Journal of Research & Development, Vol. 11 (2011) *ISSN 0972-5407*

Status and Strategies for Conservation and Management of Forest Genetic Resource of India

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ABSTRACT

Forests are the world's most important and most valuable renewable natural resource and also repositories of terrestrial biological diversity. This resource is in imminent danger due to adverse abiotic and biotic stresses resulting from urban expansion, infrastructural development, agriculture and global warming. Despite the enormous threats, there have been limited concentrated efforts to address the conservation concerns of forest trees. The management of an appropriate combination of genetic resources in various locations under diverse environmental and silvicultural practices, such as provenance and progeny trials, is considered to be the most efficient way to conserve various levels of genetic variation to increase the productivity. The erosion of these resources poses a severe threat to the world's food security in the long term. Thus, there is an urgent need to conserve and utilize the genetic resources as a safeguard against an unpredictable future.

Key words**:** Forests, biological diversity, conservation, FGR and ICFRE.

INTRODUCTION

Forests are the world's most important and most valuable renewable natural resource and also repositories of terrestrial biological diversity. This resource is in imminent danger due to adverse abiotic and biotic stresses resulting from urban expansion, infrastructural development, agriculture and global warming (Bawa and Dayanandan 1998; Brown and Pearce 1994; Stedman-Edwards 1998). Since forests are long-living, out-breeding generally highly heterogeneous and found in variable

environments, they have developed complex mechanisms to maintain high intraspecific diversity. It is well recognized that genetic variation is essential for species to evolve and adapt to changing environmental conditions. The sustained ability of forest trees to provide goods and services thus depends on the maintenance and management of Forest Genetic Resources (FGR). Despite the enormous threats, there have been limited concentrated efforts to address the conservation concerns of forest trees. India, for example, though being an acknowledged leader in conservation of crop genetic resources, has no systematic programme for conservation of FGR. Among others, critical information on the status, threats and extent and distribution of genetic diversity are required for planning effective conservation strategies. Though the basic principles of conservation of FGR are conceptually rooted in our understanding of crop genetic resources, the challenge lies in breaking free from this legacy and formulation of specific protocols that suit tree species.

STATUS OF FOREST GENETIC RESOURCES IN INDIA

India is one of the 12 centers of biological diversity in the world and the origin of several cultivated plants. It is estimated that about 45 000 species of plants occur in India, of which flowering plants account for 15 000 species. About 5000 of the flowering plants are endemic. The wild relatives of crop plants, together with other economically important species (about 150 species) are rich sources of many important and desirable characters and constitute a gene pool of potential use. The term FGR is used variedly and encloses a range of components from intraspecific diversity to inter-specific genetic diversity among a set of taxonomically and/or ecologically related species, to the entire range of forest species that are economically important and/or potentially useful (Young *et al.* 1999). It has been reported that in India there are about 6270 economically important species (Table 1).

According to Ahmed (1997), the total annual value of India's forest products is estimated to be Rs 300 000 million (about US$ 6662 million) compared to the meagre investments of Rs 8000 million (US$ 176 million) in this sector. Indian forests contribute significantly to meet the demand for fuelwood, fodder, and non-wood forest products and the major portion of all wood harvested (92%) is for fuelwood for cooking. India is

short of forest resources and the current roundwood supply shortfall of 26 million m^3 annually is expected to remain in the foreseeable future (Ganguli, 2000).

Table 1. Economically important plant diversity in India as identified in the IV International Congress of Ethnobiology, Lucknow, India, 1994 (ICE 1994)

Economic uses	Number of species
Food	1200
Fodder	2200
Fuel and timber	1000
Medicines	1500
Fibre	150
Spices	120
Oil	100

N.B. It is likely that some of the species are being used for more than one purpose.

NATIONAL CONSERVATION PROGRAMMES AND MANAGEMENT OF FGR

Many countries have national policies or special programmes for the conservation of biological diversity, including forest biological diversity and FGR. The growing attention to conservation reflects increasing concern about alterations in the forests and the long-term maintenance of the health and overall productivity of forests and forest ecosystems. The Convention on Biological Diversity (CBD), adopted in 1992, affirms that States have sovereign rights over their biological resources and that they are responsible for conserving their biological diversity and for using them in a sustainable manner. The CBD relates to ecological, social, economic and ethical values of diversity.

National policies and programmes related to FGR cover a wide range of activities, from conservation measures to protection of rare and endangered species and populations, and regulations governing seed collection and transfer in socioeconomically important tree species to comprehensive approaches to the management of landscapes, ecosystems and FGR. With these complexities in mind, considerations related to FGR in India have been integrated within broad frameworks,

such as national forest programmes and biodiversity action plans. The management of an appropriate combination of genetic resources in various locations under diverse environmental and silvicultural practices, such as provenance trials and progeny trials, is considered to be the most efficient way to conserve various levels of genetic variation to increase the productivity. However, most often genetic conservation has to be carried out without a real understanding of the genetic background of the populations and depends on population genetic models. In Indian forest ecosystems, some economically important forest tree species have been conserved in genebanks, *in situ* and *ex situ* conservation sites with wide networking between the State forest departments. National parks (87) and other protected areas in the form of biosphere reserves (12) and wildlife sanctuaries (421), which have been regarded as *in situ* conservation and management of FGR at the species level.

ROLE OF THE INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION IN CONSERVATION OF FOREST GENETIC RESOURCES

The National Bureau of Plant Genetic Resources (an independent national institute) has been working to introduce, collect and conserve plant genetic resources of mainly agricultural and horticultural species in India since 1976. Taking into consideration legal, political, economic and social issues, management of PGR has to be stratified, as these resources are imperative to sustainable development globally. The Indian Council of Forestry Research and Education (ICFRE) is an autonomous body under the Ministry of Environment and Forests, Government of India, with eight research institutes and three advanced centers in various parts of the country. ICFRE caters to the needs of different bio-geographical regions of the nation to increase the productivity through genetic and silvicultural improvement, treatment of wasteland and conservation of forest ecosystems. ICFRE has expertise and research collaboration with DANIDA and collaborative ventures with various international organizations, such as FAO, FORTIP (UNDP/FAO Regional Forest Tree Improvement Project), UNDP and World Bank on economically important species. ICFRE established a National Bureau of Forest Genetic Resources (NBFGR) with a wide network of regional institutes situated at various agroecological zones for germplasm collection, *ex situ* and *in situ* conservation as well as introduction and evaluation.

To reach the desired goals, the following priority areas for research have been identified (NFRP 2001):

- Develop mitigation strategies in forestry sector to reduce and store greenhouse gases
- Research on upland watershed management (integrated soil and water conservation to check siltation and water scarcity and to boost afforestation)
- Research on reforestation of degraded lands and problematic soils (barren, mined, waste, water-logged and salt-affected lands, etc)
- Research on conservation, protection and sustainable development of existing forests to conserve biodiversity
- Increasing productivity of existing forests and future plantations through:
- High quality seed production
- Production and multiplication of site matched planting stock
- Improvement of species and varieties using traditional breeding methods and biotechnology
- Biological rejuvenation of lands using mycorrhizae and other useful microorganisms
- Research on multipurpose trees in farming systems
- Research on improved utilization of traditional wood and paper products, including improved recovery and processing
- Research on non-wood forest products, which provide sustenance to people and supply raw materials to a large number of forest-based industries
- Research on modern tools, equipment, techniques and operations for afforestation, logging and extraction of forest products
- Protection of forest from entomological and pathological problems
- Socioeconomic research for motivating farmers/land owners to adopt tree farming in a manner similar to crop-based farming

International Forest Genetic Resource Programme

ICFRE has established a National Bureau of Forest Genetic Resources (NBFGR) under its International Genetic Resource Programme, along the lines of the National Bureau of Plant Genetics Resources (NBPGR). ICFRE is managing the collection,

documentation, evaluation and use of tree genetic resources available in India. ICFRE has established a similar line of action as established by the NBPGR, FAO, CIRAD, DANIDA, DFSC, FRED, FORTIP, World Bank-project and UNDP in promoting FGR research activities in India. ICFRE is interacting with various international organisations, such as the International Plant Genetic Resources Institute (IPGRI) on specific issues related to FGR conservation.

FUTURE REQUIREMENTS FOR SUPERIOR PROPAGULES

Being a vast country with varying climatic and edaphic conditions, India has a variety of vegetation types. The cultural diversity coupled with traditional practices has made the people highly dependent on various types of local vegetation. Therefore, preferences for different species vary considerably. This results in a dilemma in the species choice, especially when the sociological aspects are taken into consideration. Various state forest departments have developed strategies to grow species taking into consideration local requirements, in addition to other species that are required in large amount. The current annual rate of planting of social forestry species is around 1.5 million ha and the number of seedlings planted is approximately 3000 million. The future annual planting target is expected to be little over 3 million ha, consisting mainly of bamboos, *Eucalyptus, Acacia, Albizia, Prosopis, Casuarina, Dalbergia,* conifers and teak. The projected annual requirement of tree seedlings is 6160 million, of which around 23.5% is expected to be raised from SPAs of certified seed sources and around 15% is expected to be raised from genetically improved sources. Fifty per cent of the teak seeds will be coming from SPAs and 25% from genetically improved stock. Likewise, about 25% of future *Eucalyptus* seeds is expected to be provided as genetically improved stock. In the case of *Acacias* and *Albizia*, not less than 30% of seeds will be collected from identified/certified seed sources. In the case of *Casuarina* and *Dalbergia sissoo*, 20 and 10%, respectively, will be made available from genetically improved plants. It is possible that the amount of seeds of these two species available from the genetically improved plants may be doubled as a result of a tree improvement programme. In the case of conifers, however, only 20% of the seeds would be collected from the SPAs and the supply of genetically improved seeds may not be more than 2% (Table 2).

Table 2. Projected quantity of seeds needed for tree planting activities in India, including improved seeds (all figures in kilograms, percentages are in parentheses).

Species	Seed from SPA	Genetically improved seed (C.S.)	Seed by conventional practice	Total seeds
Eucalyptus spp.	650 (18.5%)	875 (25%)	1975 (56.5%)	3500
Acacias	88 800 (30%)	29 600 (10%)	177 600	296 000
Albizia spp.	48 860 (30%)	15 620 (10%)	93 720 (60%)	156 200
Casuarina equisetifolia	114 (20%)	114 (20%)	342 (60%)	570
Dalbergia sissoo	412 (10%)	412 (10%)	3 303 (80%)	4 1276
Conifers	16 660 (20%)	1670 (2%)	64 970 (78%)	83 300
Tectona grandis	228 570 (50%)	114 285 (25%)	114 285 (25%)	457 140

RESEARCH AND DEVELOPMENT IN GENETIC RESOURCES

With a view to improve the productivity and profitability of planting forest species and offering an attractive land use option, many State Forest Departments have established SPAs, CSOs, Seedling Seed Orchards (SSOs), Vegetative Multiplication Gardens (VMGs) and modern nurseries in consultation with ICFRE for production of quality planting stock material. ICFRE has also implemented a major research and development project to improve the productivity of *Casuarina*, poplar, teak and eucalypts in a short time span through the application of vegetative propagation and cloning techniques with the existing useful variation as well as development and deployment of locality-specific, high-yielding, forest-growing and disease-resistant clones (Sharma *et al.* 2002). The adopted methodology includes selection of Candidate Plus Trees (CPTs) with most desirable qualities and cloning of the CPTs through rooting of juvenile coppice shoots under controlled environment in the green house.

In order to develop better clones than what is available presently and to widen the genetic base of clonal plantations, research and development priorities have been

identified and are being carried out in various institutions of ICFRE with significant achievements (Table 3).

Table 3. Priority species for different states for the Planting Stock Improvement programme.

State	Coordinating institute	Priority species for the establishment of...			
		Seed production areas (SPA)	**Clonal seed orchards**	**Seedling seed orchards**	**Vegetative multiplication gardens**
UP, Haryana & Punjab	FRI, Dehra Dun	*Dalbergia sissoo* *Eucalyptus tereticornis* *Pinus roxburghii*	*Dalbergia sissoo* *Eucalyptus tereticornis* *Pinus roxburghii*	*Dalbergia sissoo* *Eucalyptus tereticornis* *Pinus roxburghii*	*Eucalyptus tereticornis* *Pinus roxburghii*
TN, Kerala, A. & Nicobar	IFGTB, Coimbatore	*Eucalyptus* spp. *Acacia* spp. *Tectona grandis*	*Eucalyptus* spp. *Casuarina* spp. *Tectona grandis*	*Eucalyptus* spp. *Casuarina* spp. *Tectona grandis*	*Eucalyptus* spp. *Casuarina* spp. *Tectona grandis*
Karnataka & Andhra Pradesh	IWST, Bangalore	*Tectona grandis* *Eucalyptus camaldulensis* *Casuarina* spp.	*Eucalyptus* spp. *Tectona grandis* *Casuarina* spp	*Eucalyptus* spp. *Tectona grandis* *Casuarina* spp	*Tectona grandis* Bamboo
MP, Maharashtra & Orissa	TFRI, Jabalpur	*Tectona grandis* *Casuarina equisetifolia*	*Tectona grandis* *Casuarina* spp. *Albizia procera* Bamboo	*Tectona grandis* *Casuarina* spp. *Albizia procera* Bamboo	*Tectona grandis* *Casuarina* spp. *Albizia procera* Bamboo
Rajasthan Gujarat	AFRI, Jodhpur	*Tectona grandis* *Dalbergia sissoo* *Acacia nilotica* *Eucalyptus* spp.	*Tectona grandis* *Dalbergia sissoo* *Acacia nilotica* *Eucalyptus* spp.	*Dalbergia sissoo* *Acacia nilotica* *Eucalyptus* spp.	*Dalbergia sissoo* *Eucalyptus* spp.
J&K Himachal Pradesh	HFRI, Shimla	*Pinus roxburghii*	*Dalbergia sissoo* *Pinus* spp.	*Dalbergia sissoo* *Pinus* spp.	*Dalbergia sissoo* *Populus* spp.
UP	ISF&ER, Allahabad	*Dalbergia sissoo*	*Eucalyptus* spp.	*Acacia* spp. *Dalbergia sissoo*	*Tectona grandis* *Eucalyptus*
Bihar, Orissa W.B.	IFP, Ranchi	*Acacia auriculiformis*	*Eucalyptus* spp.	*Acacia* spp. *Eucalyptus* spp. *Dalbergia sissoo* *Gmelina arborea*	*Eucalyptus* spp. *Paulownia* sp. *Gmelina arborea* Bamboo

ICFRE has established the following SPAs, CSOs, SSOs and VMGs of various species in different parts of the country (Table 4).

Table 4. State-wise planting stock improvement areas for priority species under ISFRE (areas in hectares)

State	Coordinating institute	Seed production areas (SPA)	Clonal seed orchards (CSO)	Seedling seed orchards (SSO)	Vegetative multiplication gardens (VMG)
UP, Haryana & Punjab	FRI, Dehradun	181.8	28.0	25.2	4.1
TN, Kerala, A. & Nicobar	IFGTB, Coimbatore	82.3	27.7	38.3	13.0
Karnataka & Andhra Pradesh	IWST, Bangalore	120.0	12.0	34.0	6.0
MP, Maharashtra & Orissa	TFRI, Jabalpur	425.0	41.0	83.5	10.0
Rajasthan, Gujarat	AFRI, Jodhpur	200.0	29.0	55.0	5.0
States of N-E	IRMDFR, Jorhat	24.0	5.0	60.0	10.0
J&K Himachal Pradesh	HFRI, Shimla	32.5	12.8	6.0	6.0
UP	ISFER, Allahabad	60.0	8.0	12.0	2.0
Bihar, Orissa W.B.	IFP, Ranchi	100.0	3.0	30.5	0.0

Provenance Trials

The first provenance trials for two important native species *viz. Tectona grandis* and *Pinus roxburghii* were initiated by Prof. M. L. Laurie and Sir Harry Champion, respectively, during the time when they were silviculturists at the FRI, Dehradun.

Provenance trials of teak were established during 1928-30 in a number of locations in India. The tests on teak and chir pine have yielded useful information. International provenance trials of *Tectona grandis* and *Gmelina arborea* have been established in different states in collaboration with the Danida Forest Seed Centre (DFSC). ICFRE has initiated national level provenance experiments on *Tectona grandis*, *Pinus roxburghii* and *Bombax ceiba*. ICFRE has also collaborated in international provenance testing of eucalypts, particularly *Eucalyptus tereticornis*, *E. camaldulensis* and *E. grandis*. Trials have also been laid for acacias and tropical pines, such as *Pinus oocarpa*, *P. caribaea* and *P. kesiya,* etc. Technical inputs have been extended to state forest departments for provenance tests for species of interest such as *Eucalyptus grandis* and *E. globulus*.

The provenance trials have been further systematised during the last five years by ICFRE. Different institutes conducted both national and international provenance trials in collaboration with the State Forest Departments and international agencies. The details are given in Table 5.

Table 5. Provenance trials established by ICFRE

	States of India					
Species	**U.P. Punjab & Haryana**	**T.N. Kerala & A&N Land**	**M.P. Maharashtra Orissa & Goa**	**Rajasthan Gujarat & D&N**	**Karnataka A.P. A&N**	**Bihar W.B. Orissa**
Acacia nilotica	27	34	46	14	-	-
Azadirachta indica	-	-	26	19	-	-
Pinus roxburghii	23	-	-	-	-	-
Dalbergia sissoo	31	-	10	10	-	-
Prosopis cineraria	6	-	-	-	-	-
Casuarina equisetifolia	-	40	-	-	-	-
Eucalyptus	-	17	-	-	-	10

grandis						
E. tereticornis	-	5	4	-	-	-
E. camaldulensis	-	13	16	-	-	15
E. microtheca	-	20	-	-	-	-
Acacia lebbeck	-	13	-	-	-	-
A. mangium	-	-	13	-	-	-
Santalum album	-	-	9	-	-	-
Acacia procera	-	-	11	-	-	-
Pongamia pinnata	-	-	7	-	-	-
Jatropha curcus	-	-	25	-	-	-
Dendrocalamus strictus	-	-	11	-	-	-
Tecomella undulate	-	-	-	13	-	-
Gmelina arborea	32	-	-	13	-	-

Plus Trees

The selection of plus trees was done with the help of the State Forest Departments. The ICFRE institutes maintain plus tree registers for different species. The largest number of plus trees was for teak followed by *D. sissoo, P. roxburghii*, *C. equisetifolia* and *A. indica* (neem) (Table 6).

Seed Orchards

Seed orchards contribute greatly to the production of quality planting stock of the desired species. A clonal teak seed orchard established at Walayar, Kerala consists of 20 superior genotypes from Tamil Nadu, Kerala and Andra Pradesh, and is providing superior seeds for improvement programmes. Similarly, a clonal seed orchard of *Tectona grandis* consisting of 80 clones collected from superior genotypes from different states and seed orchards of *Bombax ceiba*, *Casuarina equisetifolia* and bamboos have been established at the Tropical Forest Research Institute (TFRI),

Jabalpur. An excellent clonal seed orchard for sandal (*Santalum album*) has been established at Gottipura by the Institute of Wood Science & Technology (IWST), Bangalore. The seeds are made available to progressive planters and also used for development of demonstration plantation of sandal. Seed orchards established in different states are shown in Table 3.

Seed Production Areas

Much of the work with seed production areas is on teak with over 3000 ha established by the close collaboration between different State Forest Departments and ICFRE institutions. Different institutions have developed methods for demarcation and selection of trees in the SPAs so that trees with desirable characteristics are retained. The method for establishment of SPAs has been developed by ICFRE and the details provided to the State Forest Departments. State-wise information about seed production areas is given in Table 6.

Vegetative Propagation and Establishment of Clonal Banks

Vegetative propagation is an effective method for tree improvement as it could capture both additive and non-additive genetic variances. By using vegetative propagation techniques, it is possible to produce plants and quickly establish clonal banks, provided the plants are not recalcitrant to rooting and plageotropism in growth. Use of juvenile material or inducing juvenility in adult material greatly contributes to the success of establishing clonal lines.

Different ICFRE institutes have developed a vegetative propagation technique for a number of economically important species for establishment of a clonal bank and for mass multiplication. The details of species have been presented in Table 5. Currently, ICFRE is able to produce and supply good quality planting stock of *D. sissoo*, *E. tereticornis*, *E. camaldulensis*, *C. equisetifolia*, poplars and *Tectona grandis.* In addition, ICFRE is continuously adding more and more clones with defined characteristics and is also exchanging clonal material with various State Forest Departments.

Table 6. Details of plus trees selected in various states

	States of India				
Species	**U.P. Punjab & Harayana**	**T.N. Kerala & A&N Land**	**M.P. Maharashtra Orrisa & Goa**	**Rajasthan Gujrat & D&N**	**Karnataka A.P. A&N**
Azadirachta indica	47	40	-	-	-
Dalbergia sissoo	130	-	43	-	-
Casuarina equisetifolia		91	-	-	-
Tectona grandis	-	53	330	-	50
Eucalyptus tereticornis	-	42	-	-	-
Dalbergia latifolia	-	-	15	-	-
Tecomella undulate	-	-	-	15	-
Acacia nilotica	-	-	-	4	-
Prosopis cineraria	-	-	-	6	-
Acacia tortilis	-	-	-	8	-
Pinus roxburghii	97	-	-	-	-

Tissue Culture for Mass Propagation

Research on tissue culture of trees was initiated in late 1970s with emphasis on teak and eucalyptus for which protocols were developed. The institutes under ICFRE have taken up a number of species for mass multiplication through tissue culture, to produce adequate number of good quality planting stock material. Studies were also conducted on mass multiplication of different bamboos, including edible bamboos, and several thousands of plantlets have been transferred to the field. The technique is used in conjunction with selection strategies so that the material produced is of high quality.

Seed Bank and Seed Exchange

The programme for the production of quality planting stock involved tree selection, seed collecting, storage and distribution, not only within the region but also to other regions where the species was of interest. Seed exchange is already in progress for neem, *Casuarina*, eucalyptus and bamboos. ICFRE institutes have developed modern techniques for genetic conservation to improve the planting stock, such as storage of seeds, pollen, storage by *in-vitro* methods, growth limitation, cryopreservation and use of molecular biological methods. Seed certification is done for transportation of seeds within and outside the country. Seed certification is designed to ensure that the seed for sale is of the right variety and of good quality. Thus, legislation on seed certification has been adopted, however mostly for agriculture seeds. There is a need to develop such mechanism for forestry seeds.

CONCLUSIONS

Forest genetic resources are facing multiple threats from habitat loss, forest fires, climate change and from the invasion of exotic species. Conservation is compounded by the number of species that require protection. Plant resources, many of which come from forests, are the biological basis of the world security and directly or indirectly support the livelihoods of every person on earth by providing food, feed for domestic animals, fibre, clothing, shelter, wood, timber, medicine, energy, etc. These resources are also the raw material used in the production of new plant varieties through traditional plant breeding or through biotechnology. The erosion of these resources poses a severe threat to the world's food security in the long term. Thus, there is an urgent need to conserve and utilize the genetic resources as a safeguard against an unpredictable future.

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