8-10 years trees	5 mM IAA + 1mM Boric Acid	20hrs basal dip	26%

Beneficiaries of the technology

Forest department

Impact of the technology

Production of quality planting material and conservation of superior genotypes

Rooting of cuttings in *Dalbergia sissoo, Azadirachta indica, Pongamia pinnata, Tectona grandis, Gmelina arborea, Dalbergia latifolia*

Protocol for raising seedlings of *Litsea glutinosa* Lour. (Maida Chhaal)

Nature of technology

Package of Practices

Technology in brief

Litsea glutinosa is a multipurpose tree species and its bark is extensively used in Agarbatti industries. Due to increased demand, trees were extensively damaged for bark extraction. Therefore, the tree has been categorised as endangered and its conservation is important.

In Madhya Pradesh and Chhattisgarh, fr
during first week of October to mid-Nove

Fruits are depulped by washing in water
dried for a week. The dried seeds are stor

Bright sunny days are good for higher se
the seeds are pre-treated by soaking in
solution for 24 hours. The seeds are sow
amount of Sand: Soil: FYM.

Ensure proper moisture in root trainers and avoid excess watering. Seed germination starts from 20-25 days after sowing and continues for next 25-30 days. Seed germination varies from 30 to 34%. Seedlings attain height of about 15-20 cm after two months and are transferred to polythene bags containing same potting mixture as that of root trainers.

Though there are no major insect-pests attacking the seedlings in nursery, sometimes leaf eating caterpillar may attack the leaves of growing seedlings. It can be easily controlled through spraying of 0.02% of Imidacloprid with repeated treatment after 25 to 30 days, if required. Alternatively, 1.0% bacterial biopesticide (Biolep) may be spread for controlling the same.

Beneficiaries of the technology

State Forest Department, NGOs, research organizations

Impact of technology

Production of quality planting material. Protocol developed has been communicated to the SFD as advisory, published in the form of brochure and research paper for wide dissemination.

FOREST ECOLOGY AND CLIMATE CHANGE DIVISION

Tendu (*Diospyros melanoxylon*) harvest practices

Nature of technology

Harvesting practices

Technology in brief

The traditional pruning practices of *Diospyros melanoxylon* (tendu) bushes were evaluated for yield and quality of leaves and their natural regeneration to suggest best harvest practice in Maharashtra and Chhattisgarh. Studies were conducted in tendu bearing areas of both states. Quadrates, each of 0.1 ha size, were laid in the selected sites to study the impact. After tagging the bushes and recording initial data, leaf area and weight were measured to calculate Specific Leaf Area (SLA) for determining quality of leaves. Baseline data of tendu bushes were collected before pruning in the month of March and leaves were harvested during May and June. Tendu bushes in State Forest Department controlled forests were pruned by conventional method and tendu poles were left in Community Forest Rights villages.

The yield of healthy leaves in pruned bushes was found five times more as compared to non-pruned poles. Non-pruned poles yielded higher gall infested diseased and defoliated leaves as compared to pruned bushes. SLA, depicting quality of leaves was found higher in pruned bushes than non-pruned pole showing better quality of leaves collected from the former. Lastly, SLA of healthy leaves was recorded higher than diseased or insect attacked leaves in both pruned bushes and non-pruned poles.

Beneficiary of technology

Forest dependent communities, State Forest Departments and Community Forest Rights village samittees and researchers.

Impact of technology

The standardised harvesting practice enhanced quality of tendu leaves resulting in increase in income of NTFP collectors.

Good quality healthy tendu leaves from pruned bushes

Low quality tendu leaves from non-pruned poles

Biological reclamation of flyash lagoons

Nature of technology

Reclamation of flyash lagoons through plantation of suitable species and construction of a physical barrier model

Technology in brief

Fugitive dust emission from flyash lagoons causes serious problems in and around thermal power plants. Light weighted amorphous ash particles travel long distances, sometimes upto few kilometres and affect health of local people causing pulmonary diseases, pollute water bodies and reduce agriculture productivity. Horizontal seepage of underground water from the ash lagoons creates water logging condition in the adjacent agricultural fields. TFRI conducted experiments at Shri Singaji Thermal Power Plant (SSTPP), Khandwa (M.P.). Detailed vegetation survey was conducted surrounding ash lagoons and adjacent forest and non-forest areas to screen native dominant species suitable for plantation in and around ash lagoons. Construction of flyash dyke model was proposed to act as a physical barrier for mitigating the impact of high wind velocity, which restricted emission of flyash particles to long distances. By planting of identified shrubs and grasses like *Ipomea carnea* (beshram), *Typha aungustifolia* (reed grass), *Calotropis procera* (madar) and *Eucalyptus* hybrid trees and adopting proper cultivation and plantation techniques, fugitive ash was controlled through the biological reclamation of lagoons within a short span of a year.

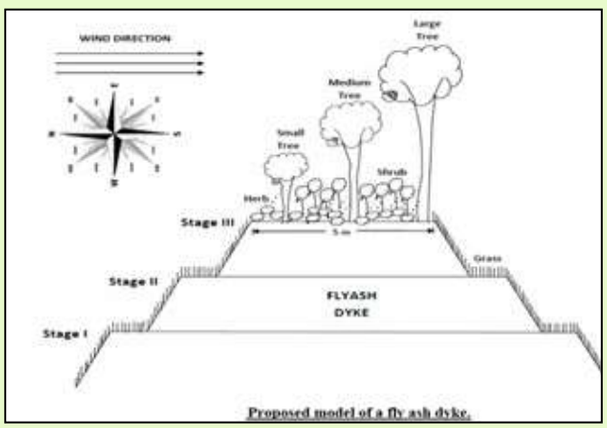
Beneficiary of technology

Thermal power plants and villagers/farmers residing around it.

Impact of technology

Plantation of identified species of grasses, shrubs and trees resulted in biological reclamation of flyash lagoons and reduction in horizontal seepage of fugitive ash to agricultural fields.

An active fly ash dyke in SSTPP



Proposed model of a fly ash dyke in SSTPP

Biodrainage of waterlogged sites

Nature of technology

Suitable tree species for waterlogged sites

Technology in brief

Water-logging in the agricultural fields due to horizontal seepage from canals and dams is a serious concern, which causes drastic decline in land usage and productivity for agricultural crops. Ten hectare plantation of seven forest tree species was raised along left bank canal of Bargi command area in Jabalpur district of M.P. The plantation sites were severely affected with water-logging due to horizontal seepage from canal. Impact of the plantation was observed on ground water table with the help of observation wells. Experiments were simulated in lysimetric tanks constructed at TFRI campus. The planted species were assessed for transpiration rate, per day use of water, receding level of ground water, growth characteristics and biomass. Multiple rows of site suitable water-logged tolerant fast-growing tree species like *Eucalyptus* (FRI 4 & 5 clones) (neelgiri species), *Pongamia pinnata (*karanj), *Terminalia arjuna* (arjun) were found to be effective for biological reclamation of waterlogged sites through the process of biodrainage.

Beneficiary of technology

Farmers, State Forest Departments, Irrigation Department, Municipal Corporation, Gram Panchayat and Rural Development Societies.

Impact of technology

Plantation of selected species in waterlogged sites along canal areas lower down the water table thereby increasing agriculture crop production.

Waterlogged area along canal

Restored waterlogged site

Eco-restoration of flyash dykes

Nature of technology

Suitable tree species screened for restoration of flyash dykes

Technology in brief

Flyash, a coal combustion residue of thermal power plants has been regarded as problematic solid waste all over the world. With increasing annual production of flyash of over 196 MT in India itself, its efficient utilisation and management is need of the hour. Flyash from NTPC Korba (CG) was used to conduct experiments in TFRI nursery, Jabalpur. Twenty tree species were grown in polybags consisting mixture of flyash, cow dung manure and soil (1:1:1) collected from site. The plants were watered, weeded and hoed up at regular intervals. On the basis of growth performance like height, girth and biomass of the plants, species were screened for plantation on flyash dumps/dykes/mounds. *Sesbania grandiflora* (agasti), *Sesbania sesban* (jayanti), *Albizia procera* (safedsiris), *Acacia nilotica* (babul), *Pongamia pinnata (karanj)* and *Eucalyptus* hybrid (nilgiri) tree species performed well on flyash.

Beneficiary of technology

Thermal power plants, State Forest Departments, research organizations, farmers residing near flyash dykes.

Impact of technology

The plantation model proposed and raised at NTPC Korba has become a success in the region. The selected species are now being replicated in restoration programmes of other thermal power plants in Chhattisgarh.

An active flyash dyke in NTPC Korba

Plantation raised over the flyash dyke

Biological reclamation of coal mine overburden dumps

Nature of technology

Suitable tree species screened for restoration of coal mine overburden dumps.

Technology in brief

Overburden dumps in mined areas exhibit completely altered ecological system and mine spoil lacks most of the physical, chemical, nutritional and biological characteristics of the normal soils. This results in slower rate of vegetation growth and increased contribution to waste and erodible lands. To initiate physical and biological reclamation, overburden (OB) dumps were levelled and compressed to less than 25m height and slope angle not steeper than 20^0 for ease and safety during reclamation work, erosion control and establishment of vegetation. Preparation of site was completed by terracing, spread of top soil and its levelling, excavation of suitable size pits and gully plugging.

An experimental trial was conducted at TFRI nursery by growing 57 species in polybags filled with a mixture of overburden spoil and compost (farm yard manure) in 1:1 proportion. Performance of the planted species was studied after 6 months on the basis of survival and growth data, where12 species were selected for field plantation. Block (monoculture) plantations of *Acacia catechu* (khair), *A. nilotica* (babul), *A. leucophloea* (Riunja), *A. mangium*, *A. auriculiformis* (Australian babool), *A. holosericea* , *Albizia lebbek* (kala siris), *A. procera* (safed siris), *Pongamia pinnata* (karanj), *Dalbergia sissoo* (sissoo), *Pithecellobium dulce* (jungle jalabi) and *Gmelina arborea* (khamer) were raised in 13 ha OB dump material in Bisrampur colliery of Surguja district, Chhattisgarh.

Beneficiary of technology

Mining authorities, State Forest Departments and Forest Development Corporations.

Impact of technology

Vegetation survey after 1, 2, 4, 6 and 8 years of plantation showed that ground flora and planted species gradually modified the nutrient status of the inert overburden spoils through constant litter return and atmospheric nitrogen fixation. The spoil changed gradually to hospitable conditions through the plantation of suitable species, which accelerated natural succession and allowed establishment of fresh invaders.

Restored site of overburden dumps

Eco-restoration of skeletal soils

Nature of technology

Suitable plant species screened for restoration of skeletal soils.

Technology in brief

Skeletal soils or soils that contain 35% or more (by volume) of rock fragments, cobbles, gravels and laterite concretions or iron stones are relatively variable in physical and chemical properties due to different mode of soil formation. Such soils are usually shallow, prone to erosion and low in natural fertility status. Experiments were conducted at Sambalpur, Odisha having skeletal soil, where pits of 45 x 45 x 45 cm^3 were dug in open field at spacing of 2m x 2m. Nursery grown seedlings (30-35 cm height) of selected species were then planted into the prepared pits, followed by application of Benzene-hexachloride (BHC) and cow dung mixture. After one year of plantation, seven tree species were screened on the basis of their survival, growth and performance for plantation on skeletal soils. *Albizia procera (*safed siris), *Dalbergia sissoo* (sissoo), *Acacia auriculiformis* (Australian babool), *Peltophorum ferrugineum* (peltophorum), *Cassia siamea* (kasod), *Gmelina arborea* (khamer) and *Eucalyptus* hybrid (nilgiri) reported good growth on the skeletal soils.

Beneficiary of technology

Farmers, State Forest Departments and Municipal Corporations.

Impact of technology

Plantation of selected tree species is effective in reclamation of skeletal soils.

Barren skeletal soil

Restored skeletal soil

Eco-restoration of lateritic soils

Nature of technology

Suitable plant species screened for restoration of lateritic or bhata soils.

Technology in brief

Raising plantations at sites having huge gravels, low soil profile, hard soil devoid of nutrients and organic matter is a very critical process and the success rate is very low. Moreover, the growth of trees planted on such soils is less compared to normal soil. Experiments were conducted by planting eight tree species at Mana, Raipur of Chhattisgarh. Among different treatments, use of compost and vermicompost mixture and grass mulch, followed by application of 40g each of urea and single super phosphate were found to be effective for survival of the plantation. Periodic observation for growth *i.e.* height and girth and biomass of the plants after 4 years was recorded to screen tree species on the basis of their performance for plantation on lateritic soils. Six tree species *viz.*, *Gmelina arborea* (khamer), *Emblica officinalis* (avala), *Hardwickia binata* (anjan), *Dalbergia sissoo* (sissoo), *Albizia procera* (safed siris) and *A. lebbek* (kala siris) were screened on the basis of their growth on lateritic soils.

Beneficiary of technology

Farmers, State Forest Departments and Municipal Corporations.

Impact of technology

Plantation of screened species with proper amendments ecologically restored lateritic soils.

Before plantation

Lateritic soils after afforestation

Eco-restoration of iron mine overburden dumps

Nature of technology

Suitable plant species screened for restoration of iron mine overburden dumps

Technology in brief

Eco-restoration of mine overburden dumps is a major environmental concern, as when left to nature may take decades or centuries to develop any vegetation cover. Soils derived from Dallirajhara and Mahamaya iron ores of Chhattisgarh were used to conduct trials at TFRI nursery. During the experiment, 20 tree species were screened by growing in polybags filled with mined soil and cowdung mixture. Among various treatments, addition of grass mulch and use of 100ppm nitrogen and 25ppm phosphorous showed better growth in the seedlings. After regular observation of growth data, tree species viz. *Leucaena leucocephala* (subabool), *Sesbania sesban (augusti), Dalbergia sissoo (sissoo*), *Albizia lebbek* (kala siris), *Emblica officinalis* (avala), *Gmelina arborea* (khamer), *Eucalyptus camaldulensis* (nilgiri) and *Dendrocalamus strictus* (bans) showed better growth on iron mine overburden dumps.

Beneficiary of technology

Mining authorities, state forest departments and forest development corporations

Impact of technology

Overburden dumps of iron ore mines were biologically reclaimed through plantation of suitable tree species.

Barren overburden dumps

Restored site of overburden dumps

Eco-restoration of limestone quarries

Nature of technology

Suitable plant species screened for restoration of limestone quarries

Technology in brief

Limestone quarries cause environmental degradation by vegetation loss, soil depletion and deep alteration of original topography of the landscape. These quarries results in physical and chemical erosion of the substrate, which hinders natural germination and establishment of young plants, thus delaying re-colonization. Experiments were conducted using soil excavated from Kooteshwar, Barhi, Katni limestone mines at TFRI nursery. Polybags containing excavated soil and cowdung manure were used to grow 21 tree species for 8 months. Biological fertilizers like rhizobium, VAM, PBS mixture (20g each) were added per plant to enhance biological productivity and growth of the seedlings. *Acacia nilotica* (babool), *Dalbergia sissoo* (sisso), *Leucaena leucocephala* (subbul), *Jatropha curcas* (ratanjot), *Gmelina arborea* (khamer), *Eucalyptus hybrid* (nilgiri) and *Simarouba glauca* (simbarooba) performed better on the basis of survival and growth in the quarried limestone soil.

Beneficiary of technology

Mining authorities, State Forest Departments and Forest Development Corporations

Impact of technology

Plantation of selected species effectively restored limestone quarries.

Barren limestone quarrie

Restored site of limestone quarrie

Eco-restoration of copper mine overburden dumps

Nature of technology

Suitable plant species screened for restoration of copper mine overburden dumps

Technology in brief

Open cast mining causes alarming and extensive damage to the surface land by immediate destruction of flora and fauna and massive disfiguration of the landscape affecting ecological balance. Studies were carried out for biological reclamation of copper mine overburden dumps at Malajkhand (M.P.). Performance of 24 tree species was assessed by growing them in polybags containing mixture of overburden dump material and cowdung manure (1:2) at TFRI, Jabalpur. To enhance growth of seedlings Nitrin, Bactin and Phosphin1g/kg was applied to each plant. On the basis of survival and growth of plants, six tree species i.e. *Pongamia pinnata* (karanj), *Lagerstroemia parviflora* (ladiya), *Gmelina arborea* (khamer), *Albizia procera* (safed siris), *A. lebbek* (kala siris) and *Acacia catechu* (kher) were selected to biologically reclaim copper mine overburden dumps.

Beneficiary of technology

Mining authorities, State Forest Departments and Forest Development Corporations.

Impact of technology

Copper mine overburden dumps were biologically reclaimed through plantation of selected species.

Barren of copper mines

Restored site of copper mines

FOREST PROTECTION DIVISION

TFRI Trichocard

Nature of technology

Biological control of insect-pests through release of parasitoid

Technology in brief

To manage Teak defoliator, *Hyblaea puera* and teak leaf skeletonizer, *Eutectona machaeralis*, through biological means, entomologists of TFRI standardized mass-rearing technique and release methods of locally available parasitoid, *Trichogrmma raoi* (Hymenoptera : Trichogrammatidae). Through mass-culture technique, the eggs of rice moth were exposed to be parasitized by this parsitoid and parasitized eggs were pasted on paper cards, to be released in pest infested areas, when necessary. Each such card contains over 2000-2500 parasitized eggs and after release, defoliation of trees were reduced to 50%. It is recommended that the suggested number of parasitoids should be liberated in 4-5 instalments and the maximum number of wasps should be released in September to get the maximum protection of teak leaves. The easy to use technology "TFRI-TRICHOCARD" is available as disposable and biodegradable. Production, utilization of this card as well as releasing technique in the field are eco-friendly, safer, non-toxic and pragmatic method of management of teak pests over large forest areas, seed production areas (SPAs), seed stands, especially man made Teak Seed Orchards.

Beneficiary of technology

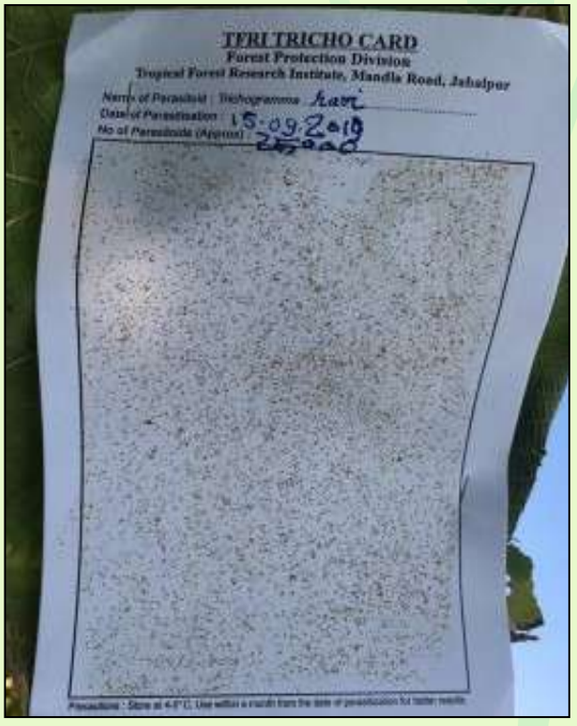
Madhya Pradesh, Maharashtra, Chhatisgarh Forest Departments, teak cultivation areas and nursery growers of central India.

Impact of technology

The species is now being remarkably used for biological management of teak leaf skeletonizer (*Eutectona machaeralis)* and teak defoliator (*Hyblaea puera*) in the teak plantations and forests @ Rs. 1.5 lakh/ha. The application of this agent has provided promising results with about 50% protection in defoliation, as compared to the unreleased sites and thereby minimizing annual incremental growth loss in teak stands.

Trichogrmma raoi

Trichoard on Teak Tree



TFRI Trichoard

FP-1

Application of *Arbuscular Mycorrhiza* and *Azospirilum* in nurseries for quality seedling production

Nature of technology

Suitable biofirtilizers for teak nurseries.

Technology in brief

Majority of tropical trees form Arbuscular Mycorrhiza (AM) association. Spores of AM fungi can be extracted from rhizosphere soil of desired tree species by wet sieving centrifugation and sucrose floatation technique. Spores sorted under a stereo-zoom microscope are introduced to mycorrhizal free trap plant. After mycorrhization the trap plants are transferred to a pot containing disinfected substrate to produce starter culture. Mycorrhizal roots of desired plant can also be used for isolation of AM fungi. Inocula of AM fungi are produced in bulk using specially designed cement concrete beds of 1 x 1 x 0.75m. The medium (soil, sand and FYM in 2:1:0.5 ratio) was sterilized by solar heating. The soil solarization was done during April-June for 21-30 days. The fine roots with hyphae of AM fungi and the rhizosphere soil with spores of the AM fungi is called the AM inoculum. 250g of Azospirilum and 5 kg inoculum of AM fungi (mixed in 5 kg vermicompost or finely grinded FYM) should be applied in polybags sown with seeds. To save the inoculum from desiccation poly bags should to be irrigated immediately. AM fungi enhanced seed germination and produced higher root colonization as compared to control.

Beneficiary of technology

State Forest Departments private nursery growers, etc.

Impact of technology

AM fungi helps in plant growth, increase disease and drought resistance. AM applied sapling establish better when out planted in the field. It would result in better growth and yield of plants.

Mixing of AM culture in FYM

Applying of AM and watering

Azospirilium culture

FP-2

Integrated Pest Management of white grubs in forest nurseries

Nature of Technology

Integrated Pest Management (IPM)

Technology in brief

White grubs, the larval stages of Scarabaeid beetles (*Holotrichia rustica*, *H. mucida*, *H. consanguinea*, *H. intermedia*, *H. problemetica* and *H. serrata* and *Schizonycha* etc) belongs to the order Coleoptera are pests which have potential of causing almost 100% mortality of teak seedlings during June to October. The onset of rainfall in presence of atmospheric relative humidity more than 50% triggers the emergence of beetles. The adults of white grub emerge out every day after dusk and disappear after dawn. The adults (beetles) feed on leaves of Ber (*Ziziphus jujuba, Z. mauritiana*), Ghont (*Z. xylopyra*), Khair (*Acacia catechu* and *A. leucophloea*), Palas (*Butea monosperma*), Sal *(Shorea robusta)* etc. They feed, mate and re-enter the soil in nursery beds before sun rise. This process is repeated during complete activity period of adults, i.e., 18-20 days, during which, every night 20 - 30 eggs are laid by each female, inside the nursery beds.

Under the concept of Integrated Insect Pest Management (IIPM), integration of all possible known methods are combined and exercised judiciously so as to minimize the use of chemical insecticides in terms of quantity as well as frequency to protect the nurseries in ecofriendly way. The integration of following techniques has led to the effective management of white grubs in the nursery.

Field survey in the nursery area is carried for selection of bushes of host plants to be selectively retained and used in 'trap and kill' mechanism at night preferably around 8:00 PM to 11:00 PM by physical killing. Nursery beds should be treated with phorate or methyl-parathion @ 200g/bed (10x1 m) or 300g/bed (12x1.25 m) as required. This would kill newly emerging white grubs from eggs, laid by the surviving adults. Insect light traps should be installed @ 1-2 traps per hectare for trapping and killing of beetles. The use of entomopathogenic nematodes were found effective for control of white grubs. These nematodes are natural parasites of the white grubs and other soil insects. The Tropical Forest Research Institute, Jabalpur has isolated and maintained the culture of six populations of such nematodes, belonging to families *Heterorhabditidae* and *Steinernematidae*. These can be used for the management of white grubs by releasing in the nursery beds @ 10 cadavers per bed (dose requirement may vary depending upon the grub population). All the methods should be applied in the proper supervision/guidance of the expert.

Beneficiaries of Technology

Forest Departments, Forest Development Corporations, nursery managers, researchers.

Impact of Technology

This technology is very effective in ecofriendly management of white grubs through Integrated Pest Management.

Beetle of *Holotrichia* sp. feeding on *Ziziphus* spp.

Eggs of white grub (adults)

White grubs collected from nursery beds

Teak seedlings mortality

Light Trap for beetle collection

Insecticide for beetles management


Piper betle

SILVICULTURE FOREST MANAGEMENT AND AGROFORESTRY DIVISION

Agri-lac culture model

Nature of technology

Agroforestry package of practice

Technology description

Lac is obtained from the insect *Laccifera lacca*. It is a resinous substance used for manufacturing of bangles, articles, toys, paint, varnish, CD cover, tailors chalk, fruit coating to maintain freshness. Agri-lac culture model is beneficial for the farmers who can utilize their farmland by intercropping of suitable agriculture crops *viz. Cajanus cajan (a*rhar*)* with lac. For cultivation of *C. cajan, s*eeds are sown in the espacement of 1.5mx1.5m during Kharif season (July) or onset of monsoon and preferably sown in line method. *Asha* variety of *C. cajan* (average yield 1 ton ha^{-1}) is suitable for this model, as good growth, yield and more branches will help for production of lac. For cultivation of lac, brood lac (seed lac) are inoculated on the soft shoots of *C. cajan* during Rabi season i.e. (October). The brood lac are kept in nylon bags to avoid enemy insect attack, depending upon weather condition and crop status. These net bags are tied with two side string parallel of new branches of *C. cajan*. The lac crop should be maintained by spraying of insecticide, if needed. The lac crop is ready to harvest within eight months i.e., during April for raw lac and in July as brood lac.

Economics of the model

Cost of cultivation	Rs. 80, 000 ha^{-1}
Total Income	Income from Agri crop- Rs. 1,00,000(1 ton ha^{-1} @ Rs. 100 per kg) Income from Lac crop- Rs. 2,40,000(12 ton ha^{-1}@ Rs. 200 per kg)
Net Return	Rs. 2, 60,000 ha^{-1}

Beneficiaries of the technology

Farmers, Self Help Groups (SHGs), NGOs, etc.

Impact of technology

Generally, lac is cultivated on the traditional lac host plants of *Butea monosperma* and *Ziziphus mauritiana.* integration of lac with agriculture crops not only helps the farmers to get additional income but also security against crop failure due to climate vagaries and insect/ pest attacks. Adoption of such high income agroforestry practice will increase the net farm income as a whole and also, increase the productivity and generate rural employment opportunities with less input. Farmers' can practice this model in their courtyard also. It would result in increased farm productivity as a whole.

Growing of lac on *Cajanus cajan* at SHGs farm at Jabalpur

Babul-paddy agroforestry model

Nature of technology

Agroforestry package of practice

Technology description

The system consists of agriculture crop-paddy (*Oryza sativa)* variety JR-75 *(*78 days crop*)* intercropped with tree babul (*Acacia nilotica* wild ex. Del var. indica (telia).) Well grown Babul seedling raised in nursery are transplanted in the field during rainy season before paddy transplantation. The system prefers sodic and alkali soils with pH of 7-8. Though babul is leguminous tree but it can adapt well to all range of pH where paddy is grown. Babul trees should be planted @ 5m x 5 m spacing (400 trees ha^{-1}). The trees are pruned initially to promote the formation of clean straight bole and root pruning of babul tree results in higher crop yield. Farmers will get interim annual income from pruned biomass from 3rd year onwards and on an average 1.60 kg $tree^{-1}$. The babul-paddy system have a benefit cost (B:C) ratio of 1.47 (over the period of 10 years). During the period, babul provides a variety of products such as fodder, fuel wood (30 kg $tree^{-1}$), brushwood for fencing (4 kg $tree^{-1}$), small timber for farm implements and furniture (0.2 cu. m) and non timber forest products such as gum. The yield of paddy obtained under this model is about 2.5 ton ha^{-1} as against 1.5 ton ha^{-1} from traditional varieties. The total net income from the system is Rs. 3.0 lakhs over a ten year period per ha. (benefit from paddy for 10 years, interim benefits from babul and final benefit may be quantified).

Economics of the model

Total Expenditure	Rs. 0.70 lakhs ha^{-1} (inclusive of field operations)
Net Income	Rs 3.0 lakhs ha^{-1}

Beneficiaries of the technology

Farmers.

Impact of technology

By adopting the babul-paddy agro-forestry system, farmers get higher returns compared to paddy monoculture. The babul-paddy model is a good insurance against failure of monsoon or climate vagaries.

Babul-paddy model

Traditional babul-paddy retaining in farmland of Chhattisgarh

Bach-paddy agroforestry model

Nature of technology

Agroforestry package of practice.

Technology description

This model is beneficial for those paddy growers who can utilize their waterlogged land by intercropping of commercially valuable medicinal plant *Acorus calamus* (bach) commonly known as sweet flag. Bach is a perennial aromatic herb, grows up to 2 m height with branched rhizomes and is used to cure cough and cold, improve nervous system and also for respiratory disorders like bronchitis. This system is suitable for water logged areas having clay, black cotton soils.

For planting rhizomes of bach plants should be cut into the small pieces of 4-5cm length having two internodes. Approximately 1 lakh rhizomes pieces are required for planting in 1ha. The cuttings should be sown in the soil up to 4-5 cm depth during the month of May and sprouting starts after 15-20 days. The sprouted material transplanted to the main rice field during 2nd week of July-August at 30cm x 30cm spacing. About 10 tonnes of FYM is necessary for one hectare. It should be applied 1/4th of quantity (2 tonnes) as basal dressing, half of the quantity (6 tonnes) after two months and remaining 1/4th quantity (2 tonnes) after six months of planting. Harvesting should be done after 10 months of planting with paddy crop. The approximate yield of bach rhizome is about 3.5 ton ha^{-1} of dried rhizome and the market price is about Rs. 70–80 kg^{-1}).

Economics of the model

Total Expenditure	Rs.1,20,000 (inclusive of field operations cost of planting material, preparation of field, FYM, Wages)
Income from paddy	Rs. 50,000
Income from Bach plants	Rs. 2 lakhs
Net Income	Rs 1.30 lakhs

Beneficiaries of the technology

Farmers.

Impact of technology

Bach-paddy agroforestry model having the potential to provide additional net farm income to farmers' and one of the best model for 'Doubling the farm income' in short rotation period. In addition, through this model waterlogged area can be utilized efficiently and effectively. This model can be up scaled through training programmes to farmers, extension materials, farmer to farmer interaction and on-farm field visits.

Paddy with bach

Rhizomes of bach under bach-paddy model

Bamboo based silvi-agri model

Nature of technology

Agroforestry package of practice

Technology description

This model is beneficial for the farmers who can utilize their land by intercropping of various suitable agriculture crops especially with urad (*Vigna mungo)* and wheat (*Triticum aestivum)* in a crop rotation mainly to improve soil fertility and water conservation purpose with bamboo for additional income from bamboo. This model will perform better in well drained sandy soil condition with optimum irrigation during its early period (up to 3 years). For bamboo farming, high yielding thornless bamboo species *viz. Bambusa nutans, B. balcooa, B. tulda, B. vulgaris,* etc. are highly suitable. Vegetative propagated plantlets of bamboos should be preferred for best survival and easy establishment in the main field. Bamboo plantlets (400 plantlets ha^{-1}) should be planted @ spacing of 5 x 5 m after making pits size of 45 cm^3 during the onset of monsoon. Bamboos are managed by timely pruning of the culms from 2^{nd} year onwards to avoid the congestion within the culm/clump and to maintain a healthy growth to fetch better returns. Generally, bamboo is ready to harvest from 5^{th} year onwards under monoculture but in agroforestry, it is ready to harvest after 4^{th} year as it is benefitted from the various inputs given to annual crops. Bamboo harvesting should be started during March-April month i.e. before onset of monsoon, 6 -7 culms per clump may be harvested subject to condition of clump. For Agri crop cultivation, variety 306 of wheat (average yield of 0.16 t ha^{-1}) and *Jawahar* urad (average yield 0.10 t ha^{-1}) is recommended. Further, farmers can grow other annual crops also (up to 5 years) as per their choice, till the canopy closes. Weeding should be done three times during each cropping period to get maximum production from annual crops.

Economics of the model

Total Expenditure	Rs. 96,000 ha^{-1} (inclusive of field operations)
Income from Urad and Wheat	Urad - Rs. 40,000 ha^{-1}, Wheat - Rs. 70,000 ha^{-1}
Income from bamboo poles	Rs. 2 lakhs ha^{-1} @ Rs. 100 per culm = 2000 culm (first harvest after 4 years)
Net Income	Rs. 2.14 lakhs

Beneficiaries of the technology

Farmers and State Forest Department

Impact of technology

Bamboo-urad/wheat agroforestry model has potential to provide additional income in a sustainable manner and this model will fulfill the government goal of 'Doubling the farm income' within short rotation period of 5 years. Further the model generates rural and women employment opportunities throughout the year. In addition, this model improves soil fertility by arresting soil erosion and increase the overall productivity.

Bamboo with urad model

Bamboo with wheat model

Flemingia based Silvi-agri-lac model

Nature of technology

Agroforestry package of practice

Technology description

This model is beneficial for the lac growers especially farmers' who are not having traditional lac host trees like *B. monosperma* (palash) or *S. oleosa* (kusum) in their field bunds. *Flemingia semialata* Roxb. is a bushy leguminous plant and proved as a good host to kusumi strain of lac. *F. semialata* plants are ready for inoculation with broodlac within a year after its planting and framers' can maintain this model and get lac upto 8 years. This system will perform better under well drained sandy loam soil condition. Since the *Flemingia* plants are fast growing in nature and having narrow crown, hence farmers' can utilize its interspaces by growing traditional agriculture crop like *Cajanus cajan* for their regular income. Seeds of *F. semialata* should be sown during the month April in poly bags with 1:1:1 ratio of soil, sand and FYM mixture and the seedlings will be ready for the transplantation during rainy season (after 2-3 months). Healthy seedlings should be preferred for best survival and easy establishment. Land should be ploughed and FYM may be applied (10 ton ha^{-1}) as basal dressing in the month of May. *Flemingia* seedlings (625 plants ha^{-1}) should be planted @ spacing of 4m x 4m after making pits size of 45 cm^3 during the onset of monsoon. Soil surface along the pit should be treated with chloropyriphos (2g l^{-1} solution) to control termite attack before rainy season. After one year of planting, plants are ready to raise good quality of broodlac during rabi season is the best time for its cultivation. For lac farming, good quality broodlac should be selected by the farmer to get maximum yield. Farmers' can select healthy, soft, disease free shoots for the infestation of Broodlac (@40g plant $^{-1}$). *F. semialata* plants should be pruned from its tip to maintain height up to 1.5m for easy cultural operations like weeding, ploughing, etc. and to protect it against heavy wind during summer season. This system performs better in well drained soil condition with optimum irrigation during its early period first 2 years. For agriculture crop cultivation, seeds of *Cajanus cajan* (*Asha* variety) can be sown during July @75cm x 75cm spacing in between *Flemingia* plantation. Weeding should be done three times to get maximum production. Light irrigation will require during October onwards weekly interval depending upon the site and weather condition.

Economics of the model

Total Expenditure	Rs. 75,000 ha^{-1} (inclusive of field operations)
Income from Lac and Arhar in mono culture	Lac (Rs. 1,00,000 ha^{-1}) or arhar (Rs.1,00,000 ha^{-1})
Income from *Flemingia* based system	Rs. 1.25 lakhs yr^{-1} ha^{-1}

Beneficiaries of the technology

Farmers and women SHGs.

Impact of technology

TFRI has introduced first time this lac host species in tropical region of Madhya Pradesh to explore the possibilities of lac culture on *Flemingia* under Agroforestry model with agriculture crop *C. cajan.* It has become popular among the lac growers due to its short period of maturity (within two years). This model is able to generate income as well as rural employment throughout the year as compared to traditional farming.

One year old *Flemingia* plants

Inoculation of broodlac on *Flemingia*

Emergence of lac insects

Settlement of lac insect on *Flemingia*

Lac crop on *Flemingia*

***Flemingia* and *Cajanus* based agroforestry model**

Teak-turmeric silvi-medicinal model

Nature of technology

Agroforestry package of practice

Technology description

This model is beneficial for the teak *(Tectona grandis*) growers, who can utilize inter-spaces of teak plantations by growing these turmeric i.e. *Curcuma longa* to get periodical income. This model will perform better in well drained sandy soil with optimum irrigation during its early period (first 2 years) and not suitable under clay, black cotton soil and water logged areas which affect teak growth. One year old root-shoot (stump) of teak should be preferred for better survival and easy establishment @2m x 2m spacing . Suroma variety of turmeric grown at (45cm x 45cm)with average yield 3.5 ton ha^{-1} is used as intercrop. Turmeric is partial shade loving crop and require moist condition which favours more yield. Adoption of this would provide additional income to farmers by using the natural resources in optimum way. Timely pruning (25% intensity) of teak branches is required to get straight stem. Yearly two times weeding is necessary. Intercropping is possible for 8-10 years. Teak trees will be felled/harvested in the age of 10-12 years for pole purpose (average height of 11m and 55-60cm girth, @ Rs.1250 per pole) and in 20 years for timber purpose (Av. height 16m and girth of 80cm, @ Rs. 2000 per pole).

Economics of the model

Total Expenditure	Rs.1.50 lakhs ha^{-1} (inclusive of field operations)
Net Income	Rs 6.80 lakhs ha^{-1}

Beneficiaries of the technology

Farmers and State Forest Department.

Impact of technology

Teak-turmeric based agri-silvi model gives risk free farming to farmers, sequester more carbon and enhances overall productivity which ensures higher net farm income.

Teak turmeric silvi-medicinal model at TFRI, Jabalpur

Processing and storage of fruits/seeds of *Celastrus paniculatus, Embelia tsjeriam - cottam* and *Terminalia bellerica*

Nature of technology

Processing and storage techniques

Technology in brief

Improper processing and storage of medicinal plants or their plant parts lead to rapid deterioration of bioactive constituents. The magnitude of such deterioration is influenced significantly by nature of collection, processing and storage conditions of plant materials. As per WHO guidelines, medicinal plant materials must be processed well and stored under specified conditions in order to avoid contamination and deterioration. The seeds of malkangni *(C. paniculatus)*, fruits of vaividang *(E. tsjeriam-cottam)* and baheda *(T. bellerica)* are important herbal medicines and their demand in national and International market is approximately 200-500 MT, 500-1000 MT and 2000-5000 MT per annum respectively. These are among the highly traded medicinal plant species. Therefore, processing and storage techniques of these valuable species has been standardized. Malkangni seeds should be washed in water and dried before storage to avoid the infestation of curculionid seed borer insect pests. Dried fruits of baheda should be depulped and stored. Sun drying proved better in comparison to shade drying and hot air drying to maintain quality of fruits/ seeds of selected species. Seeds of malkangni, vaividang and pulp of baheda fruits can be stored safely for six months without loss of oil, embelin and gallic acid contents respectively. Further thick gage (high density) polythene bags should be used for storage purposes to minimise quality loss.

Beneficiaries of the technology

State Forest Department, pharmaceutical industries, medicinal plants traders, food industries and other stakeholders.

Impact of the technology

The standardized techniques for *C. paniculatus, E. tsjeriam-cottam* and *T. bellerica* can be utilized for the proper processing and storage of their seeds/ fruits/ pulp and to maintain the quality of raw materials, thereby leading to economic benefits.

Embelia tsjeriam-cottam **(Vaividang) Seeds**

Celastrus paniculatus **(Malkangni) Seeds**

Processing of ***Terminalia bellerica*** **(Baheda) fruits**

Agro-techniques for cultivation of medicinal plants

Nature of technology

Package of practices

Technology in brief

The Indian system of medicine use medicinal plants as the main raw material. Something should be related to demand of popularity. The resource pool of the medicinal plant in forest is dwindling fast due to anthropogenic pressure. The increasing demands of medicinal plants cannot be met sustainably through natural resources. Therefore, the best alternate is to promote cultivation of medicinal plants outside forests. Agro-techniques for the cultivation of some important medicinal plants of central Indian region are as follows:

S. No.	Name of species	Common name	Suitable Soil type	Cultivation practices
1.	*Andrographis paniculata*	Kalmegh	Sandy loam to clay-loam Soils	It can be easily raised through seeds in commercial cultivation. Seeds are soaked in water for 24hours and sown in raisen beds in May-June. 10cm-15cm long seedlings raised in the nursery beds during June-July are transplanted in the main field at a distance of 15cmx30cm between plant to plant and row to row. The crop matures after 120-150 days of sowing. It is harvested 10cm-15cm above the ground when most plants are in bloom.
2.	*Aloe barbadensis*	Ghrit kumari	Sandy calcareous soil /loamy soil	It can be cultivated by small rhizomes. Plantation should be done in July-August at a distance 30cmx45cm between row to row and 30cm between plants to plants. Mature leaves can be harvested at 3 months time interval after the 15 months of crop maturity.
3.	*Gloriosa superba*	Kalihari	Loamy and Red loamy soil	It can be cultivated by seeds and rhizomes having weight approximately 50-60gm. Rhizomes should be treated with 0.1% fungicide and should be planted in rainy season optimum spacing is 50cmx50cm and 45cmx45cm between row to row and rhizome to rhizome respectively. The crop matures in 170-180 days. Fruits are plucked and seeds are separated and dried in shade.
4.	*Gymnema sylvestre*	Gurmar	Sandy loam soil	Terminal and axillary cuttings with three to four nodes are the best planting materials. Polybags are filled with soil, sand and FYM in 1:2:1 ratio and terminal or axillary cuttings are planted in them during January - February. The period between July and August is best for transplanting the rooted plants in the field. At an optimum spacing of 1m × 1m^2 leaves can be harvested in first year itself and yield increased continuously with time. Leaves can be harvested two times in a year i.e. September-October and April-May.
5.	*Plumbago zeylanica*	Chitrak	Deep sandy loam to clay-loam soil	Chitrak can be cultivated through stem cuttings or seeds. Nursery is generally raised through stem cuttings in March–April, three to four months before planting in the field in July. Crop becomes mature in 10 - 12 months and roots can be dug out after one year preferably in month of June.
6.	*Rauvolfia serpentina*	Sarpagandha	Loamy soil, Red loam soil and Black soil	It can be cultivated by seed and also through the stem cutting and root suckers. Seed sowing should be done in month of April - May with an optimum spacing 45 cm. Crop becomes mature within 18 months and roots can be harvested in January.
7.	*Strychnos potatorum*	Nirmali	Red alluvial soil	Seed is the best propagation material for growing the crop. The seedlings are raised in polybags during February–March. The seedlings are transplanted at the plantation site during June–July at an optimum spacing of 5m × 5m. It has a long span of life, that is, 50–60 years. It takes about 15-20 years for the tree to initiate flowering. The seeds are collected in December onwards when they become mature.

S. No.	Name of species	Common name	Suitable Soil type	Cultivation practices
8.	*Tinospora cordifolia*	Giloe	Medium sandy loam soil	Stem cuttings are the best planting material for raising commercial crop. The cuttings can be obtained from mother plants in June–July. The stem cuttings with nodes are sown directly in the field with an optimum spacing of 3m×3m. The stem is harvested during January –March. Basal part is left for further growth.
9.	*Curcuma angustifolia*	Tikhur	Sandy Loam soil	Germinated rhizomes should be cut into many segment. Segment having buds should be planted in the raised beds in field with spacing of 20-30cm in the month of July. Pit depth should be not be more then 5-10cm Rhizomes can be harvested in February- March after leaf fall.
10.	*Withania somnifera*	Aswagandha	Red, Sandy, Black and Loamy soil	The seeds are sown directly in the field by broadcasting in second week of July to August. The seedlings after 25-35 days are transplanted in distance of 20-25 cm to 10-15 cm row to row and plant to plant respectively. Harvesting starts from January-March i.e. 150 to 180 days after sowing.

Beneficiaries of the technology

Farmers, State Forest Department, Pharma Industries, Village Forest Committee (VFCs), State Forest Management Center (SFMCs), Non Government Organization (NGOs).

Impact of the technology

The cultivation of medicinal plants will not only fulfill the demand but also uplift the economic status of the stakeholders and help in conservation of the species in wild.

***Andrographis paniculata* (Kalmegh)**

***Gymnema sylvestre* (Gurmar)**

***Tinospora cordifolia* (Giloe)**

***Rauvolfia serpentina* (Sarpagandha)**

***Curcuma angustifolia* (Tikhur)**

Value addition of underutilized fruits of *Schleichera oleosa*

Nature of technology

Processing and value addition

Technology in brief

Schleichera oleosa (Lour.) Oken., commonly known as kusumi lac tree or kusum, is a forest tree species of tropical and subtropical region. The fruit pulp of *S. oleosa* is edible. Raw fruits are reported to be pickled and the ripe yellowish fruits, with sour pupl is often eaten during the summer. Pulp of fruit is used to cure heat stroke, as digestive, as appetite stimulant, as astringent, as antihelmintic, it is also given to dilute the excess consumption of alcohol and has cooling properties. Fruit juice has also been reported to stimulate hair growth. In Ayurveda, the pulp of the fruit is also reported to have Keshavardhaka, Vatanashaka, Snigdha and Kaphanashaka properties. NWFP division section of TFRI developed the technique for processing, storage, utilization and development of value added products viz. kusum vati, kusum jam, kusum sauce, kusum thandai, kusum squash, kusum sharbat and kusum murabba from pulp of *S. oleosa* fruits for the stakeholders especially rural and tribal communities. From socio-economic point of view; this fruit can be widely enjoyed for edible purposes for months after converting it into various value added products.

Beneficiaries of the technology

Village Forest Committee (VFCs), State Forest Management Center (SFMCs), State Forest Departments (SFDs), food industries, tribals and villagers.

Impact of the technology

The technique will help the rural and tribal communities in getting additional source of nutrient rich food as well as in generating income on a sustainable basis.

Kusum fruit

Kusum pulp

Value added products from kusum pulp

Sustainable harvesting practices of Non Timber Forest Produce

Nature of technology

Package of practices

Technology in brief

In recent years, there has been tremendous increase in interest of plant based medicines worldwide. With the commercialization of traditional systems, the demand of medicinal plants produce has gone up exponentially. To meet the burgeoning demand, supply chain of medicinal plants became a multi stakeholders activity. In the process, the principles of sustainability which were intrinsic part of traditional systems got overlooked. This has resulted in overexploitation, habitat loss, threat to plant species and even extinction. The sustainable harvesting practices of medicinal plants hold great potential as a method for integrating the use and conservation of tropical forests.

S. No.	Name of species	Common name	Part used	Time of harvesting	Technique of harvesting
1.	*Terminalia arjuna*	Arjuna	Stem bark	Any season except rainy	Blazed 1/3 or 1/4 part of the total girth of the tree. The same part should not be blazed again for almost 2 years
2.	*Litsea glutinosa*	Maida chhal	Stem bark	Any season except rainy	
3.	*Saraca asoca*	Ashoka	Stem bark	Any season except rainy	
4.	*Holarrhena antidysenterica*	Kutaj	Stem bark	Any season except rainy	Harvesting through longitudinal or alternative strips
5.	*Tinospora cordifolia*	Giloy	Stems	December and January	Cutting of the stem 30 cm above the ground with the help of sickle
6.	*Gymnema sylvestre*	Gurmar	Leaves	September-October and April-May	60% of the leaves can be plucked at a time
7.	*Andrographis paniculata*	Kalmegh	Whole plant	November-December	Harvesting must be done by uprooting the plants while leaving 10-15% plants for seed production
8.	*Asparagus racemosus*	Shatavari	Roots	December-January	Digging of rhizomes, around 50 cm radius and 30-45 cm deep
9.	*Cyprus scariosus*	Nagarmotha	Roots	December-January	Harvesting must be done by uprooting the plants. However, approx. 20% of the plants must be left for regeneration.
10.	*Terminalia bellirica*	Baheda	Fruits	January-February	Fruits are collected by shaking the branches of the trees with the help of bamboo stick or hands. An agro net or tarpaulin or similar material should be fixed at least 30 cm above the ground. Fruits can also be plucked by hands. 10% of the fruits must be left on tree for regeneration.
11.	*Terminalia chebula*	Harra	Fruits	December-January	
12.	*Phyllanthus emblica*	Amla	Fruits	December-January	

S. No.	Name of species	Common name	Part used	Time of harvesting	Technique of harvesting
13.	*Rauvolfia serpentina*	Devilpepper/ Sarpgandha	Roots	December-January	Digging of roots. Irrigation must be done in field before digging of the roots. However, some part of roots should be left in the field for reproduction
14.	*Embelia tsjeriam-cottam*	Vaidiang	Fruits	November-December	Fruits should be collected by hand-plucking, not by cutting the branches. Approx. 10% of fruits should be left on the shrubs for reproduction
15.	*Buchanania lanzan*	Achar/ Chironji	Fruits	April-May	The trees or its branches should not be disturbed or cut while harvesting the fruits. Agro net or polythene sheet or other similar material should be spread under the trees. After that the branches of the trees should be shaken with the help of bamboo stick or by hand.
16.	*Bauhinia vahlii*	Mahul patta	Leaves	June-July and November - January	Only 50-60% harvesting of leaves twice in a year without damaging the climbers is recommended to get the superior quality as well as progressive recruitment of leaves in natural forest areas. The harvesters should be encouraged to pluck leaves with the help of bamboo stick attached with plucking device or sickle or hand plucking wherever plant height is less and leaves are approachable.
17.	*Phyllanthus amarus*	Bhui-aonla	Whole plant	October	80% plants should be harvested (when fruiting initiates) to maintain sustainability
18.	*Desmodium gangeticum*	Sal-parni	Roots	December	60% plants should be dugup for roots harvested from collar level.
19.	*Dioscorea hispida*	Baichandi	Tubers	December-January	50% tubers can be harvested and 50% left for maintaining sustainability.

Beneficiaries of the technology

State Forest Department, Pharma Industries, Village Forest Committee (VFCs), State Forest Management Center (SFMCs), tribals, farmers and NTFP gatherers.

Impact of the technology

The utilization of sustainable harvesting practices will provide a new dimension to the sustainable management of NTFPs, ensure the continuous and sustainable supply of raw materials to the industries and finally lead to the conservation of these valuable resources. Besides, these will also generate employment opportunities and additional source of income to the stakeholders.

Non-destructive harvesting of *Terminaila arjuna*

Non-destructive harvesting of *Asparagus racemosus*

Non-destructive harvesting of *Rauvolfia serpentina*

Seed handling techniques of some economically

Nature of Technology

Seed handling, propagation and storage

Technology in brief

Standardized protocols for germination, collection, processing, testing and long-term storage of seeds are given as follows:

Scientific Name	Family	Flowering	Fruit maturity season	Seed processing	
Hardwickia binata	Fabaceae	July-September	April-May	The fully matured pods may be dried by placing them under sun for extraction of seeds. Seeds are then cleaned by seed blower or by winnowing.	
Emblica officinalis	Euphorbiaceae	March-May	February-April	Fruits are soaked in water for few days till the pulp softens, then macerated gently by pounding them in a mortar with a pestle to remove the pulp	
Terminalia arjuna	Combretaceae	April-July	February-May	Fruits are dried in the shade.	
Pterocarpus marsupium	Fabaceae	June-November	December-March	The seed wings are clipped off the fruits with the help of scissor to facilitate sowing operation.	
Holoptelea integrifolia	Ulmaceae	February-March	April-May	The papery wings are removed by rubbing between hands and the seeds are cleaned by winnowing or by seed blower.	
Terminalia chebula	Combretaceae	February-March	May-November	The fruits are soaked 24-48 hrs in water and the pulp is removed by macerating the fruits and washing thoroughly under water, clean seeds are then dried under shade.	
Pongamia pinnata	Fabaceae		March-May	Seeds are extracted from pods by light hammering by pressing with knife along the sutures to break them open.	
Sterculia urens	Sterculiaceae	December-March	April	The collection method is to spread a tarpaulin under the tree and collect the fruits by lopping the branches or plucking.	
Schleichera oleosa	Sapindaceae	February-April	June-September	The fruit pulp must be removed before storage, either by hand or by depulper.	

Beneficiary of the technology

State Forest Department, Farmers, NGOs etc.

Impact of technology

Production of quantity planting material and *ex-situ* conservation of species.

	Seed Moisture content	Pretreatments for germination	Germination	Seed storage behaviour
	10-12%	Nil	80-100%	Orthodox type: >5years at 0-20°C. > 2years at ambient temperature (15-46°C) with 10% moisture content.
	20-25%	Seed exposed to GA3 500ppm for 24hours resulted better germination.	85%	Orthodox type: >6years at low temperature (-20°C to 15°C, 4-12%). moisture content. Viability of seeds declines after two years of storage at ambient condition at any moisture content.
	30-40%	Seeds are soaked in Indole-3 acidic acid (IAA) at the dose of 500 ppm induce better germination capacity	50-75%	Orthodox type :> 5 years at 0 to -20°C with low moisture content. Even hermetic storage at room temperature (15-35°C) with 5% moisture content retains their viability up to 2 years.
	20-25%	Nil	60-95%	1 year viability at ambient temperature (15-35°C). > 3 years at 15°C to -10 C and 4-5% moisture content.
	12-16%	Nil.	60%	> 5years at 15°C to -20°C and 3-5% moisture content. At room temperature viability of seed can be extended up to one year, if stored at 3-5% moisture content.
	10%	Soaking and drying for 5-7days	66.7%	> 5years at 0 to -20°C, 4-5% moisture content. At ambient temperature (15-35°C, 4-5% moisture) seed viability can be maintained upto two years.
	14.32%	Nil	80%	> 5years at ambient temperature (15-35°C) and moisture content of 4-5%.
	45-50%	Seeds are filled in cloth bag and rubbed to remove the two layers, and then the seeds are washed and dried in shade.	88%	2 years at 4-8% moisture content. Seed viability can be maintained upto 3 years at 15, 5 and -0°C.
	20-25%	For optimum germination the seeds are clipped at the opposite end of the embryo and then soaked in 500 ppm of GA3 overnight.	80-85%	>1year at -20 to 15°C temp, 5-7% moisture content. Viable upto one year at ambient temperature 15-46°C, 5-7% moisture content

Seed handling techniques of some economically

Scientific Name	Family	Flowering	Fruit maturity season	Seed processing
Madhuca indica	Sapotaceae	March-April	June-August	Seeds are separated from the seeds by rubbing the fruits manually and thorough washing.
Sapindus laurifolius	Sapindaceae	October - December	February-May	Fruits are spread and dried in Sun. Seeds are then separated by gentle cracking of the fruits and removing the partially fused carpels
Boswellia serrata	Burseraceae	January-March	May-June	Seeds are extracted from the dry ripe fruits manually and wings are removed by rubbing between hands and then cleaning can be done either by winnowing or by a seed blower.
Mitragyna parvifolia	Rubiaceae	May-July	April-May	Fruits are dried in shade. They are then pounded by a thin piece of wooden board to break the capsules and release the seeds. The light brown seeds are then separated from chaff and other fruit parts by sieving and winnowing.
Haldina cordifolia	Rubiaceae	June-September	March-May	After collection fruits are spread on concrete floor and dried under sun covering a layer of tendu leaves for 7 to 10 days. The capsules open after drying and reddish brown seeds are shed. Seeds can also be extracted manually by pressing between palms. They are sieved to remove the chaff.
Kavalama urens	Malvaceae	December-March	April-May	After collection seeds should be extracted from the fruits and white and brown seeds should be discarded just after collection. After extraction, black and grey seeds should be dried under shade
Desmodium oojeinense	Fabaceae	February- May	May-June	Seeds can be extracted from the pods by thrashing and subsequent cleaning by winnowing or by seed blower.

***Pterocarpus marsupium* seeds**

***Madhuca longifolia* seeds**

***Hardwickia binata* seeds**

Germination of *P. marsupium* seeds

Germination of *B. serrata* seeds

	Seed Moisture content	Pretreatments for germination	Germination	Seed storage behaviour
	40-45%	Nil	80-100%	Viability up to 5 months at 28°C in sealed polythene bags with shedding moisture content of 40-41%.
	10%	Soaking in cold water for overnight	60-70%	Orthodox: High viability at 0 to-20°C, 3-5% moisture content. Viability up to 2 years at Seed stored at 15-35°C, 8% moisture content. >5years at 0 to -20°C, 4-5% moisture content.
	15-20%	Seeds should be immersed in water before they are sown	20-90%	Orthodox: In ambient conditions at 15-37°C upto one year; viability can be extended for more than three years, if stored at low temperature (-20°C to 15°C) with wide range of moisture content (4-11%).
	30-35%	Nil	60-70%	The viability of seeds of *Mitragyna parviflora* can be maintained up to one year at ambient temperature if stored at 3-5% moisture content. The seed are viable for more than 2 years at 15 to -20 °C if stored at 3-5% moisture content
	40-45%	Nil	50-60%	Viability can be maintained at ambient temperature for up to one year if stored at 3-5% moisture content and can be extended up to more than five years if stored at low temperatures (15 °C to -20°C).
	40-45 %	Seeds are filled in cloth bag and rubbed to remove the two layers, and then the seeds are washed and dried in shade.	80-100%	Seeds will remain viable at least for 2 years, if stored 4-8% moisture content at ambient temperature.Seed viability can be maintained more than 3 years at 15°C or below. In moisture content 10% and above, seed germination decreased if stored above 15°C
	50-55%	Nil	90-100%	Viability can be maintained for more than five years if stored at low temperatures (15°C to -20°C) and 3-5% moisture content and in ambient condition the seeds can be viable for two years, if moisture content is maintained at 4-5%.

Germination of *H. integrifolia* seeds

Schleichera oleosa **seedlings**

Terminalia arjuna **seedlings**

Sapindus laurifolia **seedlings**

LIST OF COMPLETED PROJECTS

GENETICS AND TREE IMPROVEMENT DIVISION	
1	Vegetative propagation and tree physiology: development of a procedure for root surface area measurement
2	Vegetative propagation and tree physiology: developing vegetative propagation techniques for forestry species (*Dalbergia sissoo* and *Pongamia pinnata*)
3	Vegetative propagation and tree physiology: developing vegetative propagation techniques for *Bambusa vulgaris var. striata* and *Dendrocalamus strictus*
4	Genetics and breeding of forest tree species: genetic analysis of teak clones of Maharashtra origin
5	Development of tissue culture protocols for important forestry species: *Dendrocalamus asper*
6	Development of tissue culture protocols for important forestry species : *Bambusa bambos*
7	Developing tissue culture protocols for forestry species : *Dendrocalamus membranaceus*
8	Developing tissue culture protocols for forestry species : *Bambusa nutans*
9	Development of tissue culture protocols for forestry species : *Dendrocalamus giganteus*
10	Genetics and breeding of forest tree species : studies on inheritance pattern in teak of south Indian origin
11	Development of an improved method for selection of seed stands for conversion into seed production areas
12	Vegetative propagation and tree physiology: development of vegetative propagation techniques for forestry species (*Albizia procera* and *Azadirachta indica*)
13	Genetics and breeding of forest tree species : genetic evaluation of teak of Orissa origin
14	Genetics and breeding of forest tree species : genetics of seed and seedling characters in *Albizia procera*
15	Vegetative propagation of forestry species : evolving vegetative propagation technology for teak *(Tectona grandis)*
16	Developing tissue culture protocols for forestry species : Micropropagation of *Dendrocalamus strictus*
17	Developing tissue culture protocols for forestry species: Micropropagation of *Bambusa vulgaris* and *Kaempferia galanga*
18	Screening populations of *Dalbergia sissoo* for tolerance to salt and water stress using physio-morphological and biochemical criteria
19	Studies on cataloguing the genetic variation in Teak species (*Tectona grandis* and *Tectona hamiltonaii*) using molecular markers
20	Developing tissue culture protocols for forestry species *Tectona grandis*
21	Developing tissue culture protocols for forestry species *Gmelina arborea*
22	Studies on carbonic anhydrase and its relationships with photosynthesis and productivity in teak (*Tectona grandis*)
23	Studies on inheritance pattern of selected wood traits in teak (*Tectona grandis L.*)
24	Studies on differential adventitious rooting response vis a vis clonal propagation of economically important forestry species
25	Investigations into the nature of inheritance and breeding of teak
26	Studies on refinement and scaling up of existing micro-propagation and macro-propagation technologies for *Bambusa nutans* and *Bambusa tulda*
27	Evaluation and prediction of oil bearing capacity of Sandal (*Santalum album* L.) germplasm using physio-morpho-molecular marker
28	Molecular characterization of *ex-situ* conserved germplasm and identification of molecular marker associated with wood quality traits in *Tectona grandis* L.
29	Varietal improvement of *Rauvolfia serpentina* and *Tinospora cordifolia* through germplasm selection evaluation and breeding
30	Studies on in vitro regeneration of plantlets and their genetic (molecular) fidelity in *Saraca indica* L., a vulnerable medicinal tree

31	Studies on endogenous auxin level and its relationship with adventitious rooting potential in *Dalbergia latifolia* Roxb.
32	Genetic variation for in vitro morphogenetic potential of *Dalbergia sissoo* Roxb. clones and evaluation of their field performance
33	Counter balancing the detrimental effect of Sponge Iron Factory-emitted Particulate Matters (SIFPM) with the protective effect of *Vesicular Arbuscular Mycorrhiza* (VAM) on the growth of seedlings of important tree species
34	Studies on development of in vitro regeneration system for *Albizia procera* (Roxb.) Benth
35	Development of methodology and parameters for selection of superior genetic plants of five NTFP species
36	Studies on variation in reserpine content in some high yielding genotypes of in vitro and seedling raised *Rauvolfia serpentina* Benth
37	Studies on variations with respect to in vitro azadirachtin production in selected high yielding populations of *Azadirachta indica A. Juss.*
38	Technology to regenerate/multiply mahul patta (*Bauhinia vahlii*) for getting higher production
39	Studies on assessment of genetic diversity and structure of *Boswellia serrata* Roxb. populations through RAPD and ISSR molecular markers
40	Genetic improvement of *Buchnania lanzan* Spreng.
41	Collection of germplasm of *Madhuca indica* J.F. Gmel for identification of best sources in Chhattisgarh through phytochemical evaluation
42	Standardization of technique to enhance the quality and sustainable production of *Diospyros melanoxylon* leaves in Chhattisgarh
43	Collection and morphomolecular characterization of critically endangered *Litsea glutinosa* germplasm from M.P. and Chhatisgarh
44	Genetic improvement of *Dalbergia latifolia* Roxb. through selection and evaluation of germplasm in central India
45	Bamboo genetic evaluation, improvement and propagation
46	Assessment of genetic structure, linkage disequilibrium and marker wood trait association in CPTs of teak (*Tectona grandis* L.) maintained at national teak germplasm bank a Chandrapur (M.S.) using molecular markers
47	Commercial production of quality planting material of bamboo species
FOREST ECOLOGY AND CLIMATE CHANGE DIVISION	
48	Studies on forest flora of Madhya Pradesh
49	Neem seed collection and distribution from Orissa, MP and Maharashtra
50	Seed collection, storage in seed bank and supply
51	Phenological studies on neem and teak
52	Analysis of natural forest based bamboo production to consumption system-a case study from central India
53	Biodiversity studies in protected areas- Nauradehi WLS(MP) and Debrigarh Wild Life Sanctuary (Orissa)
54	Collection of ethno-botanical data from various tribes of central India
55	Improving infrastructural facilities and ex-situ conservation of rare / threatened plants in Botanical Garden, TFRI, Jabalpur

56	To study utilization pattern of plants in ethno-medicinal uses prevalent in tribal pockets of Satpura plateau in Madhya Pradesh
57	Catalytic effect of planting on the rehabilitation of native forest biodiversity on degraded tropical lands
58	Evaluation of preservation plots of Maharashtra
59	Plant diversity in preservation plots and national parks in Maharashtra
60	Plant diversity in preservation plots of Orissa
61	Biodiversity studies in Joint Forest Management areas and adjoining forests of Sambalpur (Orissa)
62	Documentation and distribution of Forest Invasive Species (FIS) of Jabalpur, Katni, Mandla and Seoni districts of Madhya Pradesh
63	Investigation on floristic diversity in Teak plantation of various age groups in Barnawapara project division, Raipur, Chhattisgarh
64	Monitoring the impact of climate variables on plant diversity in Bhimashankar permanent preservation plot of Sub tropical hill forest of Maharashtra
65	Ecological assessment of diversity of medicinal plants in conservation areas of Chhattisgarh and strategies for their protection
66	Population dynamics of threatened medicinal plants species growing in Buffer and transition zone of Tadoba –Andheri Tiger Reserve
67	Soil –vegetation Carbon Atmosphere fluxes measurement and modeling national carbon project in India
68	Documentation of traditional knowledge on ethno-medicinal uses from tribal herbal healers (vaidyas, ojhas and guniyas) in central Madhya Pradesh
69	Study on plant diversity in sal-teak ecotone zone as influenced by ecological and climatic change
70	Screening of tropical forest tree species for their potential as carbon sink in M.P. and Chhattisgarh
71	Identification of suitable tree species and other vegetation for bio-drainage in Bargi command area Jabalpur
72	Influence of forest canopy cover on ground flora and micro-climate in western ghats (Maharashtra)
73	Survey and documentation of flora and fauna in core and buffer zones of cement plant, power plant and limestone mining areas near Maihar (dist.-Satna, M.P.)
74	Assessment of green cover and its tangible and intangible benefits and tree cover management plan for NTPP-Dadri Project
75	Counterbalancing the detrimental effect of Sponge Iron Factory-emitted Particulate Matters (SIFPM) with the protective effect of Vesicular Arbuscular Mycorrhiza (VAM) on the growth of seedlings of important tree species
76	Standardization of pruning practices and optimum doses of organic and inorganic fertilizers to increase leaf surface area of tendu
77	Utilization of automatic weather station /agrometeorological station data for agriculture, forestry and hydrological applications in Madhya Pradesh
78	Ecorehabilation of limestone mined areas of Madhya Pradesh
79	Integrated nutrient management for improved growth of trees on over burden dumps
80	Preparation of conservation plan for endangered species in and around Saraipali open cast project, SECL Korba (C.G.)
81	Preparation of conservation plan and comprehensive study of the impact on the wildlife for Rajgamar underground project, SECL Korba (C.G.)
82	Assessment of green cover and its tangible and intangible benefits and tree cover management plan for STPP-Korba Project
83	Controlling fugitive dust emission through biological reclamation of flyash lagoons in Shri Singaji thermal power project, Khandwa (M.P.)

84	Use of ash pond decant water for agriculture purpose around NTPC Ramagundam super thermal power station
85	Carbon sequestration through afforestation at Rourkela Steel Plant (Odisha)
86	Assessing the impact of pruning of *Diospyros melanoxylon* bushes on its yield, quality and natural regeneration of tree species in Maharashtra
87	Assessment of impact of constructed water harvesting structure on soil moisture/vegetation in Bundelkhand using remote sensing and GIS techniques
88	Impact of land cover change on stream flows of the Narmada River Basin using Macroscale Hydrological Model
89	Developing a predictive fire model on forests of Maharashtra with relation to various factors and to delineate suitable strategies
90	Understanding plant water relations to annual weather fluctuation in *Tectona grandis*
FOREST PROTECTION DIVISION	
91	Identify key pests of forest tree seeds, plants in nurseries and plantations and assess levels of damage
92	To develop practical techniques for control of pests through cultural practices and biocontrol techniques
93	Population dynamics and behavior of sal heartwood borer and its control measures
94	Mass multiplication of *Trichogramma* spp. and their efficacy against key pests of teak forests
95	Screening and identification of Teak of Madhya Pradesh for resistance against major insect pests
96	Screening of indigenous species of Trichogramma westwood and *Trichogrammatoidea* Girault (Hymenoptera: Trichogrammatidae) from central India and their utilization against important forest insect pests
97	Studies on forest dwelling Braconids (Hymenoptera: Braconidae) from central India and their role in biological control of important forest insect pests
98	Management of insect pests of forest nurseries in central India
99	Introduction of egg parasitoid for the protection of teak plantations from loss caused due to defoliator, (*Hyblaea puera*) and skeletonizer (*Eutectona machaeralis*)
100	Introduction of egg parasitoid, *Trichogramma* species. to prevent growth loss in plantations due to Teak defoliator and skeletonizer
101	Lead institution for Achanakmar- Amarkantak Biosphere Reserve, Chhattisgarh
102	Studies on the efficacy of toxins of soil actinomycetes against major forest insect pests
103	Evaluation of biopesticidal products against teak pests, teak defoliator, *Hyblaea puera* and teak skeletonizer, *Eutectona machaeralis* in forest nursery
104	Development of integrated insect pest and disease control system for major economically important forest tree species
105	Insect and diseases of bamboo occurring in central India and their management
106	Development of model for the management of white grubs in teak nursery under the concept of integrated pest management
107	Isolation, identification and evaluation of insecticidal phytochemicals from *Annona squamosa* L. (Annonaceae) against *Hyblaea puera* Cram and *Eutectona machaeralis* Walk., two major insect pests of teak (*Tectona grandis* L.)
108	Chemical control of insect pest and diseases of *Buchnania lanzan*
109	Studies on the natural enemies of teak pests, *Hyblaea puera* and *Eutectona machaeralis,* and their role in suppressing the population of insects in Madhya Pradesh
110	Studies on taxonomy of *Braconid parasitoids* (Hymenoptera: Braconidae) from central India

111	Biological control of insect pests of medicinal plants- *Abelmoschus moschatus, Gloriosa superba* and *Withania somnifera*
112	Standardization of management practice for tendu leaf gall forming insect and diseases
113	Field evaluation of indigenous species of *Trichogramma* against teak skeletonizer, *Eutectona machaeralis*
114	Damage assessment of gall making insect species of eucalyptus and its management by pesticides
115	Studies on larval parasitoids, Apanteles spp. (Hymenoptera : Braconidae) of major defoliators of teak and sal forests of Orissa
116	Biocontrol potential of native isolates of entomopathogenic nematodes for the management of insect pests of teak
117	Eco-friendly management of bark eating caterpillar, *Indarbela quadrinotata* on aonla (*Emblica officinalis*) in plantations
118	Development of rearing technique for production of insect predator, *Canthecona furcellata*, as biocontrol agent for larval defoliators
119	Status of sal heartwood borer, *Hoplocerambyx spinicornis* New man and its management
120	Studies on insect biocontrol agent, *Chrysoperla carnea* and its potentiality as insect predator
121	Studies on effect of introduction of honey bee on seed production in teak seed orchards
122	Documentation of insect fauna and flora of mangrove ecosystems in Odisha
123	Field evaluation of biopesticides, ivermectin and spinosad against major insect larval defoliators
124	Study of sal regeneration in borer affected areas
125	Taxonomy and documentation of fungi occurring in forests of Madhya Pradesh and Chhattisgarh
126	Studies on bacterial and viral diseases of teak, gmelina and albizia and their management
127	Studies on the role of actinomycetes and bacteria in controlling root diseases of forest tree species
128	Study of sal mortality in forest divisions of Chhattisgarh
129	Effect of microbial inoculants on growth and productivity of safed musli (*Chlorophytum borivillianum*)
130	Standardized the cultivation technique and its utilization of *Laccate stipitate* species of *Ganoderma taceae* (*Ganoderma lucidum* Karst.)
131	Application of growth promoting microbes and soil amendments to produce improved seedlings of forest trees
132	Studies on root rot and stem decay diseases in *Acacia catechu* and their control
133	Development of certification criteria and production of microbial inoculants for application in forest nurseries and plantations
134	Studies on disease of important medicinal plants and their biocontrol
135	Studies on wood-decay and its control of stored tropical timber in forest depots
136	Studies on the dynamics of litter decomposition in sal forest of central India and its impact on nutrient status of soil
137	Integrated management of vascular wilt disease of *Azadirachta indica* (neem), *Emblica officinalis* (aonla) and *Gmelina arborea* (khamer) in forest nurseries
138	Potential pathogens and insects responsible for the low seed production in teak seed orchards and their management
139	Documentation of biodiversity of forest fungi of central India

140	आय के अतिरिक्त स्त्रोत के रूप में ग्रामवासियों के बीच मशरूम उत्पादन का प्रचार - प्रसार।
141	Studies on the role of actinomycetes in controlling root diseases of teak, siras, sissoo and babool in forest nurseries and plantations
142	Studies on the causes of gmelina mortality in plantation of Madhya Pradesh, Chhattisgarh and its integrated management.
SILVICULTURE FOREST MANAGEMENT AND AGROFORESTRY DIVISION	
143	Developing coalition approach to Non Timber Forest Product for better livelihood of tribal communities of Madhya Pradesh.
144	Evaluation of medicinal plant based agroforestry system (silvi-medicinal) under existing teak plantation
145	Evaluation of productivity of maize in *Dalbergia sissoo* (Shisham) and Zea mays (Maize) agroforestry system
146	Development of new bamboo based agroforestry techniques for increased income generation in the central Indian states
147	Development of silvi-agri-medicinal System and agri-medicinal system in Vidharbha region of Maharashtra
148	Development of agroforestry model for teak plantation with medicinal plants
149	Development and standardization of management for most promising existing agroforestry systems in Central Narmada Valley agro climatic regions.
150	MPTs for agroforestry- trials of MPTs in agroforestry system in Chhattisgarh area of MP
151	Development of multitier cropping (silvi-agri-spice) system
152	Development of lac based agroforestry (silvi-agri-lac) system
153	Research on tree farming models in association with instant income yielding crop such as grasses, medicinal plants perennial pigeon- pea etc. with a view to motivate farmers to resort to tree farming
154	Study of allelopathic effect, if any, of tree growth on agricultural crops, root growth pattern under different plantation geometry and development of suitable agroforestry models
155	Studies on productivity and decomposition pattern of some tree species in alley cropping under tropical sub-humid condition of central India
156	Optimum land use through mixed cropping of Bach (*Acorus calamus*) with paddy
157	Studies on the effect of different level of seed collection on natural regeneration of Sal (*Shorea robusta*) in Chhattishgarh.
158	Germination ecophysiology of two important tropical forest tree species : *Schleichera oleosa* and *Pterocarpus marsupium*
159	Standardization of the techniques for germination, collection and maintenance of maximum viability of four important tropical species: *Bridelia retusa, Sterculia urens, Boswellia serrata* and *Saraca indica*
160	Standardization of nursery and plantation technology for *Pterocarpus marsupium* an endangered leguminous tree
161	Evaluation of management systems and level of community participation under Joint Forest Management (JFM)

162	Standardization of nursery techniques of *Strychnos nux vomica* and *Strychnos potatorum*
163	Development of nursery techniques for *Terminalia chebula* Retz.(Harad)
164	Sustainable management of medicinal plants in JFM areas in different agro-climatic zones of Madhya Pradesh
165	Seed physiology of the tropical forest species with special reference to their maturity and storage
166	Standardization of plantation techniques for major forest plant species in Madhya Pradesh
167	Processing techniques of NWFPs of Chhattisgarh TBOs–*Madhuca latifolia, Shorea robusta, Schleichera oleosa, Pongamia pinnata* and *Buchanania lanzan*
168	Quality assessment of NWFPs from different Chhattisgarh regions species: *Asparagus racemosus, Buchanania lanzan, Andrographis paniculata, Phyllanthus emblica* and *Embelia ribes*
169	Non destructive harvesting practices for selective MFPs, species–*Buchanania lanzan* (Chironjee)
170	Non destructive harvesting practices for minor forest produce- Nagarmotha
171	Processing techniques of NWFP- *Aegle marmelos* (Bael)
172	Standardization of non-destructive harvesting practices of Arjuna (*Terminalia arjuna*) and Maida (*Litsea chinensis*) bark
173	Standardization of non-destructive harvesting practices of Aonla (*Phyllanthus emblica*), Baheda (*Termania bellerica*) and Vaividang (*Embelia ribes*) fruits
174	Nutritive values and value addition of some bamboo species of central India
175	Studies on developing alternative methods of sustainable harvesting of medicinal plants
176	Establishment of multilocation trials of superior accessions of *Jatropha curcas* under the network programme of DBT
177	Determination of polysaccharides for the development of bio-products
178	Processing techniques of *Aegle marmelos* (Bael) fruits
179	Standardization of sustainable harvesting practices of Arjuna (*Terminalia arjuna*) bark
180	Standardization of sustainable harvesting practices of Bhui-aonla (*Phyllanthus amarus*), Sal-parni (*Desmodium gangeticum*) and Baichandi (*Dioscorea hispida*)
181	Central scheme for development of agro-techniques and cultivation of medicinal plants
182	Germplasm collection and commercial cultivation of threatened species of medicinal plants of Central India
183	Qualitative and quantitative variations in Tree Borne Oil Seed of Central India
184	Utilization of Non Wood Forest Produce wastes for making composites
185	Standardization of cultivation protocols for *Asparagus racemosus* (satawar)
186	Studies on the harvesting time of some selected medicinal plants for their natural antioxidants constituents
187	Development of food products from *Madhuca indica* flowers for the upliftment of the tribal / rural communities of central India.
188	Studies on the active chemical constituents of Hadjora, *Cissus quadrangularis* L. growing on *Terminalia arjuna* (Roxb.)

189	Chemo-profiling of some Dasmoola species (*Uraria picta, Solanum indicum* and *Solanum xanthocarpum*) in Madhya Pradesh
190	Evaluation of wild edible plants of central region for polysaccharide content
191	Evaluation modification and value addition of starches of forest origin (*Curcuma aromatica* and *Careya arborea*)
192	Evaluation of non edible oil seeds for development of surfactants and their utilization in pest management
193	Evaluation of phyto-polymers as eco-friendly bioadhesives
194	Evaluation of *Schleichera oleosa* (Kusum) fruits for their nutritional value and development of value added products for economic development of local people
195	Standardization of processing and storage techniques of Malkangni (*Celastrus panuculatis*), Baheda (*Terminalia belerica*) and Vaividang (*Embelia tsjeriam-cottam*) fruits/seeds
196	Market survey of prevailing tree species and forest products
197	Identification of markets of NTFPs, their potential prices and marketing pattern in M.P.
198	Social and livelihood analysis of dependence of tribal people on forests
199	A sample survey to update rates and ratio of timber and non-timber forest products
200	Documentation of best practices in collection and processing of NWFPs in Chhattisgarh
201	Training of societies in collection and grading of NWFPs

INTERPRETATION CENTER