

# Multipurpose Tree Species for Agroforestry in India

Proceedings of the  
National Workshop  
held 6-9 April 1994  
in Pune, India



Editors :  
N. G. Hegde and J. N. Daniel

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**Development Research Foundation**

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Editors :

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President

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and

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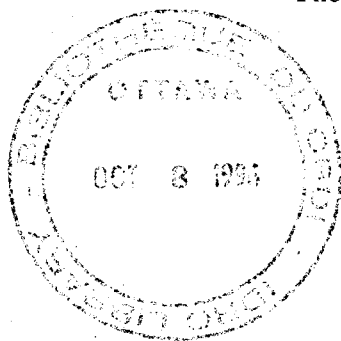
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The BAIF Development Research Foundation, founded by late Dr. Manibhai Desai in 1967, is a voluntary organisation involved in rural development and environmental protection in the states of Maharashtra, Karnataka, Gujarat, Rajasthan and Uttar Pradesh.

The mission of BAIF is to create opportunities of gainful self-employment for the rural families, especially for those belonging to disadvantaged sections, to ensure sustainable livelihood in harmony with nature that leads to an improved quality of life, and good human values.

Realisation of this mission is through applied research and outreach programmes that encourage the adoption of appropriate technologies and upgrade the skills and capabilities of rural families for the effective use of local resources.

Committed to an apolitical secular principle, BAIF has a professional and scientific approach to succeed in its mission.

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**Cover :** A row of *Melia azedarach* trees on the bund of an agricultural field in Maharashtra.

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## **Preface**

Agroforestry, a traditional practice in India, has been receiving increasing emphasis in recent years as a sustainable land use option of high potential. The contribution of trees towards the total farm output is often negligible in traditional agroforestry practices. Current research and outreach efforts strive to increase the economic importance of the tree component by introducing appropriate species in greater numbers in agroforestry systems.

Adoption of improved agroforestry systems is yet to become widespread. Inadequacy of information about viable models is one of the constraints to successful implementation of agroforestry programmes. However, promising agroforestry models are emerging from many research institutions and universities. Field experiences of government departments, voluntary organisations and development agencies in implementing agroforestry and related programmes are also encouraging.

An objective of the National Workshop on Multipurpose Tree Species for Agroforestry in India was to document and disseminate recent research and field experiences in agroforestry. The workshop, held 6-9 April 1994 in Pune, was attended by 48 participants representing agricultural and forestry institutions, forest departments and voluntary organisations. Papers presented at the workshop are compiled into this proceedings.

The generous support of our sponsors enabled us to organise this workshop and publish its proceedings. We gratefully acknowledge the grants received from the Australian High Commission, New Delhi; the Danish International Development Agency, New Delhi; the Overseas Development Administration, New Delhi; the International Development Research Centre, Canada; the Winrock International Institute for Agricultural Development, USA; and the National Bank for Agriculture and Rural Development, Bombay.

Our thanks to Ms. Tinku Dhar for editorial assistance and coordination in the preparation of this publication.

Successful propagation of agroforestry requires a continuous flow of information from research programmes as well as field experiences. The BAIF Development Research Foundation is happy to be a channel for the information flow through its publications.

**Narayan G. Hegde**

**Joshua N. Daniel**



# Inaugural Address

**Shri Jayantrao Patil**

Member, Planning Commission

New Delhi

Respected Mohan Dhariaji, Dr. Narayan Hegde, Shri Srivastavji, Shri Girish Sohani and distinguished participants,

This is my first visit to Pune after the passing away of Dr. Manibhai Desai. It is hard to imagine that Manibhaiji has departed so soon, but it is our duty and privilege to continue his mission and keep the pledge which he gave Mahatma Gandhiji.

The theme of this workshop, Multipurpose Trees for Agroforestry, is very specific. The workshop deliberations will certainly help increase the adoption of agroforestry programmes, particularly by voluntary organisations.

Shri Sunderlal Bahuguna told me that I should focus on horticulture and tree-based farming. According to him, Kakasaheb Kalelkar asked Gandhiji in 1928 what should be the future agriculture of India. Bapu told him that it should be tree-based farming with emphasis on horticulture because malnutrition, the greatest problem of India, can be solved by making available fruits that contain vitamins and minerals. Similarly, Gandhiji suggested non-perishable fruits and nuts for the Himalayan region.

Although a number of fruit species are grown in the Himalayas, attempts to introduce suitable species since independence are limited. This is mainly due to inadequate awareness among people and lack of nurseries. I feel that a chain of nurseries is an important pre-requisite for the introduction of multipurpose trees for agroforestry. There are nurseries at the taluka level, but farmers find it difficult to transport the polybag seedlings during the busy rainy season. Therefore, nurseries should be set up at the village level.

Land and water issues can be dealt with more effectively by panchayats following the 73rd amendment to the Panchayat Act. Village people have to be trained and empowered. Women have maintained seeds of cereals for generations and have made excellent selections resulting in varieties such as Basmati, Kolam or Zenia. Unfortunately, we are not accustomed to collecting seeds of tree species. It would be an interesting study if a social scientist or philosopher investigates why we have not maintained seeds of neem or mangoes.

Teaching on tree farming principles should begin at primary school and continue up to the college level. Experienced farmers should be invited to teach practical aspects. When I was at the University of the Philippines, an ordinary farmer having years of experience was called to lecture us on mixed farming. He described the concept of combining rice cultivation with fish culture so well that it was easier to understand than the lectures of professors. Similarly, native farmers experienced in tree farming could be made use of in our programmes to promote multipurpose tree species for agroforestry.

In our endeavour to continue the mission of Manibhaiji, what matters is the commitment rather than the number of species. We have been lagging behind in plant introduction. We should introduce species from other countries and also from other states. When Dr. Yogendra Alagh was a member of the Planning Commission, he promoted a programme called 'agro-climatic regional plan'. The purpose of this programme was to bring about an ecological bondage between ecological regions and crops or perennials.

Another constraint is the availability of funds from the state. This has to be overcome by evolving appropriate technologies. Techniques for direct sowing can reduce the cost on transportation of seedlings. Because they are more efficient in water utilization, cost of irrigation is lower for trees. This workshop should deliberate such issues and come out with strategies to promote multipurpose tree species and agroforestry systems among farmers. That will be a valuable contribution for programmes in agriculture as well as forestry in our country.

# Presidential Address

**Shri Mohan Dharia**  
President, Vanarai, Pune

Our Chief Guest Dr. Jayantrao Patil, Dr. Narayan Hegde, Shrivastavji, Mr. Girish Sohani and friends,

It is indeed a great pleasure and privilege for me to be here this morning and to say a few words regarding tree species for agroforestry in India. Dr. Manibhai Desai was always insistent that we should have discussions which will ultimately provide solutions to the manifold problems of the country.

I do appreciate the timing of this workshop because we have to think ahead about our future programmes and objectives. So far as our objectives are concerned, we want sustainable development, biodiversity, growth, social justice and environmental conservation. In addition, we have to think of the tree species to be planted to meet the needs of the common people. It is very clear that people need fuel, fruit, fodder, fibre and forests for timber.

There are several issues involved when we speak of tree species. It would be appropriate to think of the country and the land that are at our disposal. We have 329 million ha of land in our country. Out of that, an area of 75 million ha is under forests. So far as forest lands are concerned, our endeavour must be to maintain the biodiversity that is necessary for the country. In this context, we should not think in terms of monoculture but multiculture and biodiversity as species are getting extinct. Forest lands should be maintained for permanent green cover and not for agroforestry.

Nature has to be taken care of to ensure sustainable development. For a balanced environment, we need a third of the total land area under permanent green cover. Thus, we need about 110 million ha of land under permanent green cover for a balanced environment. While introducing agroforestry, we also have to take into consideration the additional lands where trees will be cut.

Proper planning for land use under agroforestry is important. Introduction of tree species should be done only after thorough research. At present, advanced research on neem and many of our indigenous tree species is being carried out in countries like Germany, America, and Australia. The time may not be too far when somebody has to go to Germany to secure a doctorate in tulsi plant. The Forest Research Institute in Dehra Dun has been engaged in research and development on neem.

The benefits of vegetative propagation of species such as neem should be taken advantage of. Branches of banyan trees can be provided support by guiding the aerial roots to the soil so that they establish a base. It is estimated that 60 million ha of our land are occupied by bunds alone. Identifying tree species that do not adversely affect the crops in adjacent fields when planted on these bunds is necessary. India is fortunate in having a large number of native species. It is necessary to convene a meeting of all the research institutes engaged in research on these tree species in the country to assess the efforts made by them and evolve strategies to strengthen these efforts. The Planning Commission should even go to the extent of maintaining some planned grants for the development of this programme.

In China, nurseries are set up in open fields without the use of polythene bags. This reduces the cost of seedlings. Technologies such as tissue culture should also be attempted in tree species, especially those in danger of extinction. Horticultural plantations can be established in the barren lands of Maharashtra. Farmers taking up horticulture in their fields are covered by the employment guarantee scheme of the state. Since the commencement of this scheme in May 1990, more than 500,000 ha of land in Maharashtra have come under additional horticulture.

We should plan for massive agroforestry programmes so that there will be no scarcity. My own farm of less than 0.5 ha was barren with hardly any soil when I planted subabul eight years ago. Now it has a beautiful layer of top soil. I do not believe that all the research should be conducted in the campuses of research institutes. On-farm research is also necessary. Without the involvement of people, it will never be possible to carry out any programme in the country. Therefore, research is also an activity where people have to be involved.

Elimination of poverty could be clubbed with tree planting programmes in the country. Sustaining growth and realising social justice while caring for the environment and maintaining biodiversity through sustainable development is the real challenge: let us face it.

## Keynote Address

**Dr. D.N. Tewari**

Director General

Indian Council for Forestry Research and Education

Dehra Dun, Uttar Pradesh

### **Orienting Multipurpose Tree Species Research in India**

#### **Introduction**

Under the present conditions of heavy pressure of human (850 million) and livestock (416 million) populations, decreasing size of landholdings (0.25 ha per person), acute shortage of fuelwood, fodder, timber and other tree-based products, plantation forestry has tremendous scope in India. Tree planting will need considerable attention in view of the vital and permanent requirements met by trees. The basic aim is to supply goods and services and meet the genuine needs of the people, be it for general necessities such as firewood, fodder, food, fertiliser, fibre, timber and medicine or for industrial purposes.

There has to be a massive afforestation programme with indigenous and exotic tree species to meet such needs. The choice could, however, be of multiple use species. A multiple use tree should be capable of producing a range of products and have the capacity to contribute in its specific functions towards the sustainability of yields, an increase in output and/or reduction in inputs, and maintaining the ecological stability of the region. Therefore, multipurpose tree species (MPTS) should be introduced in land use systems to exploit their ability to provide the basic needs of people and protect the environment. The intended benefits derived from trees by people are categorised in Table 1.

**Table 1.**

Consumptive Products	Products for Income	Environmental Conservation
Food	Wood	Soil
Fuelwood	Sap	Water
Fodder	Resinsp	Shade
Medicine	Medicine	Clean air
Fibre	Fibre	Fertiliser
Mulch		Nitrogen fixation
Small timber		Security

The paramount importance placed on trees is not merely due to their ability to meet multiple needs, but also due to their long-term sustainability. Nowadays there is a growing awareness about woody perennials playing an important role in sustainability of tropical land use systems and meeting the fuelwood needs of the rural poor. Predominancy of *Prosopis cineraria*, *Azadirachta indica*, *Madhuca longifolia*, *Acacia nilotica*, *Dalbergia sissoo*, *Syzygium cumini*, *Sesbania grandiflora*, *Albizia procera*, *Artocarpus heterophyllus* and *Cocos nucifera* among rural people are some of the best examples.

Since hundreds of species provide wood, shade and mulch, only those which have the potential to provide fuelwood, fodder, posts, poles, shade / shelter, ground cover and other services qualify as multipurpose. The general criteria of site suitability and species characteristics determine the right choice of tree species, but the main consideration remains the specific purpose. Generally, MPTS which can be used for meeting various social needs are preferred. Another consideration is for meeting industrial needs. The Forest Policy of 1988 states that forest-based industries should establish a direct relationship with individuals who can grow the raw material for them. Industries should provide support with inputs including credit, regular technical advice, harvesting and transport services. The people thus have a choice in selecting species depending upon the merits of the alternatives available to them. Another important aspect is environmental protection. Tree species useful for environmental protection should have characteristics like checking water and wind erosion, stabilising landslips and disturbed soil surfaces, controlling ravines, reclaiming wastelands and improving soil productivity.

MPTS are planted by farmers, specially smallholders, for satisfying their day to day needs. However, from the national and community standpoint, trees can be grown to help conserve both the soil and the growing environment. They can greatly reduce fossil fuel requirements for agricultural production and extend the use of fragile environments and marginal lands. For the farmer, trees can increase returns on human effort; provide multiple uses for his family; lower capital requirement; and seasonally extend photosynthetic activity. The primary concern of the small holder is to increase productivity and other economic returns, mainly from his own efforts. The wider use of MPTS, specially nitrogen fixing tree species, would become an important factor in improving productivity and maintaining an enhanced nitrogen status in many tropical land use systems. Various agroforestry systems involving common MPTS in this country are listed in Annexure 1.

## **Research Requirements**

Experimental findings related to cultivation of MPTS in various land use systems are scanty. Much more evaluation of MPTS need to be done. Following research priorities and recommendations are proposed for consideration :

### **Plant Exploration**

The most urgent research needed is to carry out plant exploration for economically useful tree species. The exploration need not be limited only to those species currently in use, but should stress the need for several uses and economic products. The discovery of cereal-equivalent products from trees would be particularly interesting, though very few possibilities are available at present (eg. mahua, khejri).

### **Adaptability**

The next step would be to determine the adaptive and potential uses of the more promising species based on a reasonable range of variation within each of them. It is essential to intensify studies on the biology, silviculture and management as MPTS are currently being planted outside the forest area. There is also a need to study the succession and species diversity with reference to anthropogenic disturbances.

### **Genetic Improvement**

Tree species showing potential should be considered for genetic improvement and manipulation through the use of plant breeding, genetic engineering, tissue culture and grafting. Tree improvement objectives should be to evolve short rotation and high yielding varieties, increased productivity, improved quality of products, broader adaptation, greater tolerance to stresses, resistance to harmful biota, ease of establishment and handling, and multiple uses. Identification of plus trees within and outside India to select suitable provenances/varieties and individual plants/clones with greater potential for specific sites and purposes is required.

### **Silviculture and Management**

Though methods of silviculture and management are well developed for many tree species planted in India, these techniques have to be transferred to tree growers/farmers. Since MPTS are grown in agroforestry systems under various situations, the development of appropriate silviculture and management techniques for shelterbelt and field bund planting requires careful attention in arid and semi-arid areas. The role of nutrition and fertiliser application to increase productivity and understand the nutrient cycling in these systems requires thorough investigation. Very few studies on biomass and productivity have been carried out in different parts of the country. Accurate growth information of MPTS under different site conditions to allow prediction of biomass production should be collected.



## **Physiology and Environmental Requirement**

Tree physiology including nutritional requirements, biochemistry of nitrogen fixation, mycorrhizal associations, vegetative propagation methods and prolonging seed viability should be investigated to increase production. Assessment of the nitrogen fixing capacity of individual species needs more studies. Eco-restoration of mined saline and alkali soils has become more crucial in the country as this results in the loss of vegetal cover leading to inhospitable conditions and degradation. The saline and alkali soils which occupy an area of about 8.0 million ha are largely lying barren. In the eastern Himalayas, about 492,000 tribal families are engaged in shifting cultivation practices in 269,000 ha. Research efforts are needed to select suitable MPTS for these areas.

Species such as *Dalbergia sissoo*, *Acacia nilotica*, *Pongamia pinnata*, *Eucalyptus* spp., *Ficus* spp., *Azadirachta indica*, *Albizia lebeck* and *Terminalia arjuna* have shown promise in these areas. Nutrient cycling studies in relation to the retention/uptake ratio, redistribution and nutrient use efficiency in respect of each tree species planted under different ecosystems are needed. Work on these lines has been done at the Indian Council for Forestry Research and Education (ICFRE) on species like *Dalbergia sissoo*, *Acacia nilotica*, *Populus* spp., *Eucalyptus* spp. and pine. The ability of MPTS to protect the soil by reducing wind and water erosion with a superficial root system, a thick canopy cover and addition of leaf litter is known, but needs quantitative estimation for many species. Research is needed on general cultural practices and plant, water and site relations correlated with tree physiological studies aimed at providing information for improving management practices.

## **Farming Systems Research and Development**

This approach to agricultural research and development views the whole farm as a system with a focus on the interdependence between the components under the control of members of the farm household. It predicts how these components interact with the physical, biological and socio-economic factors not under the control of the household. The role of trees in an integrated farming system needs to be investigated.

## **Diagnosis and Design**

It orients the research programme towards fully understanding the scope of incorporating MPTS into the farming system. Its key features are flexibility, speed and repetition with the main advantage of linking agroforestry to the farming system. The ex-ante approach intends researchers to place all their options in proper perspectives.

## **Farmer First and Last**

The end users need to be consulted throughout the research and development process. Though resource-rich farmers may be more responsive to the research programme, the needs of the small-scale, resource-poor farmers have to be focussed in this system. The farmers involved provide the essential feedback about the interaction between the introduced technology and their other activities and inform about unforeseen benefits that the system provides.

Already existing trees on farms are a valuable source for conducting yield studies. The use of such trees for yield studies to look at treatment variables and interactions between treatments may not be feasible. The on-farm trials to be conducted, therefore, should be different from those suitable for research station conditions.

## **Utilisation**

To be comparable between different locations, the assessment of MPTS requires absolute values. Fodder and foliage yields and the proportions of twig consumed and wasted by livestock need to be determined. It may vary significantly from location to location depending on factors such as alternative feed available and feeding systems.

At the farmer level, any attempt to evaluate the range of MPTS products must relate to farmers' needs and perceptions which may vary according to the individual, location, time and circumstances. For quantity and quality, the biggest factor in a farmer's assessment is the access to alternative sources of these products. The evaluation should take into consideration socio-economic issues such as labour availability, land management, restrictions or access to forest and type of livestock owned.

## **Multipurpose Tree Species for Non-Timber Forest Products**

While the stress on production of fodder, fuelwood and small timber from MPTS may continue, the role of non-timber forest produce (NTFP) in employment and income generation should not be overlooked. The advantage of NTFP over major forest produce is little or no harm to the tree at the time of harvest, besides the possibility of obtaining repeated harvests from the same tree over a long period of time. Sometimes, the monetary value of a small quantity of NTFP from a tree is equivalent to or more than the value of the entire wood from the tree. Rural communities and forest dwellers, particularly tribals, traditionally depend on NTFP as a means of livelihood.

There are many under-exploited tropical MPTS which yield edible products such as fruits, oils, nuts and spices. Their cultivation practices and the processing techniques of their products are similar to that of common horticultural and spice species. However, the existing knowledge on uses and processing techniques is often traditional, and the

marketing infrastructure is weak. Thus there is a need to increase the benefits from NTFP by exchanging information on MPTS and their products, improving processing techniques and developing marketing channels to ensure that the producer gets a major share of the profit. Since the resurgence of interest in herbal medicines and the search for substitutes of biological origin in place of harmful chemicals has increased, the demand for several NTFP-based medicines and consumer products has increased in developed countries.

Research should be initiated to identify active ingredients in plants and develop low-cost machinery for processing. Developing a package of incentives, an extension network, a marketing infrastructure and policy measures governing all aspects of NTFP production and utilisation is urgently required.

### **Socio-Economic Aspects**

MPTS hold an important place in the rural economy of India. They not only meet the basic needs of the people, but also provide cash benefits and raw materials to village artisans and forest-based industries. Since time immemorial, trees were esteemed by farmers which manifested itself in tree-based agricultural systems like agri-siviculture, silvi-horticulture, silvi-pasture and tree husbandry. MPTS have shown their worth in meeting the objectives of social forestry.

Research is required to address the role of MPTS in agroforestry and social forestry to develop models and mixtures and the most efficient methodology of raising plantations for improving the socio-economic status of the community/farmers practising tree farming. There is an urgent need to study utilization patterns of MPTS on short and long rotation and their contribution to socio-economic well-being so that the impact brought about on the rural economy can be evaluated.

### **Cooperative Activities**

Effective MPTS research to meet the needs of small-scale farmers requires establishing research institutions to generate and adopt technologies for MPTS and provide training, funding, political support, information services and coordination to users. International cooperation is essential if the potential of MPTS is to be fully utilized. A network is required for the collection and dissemination of information on MPTS research. Meetings, seminars, workshops and conferences which are important mechanisms for disseminating information need to be regularly organised. Monographs, newsletters, user manuals, seed/germplasm directories and directories of institutions and scientists engaged in MPTS research should be regularly published.

A Working Group should be established to facilitate the regular exchange of information between scientists and managers. The following broad areas of interest are recommended.

1. Orientation of funding agencies on research and the problems of small farmers to assist individual scientists and their organisations in conducting research on MPTS with international financial assistance.
2. Providing linkages and channels for feedback from the field.
3. Conducting and establishing on-farm trials.
4. Demarcation and delineation of provenances of important MPTS and establishment of international provenance trials.
5. Establishment of centres for procuring, handling and storing seeds based on standardized methodology.
6. Promoting a network for association of forestry scientists, social scientists, development workers and extension staff.
7. Development of a database of the problems of tree growers.

ICFRE is the oldest and richest repository of information on forest and tree species. It can act as a nodal agency for planning, organizing and executing international provenance trials and other related research including seed collection, handling and storage.

## **Conclusion**

It may be concluded that although tree species with a multiplicity of uses have been managed for a long time, scientific investigation on them with regard to propagation, growth performance, management and use has been restricted to timber only. Management of these species for purposes other than timber calls for an entirely different research approach which is being gradually introduced. Under this approach, research priorities to improve MPTS to be used in agroforestry systems and their selection and management practices are defined on the basis of priority uses. Screening for the economic, social and cultural needs of the local people should be done simultaneously. It must be acceptable to the farmer and to the local community in all respects.

Tree characteristics to be taken into account are smokiness of the fuelwood, odours and flavours imparted by the fuelwood/charcoal and thorniness. The overriding factors should be the economic benefits and a reduction of risk. A new species or technology

will not be acceptable to local farmers unless its superiority is demonstrated in all these respects. For this reason, long-term research programmes must include collection and analysis of appropriate economic data.

MPTS research also has to focus on the diagnosis of land use problems and designing of agroforestry technologies. The institutes under ICFRE have already identified the problems and potentials of various types of lands and research priorities. The next step is to design and test new technologies, identify the ideal trees or ideotypes for various agroforestry systems, and for various end uses. This research involves identification of association, competitiveness, compatibility, form, wood quality and nitrogen fixing ability of the species under consideration.

A thorough review and documentation of existing information is necessary to avoid “reinventing the wheel”. Data should be compiled not only from existing publications and records of forestry and agricultural institutes in the country, but also from international agencies and organisations from Africa, Asia, and South America that have compiled a wealth of data on MPTS. ICFRE is also compiling an extensive database on indigenous species based on the MPTSys Database developed by the Forestry and Fuelwood Research and Development (F/FRED) Project.

Another aspect of MPTS research is the identification of suitable germplasm and location of genetic resources through an exhaustive network of seed production areas. Provenance trials are required for indigenous species and promising exotic species such as *Paulownia* and some *Acacias*. This should be followed by a thorough assessment of their survival, form, phenology, growth, bole and crown characteristics, response to management, utilisation and susceptibility to pests and diseases. Regular soil and microclimatic monitoring to assess any adverse impact of the introduction on the site is also necessary. All these studies should be conducted in close collaboration with the ultimate endusers, farmers, who should provide the necessary feedback. Based on this feedback, experimental designs and species mix should be suitably modified and tested in on-farm research trials.

**Annexure 1.** List of various MPTS suitable for different regions.

**A. Himalayan Region**

**a. Kashmir**

1. Almond/apple in rows with saffron/vegetables.
2. Walnut (on drains and bunds) with maize and beans.
3. *Robinia pseudoacacia/Celtis/Ailanthus/Morus/Salix*/poplar with wheat and paddy.
4. *Leucaena*/mulberry/poplar with paddy-wheat.
5. *Acacia nilotica, Eucalyptus* with pulses-maize/fallow/citrus.

**b. Himachal Pradesh and Uttar Pradesh**

1. Mixed plantations of fodder, fuel, timber and forest trees with vegetable crops under irrigation; *Eleusine coracana* and wheat in drylands.
2. *Kydia calycina/Morus* with paddy-wheat on terraces.
3. *Sapium insigne* with paddy-wheat.
4. *Boehmeria rugulosa, Grewia optiva, Terminalia, Celtis caucasica and Parkia roxburghii* with paddy-wheat or maize-wheat or ragi/jhingora on terraces.

**c. North-Eastern States**

1. Arecanut/citrus with black pepper, banana and papaya.
2. Arecanut with pineapple, betel vine/citrus with cardamom.
3. *Grevillea robusta* with paddy.
4. Bamboo, *Parkia roxburghii, Mangifera indica, Syzygium cumini, Emblica officinalis and Morus alba* with vegetables.
5. *Dipterocarpus macrocarpus* with coffee, cocoa and *Terminalia microcarpa*.
6. *Shorea robusta/Grevillea robusta/Alnus nepalensis* with tea, cardamom, turmeric and ginger.
7. *Indigofera tasmianii* with *Albizia lebeck, A. procera, A. odoratissima, A. stipulata, A. mollucana* and *A. sumatrama* with tea.
8. *Terminalia microcarpa, Bischoffia javanica* and *Alnus nepalensis* with cardamom.

## **B. Tarai Region**

1. Eucalyptus with soybean/maize followed by wheat.
2. Eucalyptus with lahi followed by lentils/gram.
3. Poplar with soybean/maize/lahi followed by wheat/lentil.
4. Sugarcane with poplar up to three years followed by paddy/potato.
5. Poplar/Eucalyptus with sugarcane for three years followed by paddy/potato.
6. Leucaena/Sesbania/Poplar with Brassica/Cymbopogon.
7. *Dalbergia sissoo* and *Acacia nilotica* with sugarcane for three years followed by wheat.

## **C. Alluvial Plains**

1. *Acacia nilotica/Tamarix articulata/Agave sisalana/Cajanus cajan* on bunds with paddy and wheat or maize and wheat/Eucalyptus/Poplars/mango/shisham/ber/mulberry.
2. *Leucaena/Prosopis cineraria/Azadirachta indica/Albizia lebbbeck/Toona ciliata* in mixture with crops.
3. Along the orchards a local variety of *Eugenia* is grown as a shelter crop to protect the orchard from the scorching sun. The jamoa crop is thinned for fuel and small timber.
4. *Leucaena leucocephala, Shorea robusta, Tectona grandis, Champa, Cryptomeria* and *Chukrasia* are the main tree species grown with ginger, turmeric, bamboo, black pepper in vacant places in West Bengal.
5. Shisham and bamboo are grown on the bunds in Bihar. In early stages, maize is grown and later pulses. Intercropping is confined to better sites where wheat is the principal crop.
6. Eucalyptus with marigold flowers/bajra/castor/vegetable/sugarcane in Gujarat.
7. *Casuarina equisetifolia* on field bunds with cabbage and mango in coastal areas.

## **D. Arid and Semi-Arid Region**

1. *Faidherbia albida* with cereal and grasses.
2. *Albizia lebbbeck* with moth bean/groundnut, sesamum/castor/cluster bean.
3. *Azadirachta indica* with moth bean/cluster bean/groundnut/sesamum/castor/pasture grass or forage legume.
4. *Prosopis cineraria* with pearl millet / green gram / sesamum / castor / pasture grass.
5. *Zizyphus* mixed with moth bean and pearl millet.



# Workshop Background and Recommendations

## Background

The urgent need to protect our natural resources has resulted in the search for agricultural systems that reduce the dependence of rural communities on forests. In this context, agroforestry systems that include multipurpose tree species have received increasing attention in recent years because of their potential to yield fodder, fuelwood and small timber in addition to food. Since the livelihood of a majority of the rural population is in some way linked to the availability of these products, there is tremendous scope to motivate farmers to adopt agroforestry.

Agroforestry practices such as planting trees on field bunds and farm borders are not new to farmers in India. Intensive agroforestry models being evolved at present attempt to increase the contribution from the tree component without a sizeable loss in the yield of arable crops in the system. Therefore, the critical elements in the successful implementation of agroforestry programmes are the selection of compatible tree and crop species, the density and spatial arrangement of trees and their canopy management.

Promotion of agroforestry needs effective coordination among organisations engaged in research, extension and utilisation of tree produce. Presently, agroforestry research in India is conducted mostly by institutions under the Indian Council of Agricultural Research, the Indian Council of Forestry Research and Education and Agricultural Universities. Agroforestry extension is being handled by the state departments of agriculture, social forestry units of forest departments and a large number of non-government organisations working at various levels.

The infrastructure for utilising tree produce is at present confined to only a few localities where wood-based industries have consolidated their operations. Besides fodder, fuelwood and timber, agroforestry systems can also yield medicinal products, edible and non-edible oil seeds, tannin, gum, fruits and nuts. Established marketing outlets do not exist for many agroforestry produce.

There were 25 papers on research advances and field experiences presented at the National Workshop on Multipurpose Tree Species for Agroforestry in India. In addition, working groups deliberated on a) technical, b) extension and infrastructural and c) socio-economic issues related to agroforestry application, and recommended strategies to overcome the constraints.

Among the research constraints identified were the weaknesses in existing forestry and agricultural experimental methodologies for agroforestry studies, the non-

committal of both human and financial resources on a long-term basis and inadequate interaction with prospective practitioners during research planning and implementation. Extension and infrastructural constraints such as lack of qualified staff and innovative approaches for technology transfer and unavailability of inputs like tree seeds have also hampered progress in agroforestry adoption. Similarly, small farm size, absence of credit facilities and lack of organised marketing channels for tree produce are some of the socio-economic constraints to the application of agroforestry.

## **Recommendations**

### **Technical Issues**

1. A compendium of traditional agroforestry practices in different regions of the country should be prepared; agroforestry abstracts of local literature should be brought out regularly by a designated institute to facilitate information transfer among the scientific community.
2. Methodologies for both on-station and on-farm agroforestry research should be standardised to minimise the variation in experimental techniques among researchers.
3. Extensive on-farm research should be carried out before definite recommendations are made; on-farm trials with existing trees may be initiated to reduce the tree maturity period.
4. Superior germplasm of promising MPTS should be evolved through tree breeding and mass selection programmes; additionally, techniques should be developed for mass propagation of such planting material at low cost.
5. Agro-climatic conditions, resource status of the people, local priorities and market opportunities should be the major criteria in the development of agroforestry models.
6. The availability of finance and manpower for research should be assured as the development of agroforestry technology requires long-term commitment of these resources; establishment of corpus funds and eliciting support from industries that use products of agroforestry should be explored.
7. Research planning and implementation for an ecological zone should be done in consultation and coordination with specialists in agricultural and forestry research and implementation agencies, farmers and development workers of the zone.
8. Economic analyses should be carried out to identify profitable and sustainable agroforestry models, and suitable procedures should be developed to identify parameters to quantify tangible and intangible benefits.

9. A network of agroforestry researchers, practitioners and promoters should be established to review research, exchange germplasm, organise training and share field experiences.

### **Extension, Infrastructural and Socio-economic Issues**

1. Competent agencies should be identified for different regions to produce and distribute seeds of superior tree genotypes under a seed certification programme.
2. Agroforestry field demonstrations should be established regionally to train and motivate farmers.
3. Extension efforts should highlight the overall benefits of agroforestry and dispel farmer apprehensions about loss of annual crop yields and land tenure.
4. Local authorities and institutions such as Gram Sabhas, Gram Panchayats, schools, youth clubs and non-government organisations should be involved in promoting agroforestry through meetings, film shows, demonstrations, exhibitions and individual contacts.
5. Formation of tree growers' societies should be encouraged to establish agroforestry plantations on large field blocks and to undertake organised processing and marketing of the produce.
6. Schemes that facilitate availability of bank loans for establishing agroforestry and processing and marketing of tree produce should be introduced.
7. Awareness should be created among farmers about their rights and the procedures involved in selling trees grown on private land.
8. The protection of local forests should be entrusted to Gram Sabhas and Gram Panchayats by empowering them to reward or punish forest users; Gram Panchayats should also be the authority to grant permission to cut and transport trees grown on private lands.

# Agroforestry for Forage and Fuelwood Production in India

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## *Abstract*

*India faces an acute shortage of forage and fuelwood which is likely to increase in the years to come. The activities of human and animal populations on limited productive resources (329 million ha) has rendered vast areas of land unproductive. The forest area has declined and land degradation is proceeding unabated. Agroforestry is seen as an alternative to tackle these problems. Based on current research, the paper presents the potential of agroforestry for forage and firewood production in India.*

## **Introduction**

Agroforestry has been the way of life in India. Permanently settled agriculture evolved through forests and pastoralism. Even today, we find the remnants of age-old agroforestry practices in some areas. The increasing human and animal populations coupled with their demands on limited productive land resources has rendered vast areas degraded and unproductive. Olson (1981) remarked that soil degradation was responsible for the extinction of the Harappan civilization in western India, Mesopotamia in western Asia and the Mayan culture in central America. Therefore, the degradation of natural resources has to be halted forthwith for ensuring sustainability.

According to current estimates, more than 175 million ha of arable land in India are facing degradation of different kinds. This has resulted in the shortage of food, fodder, firewood and timber on the one hand and loss of biodiversity, soil, environmental stability and sustainability on the other. This paper examines the prospects of agroforestry for arresting land degradation, meeting the deficits of vital resources for survival and long-term sustainability of our land resources.

## **Our Resources**

The effects of deforestation, shifting cultivation, mining, construction of dams and mega-projects, industrialization and pollution, overgrazing, fire, changes in land use pattern, urbanization and land encroachment have contributed to ecosystem degradation (Patil and Pathak, 1977).

The estimated annual forage demand for satisfactory animal production and economic returns is 1156 and 1253 million t dry matter by 1995 and 2000 AD, respectively. This requirement when split into dry and green fodder for 2000 AD is 949 and 1136 million t, respectively. As against these, the present availability is 199, 215, 13 and 11 million t of dry fodder, cultivated green fodder, natural herbage and concentrate which should be raised to 357, 695 and 77 million t of dry, green fodder and concentrate, respectively, by 2000 AD. Thus, there is a vast gap in demand and supply. There has been an increase in the number of animals grazing in the forests from 35 million in 1956 to 90 million in 1986. The animal pressure per 100 ha of forest in some states ranges from 173 to 492. This high pressure accelerates the process of degradation.

Similarly, the fuelwood demand is likely to vary between 200 to 385 m<sup>3</sup> by 2000 AD for which about 40 million ha of additional land area will be needed. Besides these apparent needs, we need permanent land cover to protect the soil, improve system sustainability, optimize production, protect biodiversity and improve the environment. A holistic approach is required for the rehabilitation of degraded lands which is not only a technical problem, but a socio-economic one as well.

While outlining the policy and socio-economic research needs, Gregersen (1990) emphasized :

- a. Containing unproductive deforestation in humid tropics and improving sustainability of use of remaining forest lands and lands that are cleared;
- b. Reducing forest destruction and land deterioration in dry regions and improving productivity and use of wastelands;
- c. Reducing the rate of forest destruction and degradation on upland watersheds and improving their production capacity and use;
- d. Improving ways in which trees on farms and in communities contribute to household welfare and income security.

## **Agroforestry - The Only Alternative**

Agroforestry is a land management system involving trees or woody perennials grown or retained with agricultural crops and pastures with livestock. Carefully managed systems aim at reducing negative interactions to promote multiple land use with diverse products in time and space. This intricate interactive system is based on a holistic approach where long-term system sustainability is the objective. The hard realization of the benefits of such systems has encouraged global research efforts in the past decade.

A review of fifty years of research in dryland agriculture concluded that on rainfed crop lands, the best land use options are :

Arable lands : Agroforestry systems (alley cropping, agri-horticultural system and horti-pastoral system)

Culturable waste and marginal lands : Tree farming/woodlots, range/pasture/silvipastoral management system, timber and fibre production systems

Varshney (1972) calculated the foodgrain demands at the peak production efficiency as achieved by the Krishi Pandits for crops like paddy and wheat. He remarked that to support the population at 1972 level, only 17-18 million ha of arable land is required with intensive cropping without deterioration of soil fertility. He also suggested the allocation of the remaining cultivated land for the production of wood, food and ecological security.

Patil and Pathak (1981) compared the rainfed cropping systems with silvipastoral systems on degraded lands in the same climatic zone and found that tree-based systems were not only highly productive, but were highly efficient from the energy and monetary points of view (Table 1).

### **Agroforestry Systems**

An attempt made by Patil and Pathak (1977) described 10 types of agroforestry systems in India broadly grouped under four major areas : (a) social forestry, (b) silviculture, (c) forest farming and (d) agrosilvipasture.

**Table 1.** Comparative estimate of the energy fixation in harvestable biomass by different systems of use.

Land use system	Aerial biomass	Energy
1. Grazing lands	2.8 - 8.0	250 - 960
2. Managed pastures	3.5 - 5.5	1120 - 2000
3. Rainfed agriculture (with inputs & management)		
Sorghum (105 days)	5.9	2597
Pearl millet (67 days)	7.3	3198
Maize	1.7	782
4. Silvipasture (with intensive management possibilities)	7.0 - 15.0	3040 - 6511

This provided a basis for further systems approach since it involved structure, geometry, habitat and perceived benefits of the system. Based on the kind of associated agricultural products, major functions of the tree components, spatial arrangements of trees and the duration of the combination, Combe (1982) suggested 24 agroforestry systems. A broader geographical framework adopted by Nair (1985) included agroecological zones and socioeconomic aspects to describe the system and classify it. According to Tejwani (1987), there could be as many as 48 agroforestry systems. For a general description, the system in practice in different agroecological zones should be adopted.

### **Fodder and Firewood Production in Agroforestry Systems**

Some salient features of a woody species for agroforestry are tolerance to high incidence of pruning, multiple purpose such as forage and firewood, ability to fix nitrogen, low crown diameter to bole diameter ratio, tolerance to side shade and phyllotaxies that allow light to the ground. In addition, the phenology of leaf flushing and fall should favour growth of annual crops. They should be compatible with other species with ideal root growth habit and should be efficient nutrient pumps (King, 1979). The production of forage and firewood in some major agroforestry systems is described below.



## **Agrisilviculture**

In arid and semiarid areas, *Prosopis cineraria* and *Acacia nilotica* are naturally grown with crops like pearl millet and cluster bean. Depending upon the rainfall, about 20-120 mature trees per ha are normally retained and crop production is normally not affected. If regular lopping and pruning are done, 100 trees / ha could be easily maintained without affecting crop production (Shankarnarayan *et al.*, 1987). In some areas, crop yields have increased under these trees. The leaf fodder production from the two tree species has been reported to vary from 1.8 - 7.3 kg/tree and 2.0 - 6.0 kg/tree in *P. cineraria* and *A. nilotica*, respectively. Since the leaf/stem ratio in most of these species varies from 0.4 - 0.7, the woody biomass produced through lopping would be around 6-11 and 5-10 kg/tree, respectively, for the two species. These practices have been found economically sound and socially acceptable in these regions.

The commonly practised taungya system for raising trees in the terai region and the slash and burn agriculture in the north-eastern region are other forms of agrisilviculture followed in this country. These practices add to the rural resources of fodder and firewood. Eucalyptus farming in Punjab and poplars in northern India are further examples of the system where the trees are grown for pulp or match wood while the lops and tops are available for energy (Pathak and Roy, 1993).

A very common practice in the dry zones of Africa, which are similar to the arid zones of India, is the parkland agroforestry system with *Faidherbia albida*. It provides a favourable growing environment for the understorey crops as well as yields products like fodder and wood. Recent introductions of this species in India have been very promising. According to Vandenberg (1993), crops growing under these trees perform better than those growing away from the trees.

## **Farm boundary plantations**

Trees are maintained on the farm boundary by farmers for different purposes. They are either planted systematically or as a mixture. In one of the studies around Jhansi, Tiwari and Sharma (1990) observed variations in tree species and their relative numbers based on soil types and on whether the crops are rainfed or irrigated. Most common species were *Butea monosperma*, *Zizyphus* sp., *Acacia nilotica*, *A. leucophloea* and *Azadirachta indica*. In a study with *Leucaena leucocephala*, Pathak *et al.* (1981) observed that 11-27 t/rkm and 1.0-2.5 t/rkm of firewood and fodder (dry) can be produced in three-year rotations from trees planted at 3.0 m spacing on the farm boundary. Similar results are observed near Pune where farmers are able to grow *Melia azedarach* at 1.0 m spacing to produce a pole crop at 3-4 years yielding about Rs. 80/- per pole, besides the leaf being used for fodder (Personal observation).

## Energy plantation

Planting fast-growing trees at closer spacing for shorter or mini rotations is known as an energy plantation. The basic purpose is to produce small timber and firewood. Eucalyptus and leucaena have been found to be the highest yielders (Table 2) in such plantations.

**Table 2.** Yield of different species in energy plantation.

Species	Yield (t/ha/yr)
<i>Alnus sp.</i>	14 - 17
<i>Calliandra sp.</i>	33
<i>Eucalyptus sp.</i>	31 - 58
<i>Leucaena leucocephala</i>	40 - 60
<i>Paulownia sp.</i>	20 - 23
<i>Platanus occidentalis</i>	27
<i>Populus sp.</i>	5 - 19
<i>Salix sp.</i>	10 - 13
<i>Albizia lebbek</i>	8.5
<i>Dalbergia sissoo</i>	9.9
<i>Acacia nilotica</i>	20
<i>Cassia siamea</i>	12.4
<i>Acacia tortilis</i>	11.8
<i>Prosopis juliflora</i>	13

## Alley farming

Recently heavy emphasis has been laid on alley cropping which integrates woody perennials with crops. Results show variance with the edaphic, soil moisture and crop species examined for the purpose. Leucaena at 2.0 x 0.5 m spacing pollarded at 1.3 m height with crops like sorghum and wheat rotation did not show any reduction in the crop yield while the hedgerows produced 6.0 t/ha dry fodder/yr and 3.0 t/ha/yr firewood from the poles coppiced at three years (Pathak, 1988). Malviya and Patel (1989) reported a remunerative system with leucaena and crops like groundnut, green gram and black gram compared to the sole crop in the Saurashtra region. Osman *et al.* (1989) reported that four-year old trees of leucaena planted at 7.5 x 2.0 m spacing with sorghum reduced the

crop yield by 57%. They recommended wider alleys for reducing the negative effect on crop yield in rainfed agriculture. There are many conflicting reports about the use of alley cropping in dry areas. But these systems are to be seen in the holistic framework where the production of nutritious fodder from the trees is a bonus (Table 3).

**Table 3.** Forage production from hedgerows.

Species	Spacing (m)	Yield
<i>Sesbania sesban</i>	4	17.3
	2	7.2
<i>L. leucocephala</i>	2	9.5
	4	7.4
<i>Gliricidia sepium</i>	4	5.5

### Silvipastoral systems

Silvipasture involves planting of multipurpose trees in existing pastures/grazing lands or on wastelands/denuded lands followed by sowing/planting grasses, legumes or cereals in between the rows of trees. During the initial years of tree establishment ranging from 3-5 years, depending upon the species, grasses and legumes are harvested as hay. Thereafter, the area is maintained either as a seasonal hay plot followed by grazing or grazing as per the carrying capacity of the land in a rotational or deferred rotational grazing system.

### Home gardens in the humid tropics

In the humid tropics, a multi-tier arrangement of trees, shrubs, creepers, grasses, legumes and crops makes it a highly productive system. The emphasis is more on the overall gains from different components. Shade-loving grasses, tree loppings and biomass residues make provision for firewood and fodder.

### Forage production

Systematic studies on established silvipastures with *Acacia tortilis* and *Cenchrus ciliaris* and *C. setigerus* over a period of five years indicated variability due to species and the annual precipitation. Maximum production of 4.27 t/ha was obtained with leucaena + *C. ciliaris* combination. *C. ciliaris* and *Chrysopogon fulvus* produced 7.87 and 7.38 t/ha of forage in association with leucaena. In another study, in the second year of establishment, 7.18 t/ha of *Sehima nervosum* under *A. tortilis* was harvested. Further, Muthana and Shankarnarayan (1978) observed no significant differences in the

production under the canopy of different trees. A forage yield of 2.3 t/ha under *P. cineraria* has been observed under ravine conditions while a mixture of *C. ciliaris* and *D. annulatum* yielded 2.5 t/ha (Prajapati, 1979). On class V and VI wastelands at Dehradun, *C. fulvus* under *D. sissoo* yielded 10.55 t/ha. Thus, depending upon the soil moisture and nutrients, yield differences from 2.0 to 10 t/ha could be obtained per year from grasses.

### **Firewood**

Production of firewood at eight years of growth under silvipasture on wastelands was attempted on *A. tortilis* and *A. amara*. The former yielded 28 t/ha and the latter 38 t/ha. In 10-year rotations on such lands, most short rotation species can produce 4.0-6.0 t/ha/year of firewood at a density of 500 trees/ha. In many trees, annual lopping at 6-7 years has been found to give 2.3-3.5 t/ha fodder and 4.5-6.5 t/ha firewood. Thus, the total biomass produced as forage and top feed is about 10 t/ha.

In long-term studies, subabul produced 1.36 t/ha forage and 0.6 t/ha firewood while the Israeli babul (*Acacia tortilis*) produced 0.5 t/ha forage and 1.44 t/ha firewood at nine years. Lopping has shown improvement in forage and firewood yields of trees in successive years in both these species. Production in summer was less than that in winter. The total biomass produced was 7.0 t/ha; felling at this stage provided 2.2 t/ha wood biomass, thus making 9.2 t/ha/year. In another study, Pathak *et al.* (1992) reported a wood yield of 2.19 t/ha/year in *Albizia lebbbeck* at 15 years. This indicates the possibility of producing 10 t/ha/year in conditions similar to Jhansi.

### **Grazing**

After harvesting the grass in the fourth year when animals were allowed to graze between December to June, they not only maintained their body weight, but showed growth without additional concentrate or salt. The growth and production of grasses during the next monsoon was found to be normal. The leaf litter of trees, the legume component in the pasture and the occasional tree leaf balanced the ration.

### **Land Improvement**

An analysis of soils after six years of silvipasture establishment indicated an increase in nutrients like nitrogen, phosphorus, organic carbon and potassium despite the removal of grasses every year (Singh *et al.*, 1977). Misra *et al.* (1982) also observed an improvement in soil physical properties, pH, nitrogen and organic carbon after four years under silvipasture on a calcareous soil. It has been found that the initial organic matter, available nitrogen, available phosphorus and field capacity are improved by silvipasture over a period of 10 years.

## Conservation and Socio-Economic Gains

Consideration of the net benefit of these systems in a rural setup could indicate its multi-dimensional values in terms of forage, top feed, fuelwood, minor timber and occasional cash crops. Tree growth improves the local microclimate and enhances aesthetic value. The annual litter fall which may vary from 3-6 t/ha/year adds organic matter and pumps up valuable nutrients from the lower levels of soils and makes them available to grasses and legumes for their optimum growth.

Role of such a system in improving salt-affected soils has been highlighted by Yadav (1980). Besides, the availability of firewood would release precious cow dung for manuring crop fields. This system enriches the overall quality of rural life by increasing employment potentials, a healthy environment and overall happiness (Patil and Pathak, 1977). In another study, Pathak (1993) observed a benefit/cost ratio of 1.48 with 22.7% internal rate of return in a 12-year rotation of a silvipastoral system.

In addition, the value of top feeds during lean periods or dry months for animal health and production is enormous. In most of the dry tracts, animals are maintained on these resources and trees such as *Hardwickia binata*, *Prosopis cineraria*, *Ailanthus excelsa*, *Grewia oppositifolia* and *Azadirachta indica* are lopped heavily. The silvipastoral management of wastelands is the most promising approach for conserving soil, water, genetic resources and the environment which are the prime needs of the day.

## Looking Ahead

The systems described above can bridge the gap between demand and supply of firewood and fodder if implemented even on half of the degraded marginal land use systems (Table 4).

**Table 4.** Expected production of firewood and fodder on degraded lands.

System	Products	Present Prod.		Expected Prod.	
		Rate t/ha/yr	Total million/yr	Rate t/ha/yr	Total million/yr
Silvipasture (50 million ha)	Forage	0.5-1.0	25-50	4.0-5.0	200-275
	Top-feeds	Negligible	-	1.6-2.5	80-125
	Firewood	Negligible	-	2.0-3.0	100-150
Agri-silvi	Top-feed	Negligible		0.5-0.8	15-24
	Firewood	Negligible		0.7-0.9	21-27
Alley cropping	Fodder	Negligible		3.0-5.5	90-165

## **Future Research Needs**

Realizing the overall need for a productive and adaptable system for our climatic conditions, the following priorities are identified :

1. Germplasm collection, testing and improvement to broaden the genetic base of multipurpose trees and shrubs for fodder and fuelwood;
2. Studies on tree management and utilization leading to higher productivity;
3. Understanding of the interactive mechanisms of grasses, legumes and trees at different stages of growth and system synthesis for higher yield with sustainability to advise suitable management principles for optimum production from these systems;
4. Use of biofertilisers and moisture-conserving chemicals for improving the establishment of plants on degraded lands;
5. Bioeconomic modelling of growth and production in each region commensurate with local traditions;
6. Produce marketing and pricing structure of tree produce and their value-added products.

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# Nitrogen Fixing Tree Species for Fodder Production through Agroforestry

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## ***Abstract***

*Developing countries like India are experiencing tremendous pressures on natural resources due to overpopulation. As a majority of this population resides in villages, the optimum use of natural resources remains the only viable option for generating gainful employment. India's livestock population is an apt instance of an untapped resource; it is the largest in the world, but approximately 95% of it may be categorised as underproductive and uneconomical. Consequently, the production of fodder for feeding these animals is also economically infeasible. Hence, the livestock is allowed to graze indiscriminately on degraded pastures. Commercial production of fodder can constitute a primary step in the revival of livestock. Since there is enormous pressure on agricultural land to produce food first, fodder production can be taken up on barren tracts using specific tree species. Depending upon the productivity of land and moisture availability, fodder trees can be managed under different systems for intensive fodder production. This strategy will improve the supply of cattle feed.*

## **Introduction**

The 21st century will be an era of challenges for India. India has to plan for an increase in national food production levels from the current 195 million tonnes to 240 million tonnes annually. This denotes a food output augmentation of 40% over the next decade. As population figures rise to the one billion mark, a demand in consumables, apart from foodgrains, will escalate. Thus a scarcity of natural resources combined with limited opportunities in the industrial sector will result in decreased employment generation. Given this scenario, the overarching challenge for India will be boosting production levels while devising novel employment generation schemes.

India has the largest livestock population, which is approximately 15% of the world total. Indian farmers traditionally maintained cattle for milk and bullocks for farm operations. However, prolonged indifferent breeding and inadequate feeding practices resulted in inferior livestock with low productivity traits. Farmers, however, continued maintaining these cattle because of the free access to common property resources such as pastures and village forests; there was no attempt to cull the unproductive animals. Simultaneously, farmers started maintaining goats for milk and meat, as goats consumed low quality vegetation usually not browsed by cattle.

Nationwide, this overpopulation of livestock with indiscriminate grazing patterns has severely eroded the productivity of community pastures. A direct consequence is a significant reduction of fodder from forests and common lands. Fodder supplies have been further depleted by the introduction of high yielding crop varieties which produce lower quantities of crop residues compared to traditional varieties. Therefore, in spite of an increase in cultivated area and improved crop management practices, the supply of crop residues has actually declined.

In the absence of suitable measures to increase fodder production, India experiences a fodder shortage of 64 million tonnes per annum. Estimates for India for 2000 A.D. project annual shortages of 63% and 48% of dry and green fodder, respectively. With fodder and feed in short supply, a bulk of the livestock will starve and remain unproductive. Thus a potentially valuable asset may become a liability.

### **Scope for Fodder Production**

Farmers have shown little interest in undertaking fodder cultivation as an economic activity. In a recent study conducted in Maharashtra, only 2% of households were growing fodder crops like sorghum, maize, and lucerne on agricultural lands. Other fodder crops traditionally grown in the country are burssem (*Trifolium alexandrinum*), oats (*Avena sativa*), napier (*Pennisetum purpureum*), guinea (*Panicum maximum*), cowpea (*Vigna sinensis*) and paragrass (*Bracharia mutica*) which require fertile soil and assured irrigation. The study further indicated that farmers having milking cows, buffaloes or bullocks for farming or transport have taken up fodder production to reduce the cost on concentrate feeds and maximise returns. Although the cultivation of such fodder crops was more profitable than growing food crops, more than 95% of the farmers preferred to maintain their livestock on agricultural by-products and crop residues because a majority of the non-descript animals owned by them did not respond to the feeding of nutritious fodder. Cultivation of seasonal fodder crops can be economical only when the fodder can be sold easily at a remunerative price or used to feed productive animals.

Therefore the challenge is to search for alternative sources of fodder from forests, community wastelands, pastures and underutilised agricultural fields to maintain non-descript animals. The problem is magnified in the case of cattle : there is limited scope to cull a large number of the surplus unproductive stock due to people's sentiments against cow slaughter.

Unfortunately, more than 100 million ha of degraded land, amounting to approximately 30% of the total land area, remains underutilised due to an absence of appropriate technology.

These wastelands can be inducted for fodder production using specific tree species; a combination of fodder trees and agroforestry practices has the potential to generate additional income while reclaiming degraded regions.

## **Agroforestry**

Agroforestry is a sustainable land-use system to cultivate seasonal crops in combination with woody perennials. Depending on the productivity of the land, various trees and arable crops can be combined to increase the returns. This system can be introduced not only on wastelands and marginal agricultural lands, but also on highly productive irrigated lands where the cropping intensity is more than 100%.

The advantage of this system is the possibility of income generation from arable crops from the very first season while trees planted on the field bunds generate additional income in the form of fodder, fuel, timber and other valuable produce. In such a system, trees can be given preference to produce fodder as well as fuel, pole and timber without affecting the total income of farmers.

In many parts of India, poles harvested from 4-6 year old trees is widely used for housing in rural areas and hence fetch a premium price even in rural markets. As these species grow straight with very few side branches, the trees planted in rows on field bunds serve as windbreaks for protecting arable crops from wind and hot weather without competing for sunlight and moisture. As the foliage of some of these species can be used for fodder, farmers can lop side branches regularly to control excess shade in the field and use this foliage to feed their livestock. This may be the first step in motivating farmers to produce quality fodder leading to profitable milk production. Productivity of the soil remains the main criterion in deciding plant density.

## **Advantages of Fodder Trees**

Cultivation of fodder trees and bushes has several advantages compared to seasonal fodder crops. Foremost is their adaptability to harsh agro-climatic conditions. Fodder trees utilise limited quantities of water while remaining productive for longer periods. As

they require minimum maintenance after establishment, the cost of production is low. Flexibility in harvesting fodder from woody perennials is an added advantage; tree fodder is only used when other fodder resources are exhausted. In contrast, most of the seasonal crops mature at one time and any delay in harvesting, even by a week, may affect fodder quality. With proper planning and careful management, it is possible to establish fodder trees even in areas exposed to severe biotic pressure by pollarding the main stems at a height of 1.5 - 2.0 m, so that new shoots produced at that height are beyond the reach of stray animals. In protected areas, this is an ideal strategy to maintain a two-tier system of fodder production.

Establishment of fodder trees on perimeters of agricultural fields as a live hedge, by trimming all branches at 1.0 - 2.0 m, also helps conserve both soil and moisture, thereby enhancing the micro-ecosystem. Live hedges enrich the soil through litter fall and protect arable crops from winds. Fodder output from live hedges is higher compared to windbreaks. As these systems do not harm crop production, instead of growing fodder as a sole crop, it is advantageous to promote it through agroforestry.

## **Tree Fodder Production Systems**

Depending on land characteristics and availability of resources, perennial fodder species can be managed under different systems. These species can be maintained either exclusively for fodder production; or for fuelwood and timber while lopping side branches for fodder. In addition to fodder, several tree species produce fruits and pods which are used as feed for livestock.

While selecting a fodder production system, fertility of the soil and moisture availability should be taken into consideration. For establishing a sole crop of fodder, an adequate supply of water is essential. It is advisable not to establish fodder plantations in dry areas as growth is stunted during the dry season and fodder can be harvested only during the rainy season. Saline soils in irrigated areas, sandy soils where the water table is high or wastelands located on river banks are ideal locales for establishing fodder species. In agricultural fields where soil productivity is high, it is better to undertake alley cropping by planting fodder trees in hedgerows and by cultivating food crops in alleys.

## **Selection of Tree Species**

### **Trees for Fodder Hedges**

Tree species like *Leucaena leucocephala*, *Albizia amara*, *Gliricidia sepium*, *Pithecellobium dulce*, *Desmanthus vergatus*, *Sesbania sesban* and *Calliandra calothyrsus* can be established as fodder hedges by close planting in rows, and managed as bushes by cutting the main stem at a convenient height of 1.0 - 2.0 m. These plants regrow

vigorously after the harvesting of shoots at intervals of 30-60 days depending on the season, soil fertility and moisture availability. It is possible to harvest approximately 15-20 tonnes of dry matter per ha per annum with regular irrigation and fertiliser application. Species like *leucaena* can be maintained for 15-20 years, while *Albizia amara*, *Calliandra* and *Gliricidia* can be managed economically for 8-10 years. Other species like *Sesbania sesban* and *Desmanthus virgatus* lose their vigour and productivity after 3-5 years. These leguminous species fix atmospheric nitrogen in association with the *Rhizobium* bacteria. The fodder from these species is rich in protein and high in digestibility; fodder harvesting is possible 5-7 times annually and there is an assured supply through the year.

Under well-assured irrigation, fodder yields remain very high compared to other traditional fodder crops. As the cost of cultivation after initial establishment is low, these fodder crops are a lucrative option.

### **Fodder Trees for Lopping Side Branches**

Many tree species are not used for harvesting fodder regularly, but their foliage is browsed by livestock. Such species can be managed suitably to harvest some fodder, while the main focus remains the production of timber and other minor produce. However, due to the high value of produce as poles, timber, fruits and oilseeds, it may be uneconomical to maintain these species exclusively for fodder. Therefore, it is preferable to maintain them for poles and other uses while lopping side branches for fodder.

Trees under this system will not contribute significant quantities of fodder regularly, but can yield feed when alternative sources are not available or can supplement crop residues. Important species for lopping fodder in the tropics are :

*Albizia amara*, *Albizia lebeck*, *Albizia falcataria*, *Albizia procera*, *Albizia saman*, *Bauhinia perpurea*, *Dalbergia sissoo*, *Erythrina indica*, *Gliricidia sepium*, *Hardwickia binata*, *Leucaena leucocephala*, *Leucaena diversifolia*, *Pithecellobium dulce*, *Prosopis cineraria*, *Sesbania grandiflora* and *Sesbania sesban*.

This system can be introduced in agricultural fields by planting seedlings on field bunds to establish windbreaks. Experiments have proved that supply of moisture in such a system can enhance crop yields while contributing to farmer's income by way of fodder, fuel and timber.

### **Trees Producing Edible Pods**

Pods and fruits from tree species are highly palatable and can substitute the concentrate feed to some extent. Some of the tree species which produce edible pods are :

*Prosopis juliflora*, *Acacia nilotica*, *Albizia saman*, *Pithecellobium dulce* and *Parkia speciosa*. It has been estimated that a well-maintained *Prosopis juliflora* plantation can yield 2.0-5.0 tonnes of pod every year. Species like *Leucaena leucocephala* produce 1.0-2.0 tonnes of seeds every year which can be crushed and used as cattle feed. Mature pods of *Sesbania grandiflora*, *Sesbania sesban* and most other legumes are rich in protein and make good feed for cattle.

Collection of pods from the trees can be economically viable if the yield is high. These species can boost the productivity of the pastures not only by contributing feed, but also by adding organic matter and conserving soil and moisture.

# Status of Agroforestry in Punjab

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## ***Abstract***

*Excessive use of chemical and underground water in the paddy-wheat cropping system led to soil sickness and the lowering of water table in Punjab. Therefore, a strong need was felt to bring in diversification for sustained agricultural production and environmental protection. With the introduction of fast-growing multipurpose tree species (MPTS) in Punjab, agroforestry has been recognised as a system of high potential to boost the state's meagre forest resources. In particular, boundary planting of eucalyptus in the paddy-wheat cropping system and block planting of poplar intercropped with wheat, oats, berseem, mustard and vegetables are becoming popular in irrigated tracts of the state. Scattered trees of Acacia species on cultivated lands under rainfed conditions, especially in the Kandi region, play an important role in soil conservation and economic returns.*

## **Introduction**

Punjab is one of the leading states of India in agriculture where the area under cultivation is 84% of the total geographical area. About 90% of the cultivated area is irrigated. Although it comprises of 1.5% of the geographical area and 2.5% of the total population of the country, Punjab has been contributing 60-70% of wheat and 40-50% of rice to the central food reserve during the last two decades. The cropping intensity in the state has reached 176 (Bains, 1990).

The economy of Punjab is mainly agriculture-based. Therefore, the socio-economic development of the people, especially of farmers, is also based on the agricultural economy. Agricultural productivity differs considerably in different parts of Punjab. The major causes for such variations are the quality of agricultural land, availability of irrigation facilities and the farming system adopted by farmers. The predominance of the wheat-paddy rotation has depleted the underground water resources of the state. The misuse of natural resources, especially of underground water and felling of forest trees, will adversely affect agricultural productivity further. Therefore, judicious



and efficient use of water and forest resources is one of the most important requirements to improve the socio-economic standards of the people.

## Present Land Use Pattern

The classification of the land area in Punjab (Table 1) shows that the green revolution has not reduced the forest area, but has adversely affected trees grown on farms. Major changes in tree number and species distribution were in farmers' fields.

**Table 1.** Classification of Land Area in Punjab (in '000 ha).

Land Classification	1956-66	1991-92
Net area sown	3796	4227
Forest	87	209
Barren and unarable	181	62
Fallow	314	109
Culturable waste pastures and other unavailable for cultivation	-	45
Non-agricultural uses	381	
Total	5038	5033

Source : Statistical Abstract of Punjab, 1968 and 1992

## Forest Resources

The forest area in Punjab was only 4.15% (209, 000 ha) in 1991-92 as against the 20% recommended by the National Forest Policy of 1952. Most of the forests are in the sub-mountainous and undulating plain regions in the districts of Hoshiarpur (33.0%) and Ropar (23.4%). The productivity of these forests is very low due to grazing, encroachment and over-exploitation. Natural reserve forests do exist in the form of 'birs' in different parts of the state. There are also forest areas in the form of linear strips along canals and roads. What is designated as forest area represents only those forests which are under the control of the Forest Department and does not include the tree plantations on farmers' fields.

## Status of Tree Species on Farmlands

There is a tremendous change in the composition and intensity of tree species in farmers' fields since the advent of the green revolution. Before the green revolution, the tree species grown were *Dalbergia sissoo* (sissoo), *Acacia* spp. (kikar), *Azadirachta indica* (neem), *Prosopis cineraria* (khejri), *Capparis decidua* (karir), *Cordia dichotoma*

(lasoor), *Morus alba* (tut), *Albizia lebbek* (siris), *Butea monosperma* (dhak), *Tamarix articulata* (farmah), *Zizyphus jujube* (ber) and *Salvadora oleoides*. These tree species are included in the farm to meet the needs of the farmers for shade, fuel, fodder and soil conservation. During the consolidation of land-holdings, almost all the trees were felled and removed because of the fear of transfer of ownership.

A major setback to native tree species occurred with the introduction of highly advanced production technology, particularly the heavy tractors and combine harvestors during the green revolution. Farmers uprooted the trees in their fields which were obstructing agricultural operations. In addition, competition from trees to high-yielding varieties of crops was also not acceptable to farmers. Consequently, a severe shortage of tree products was felt by the farming community.

Fortunately in the 1960's and the 1970's two exotic tree species, *Eucalyptus tereticornis* (Mysore gum) and *Populus deltoides* (poplar), were introduced in the state. Subsequently, *Melia* spp. and *Leucaena leucocephala* were also planted on farm lands.

The farmers of the state are mainly interested in only trees which can supplement their income. Therefore, fast-growing trees which can bring early and lucrative returns are preferred. Traditional agroforestry systems are being replaced by those that include fast-growing exotic tree species. Some important agroforestry systems in Punjab are detailed below.

## **Agri-Silviculture System**

### **Kandi Region**

The Kandi region lies in the foothills of the Shivaliks. It covers 9.5% (4800 sq. km) of the total area of the state (Rao, 1987). The topography of this area is undulating. The annual rainfall varies from 750-1200 mm; 80% of the rainfall is received during the monsoon season. Agricultural productivity in this region is very low due to poor soils with low water retaining capacity and heavy soil erosion. In addition, animal wealth is also poor due to the scarcity of grasses and water. As a result, the socio-economic status of the people is low.

Agroforestry has been in practice in this region since ages. Farmers retain local trees like kikar, dhak, sissou, mango, phulai and beri in their cultivated fields. There are many local bushes that bring about soil conservation. Traditional rainfed crops like wheat and maize are cultivated with scattered trees, especially kikar in the fields. As irrigation facilities are increasing, people are retaining kikar and other trees on the bunds only.

### Central Zone (Irrigated)

This region covers the central districts of the state. It is intensively cultivated with the help of highly advanced production technologies supported by well developed irrigation facilities. In order to diversify production in the present farming systems and increase economic returns from the marginal lands, agroforestry practices are being adopted in farmlands in this region.

Boundary plantation of eucalyptus in the paddy-wheat cropping system is very common in this region. Usually a single tree line is planted on farm boundaries, approach paths and water channels. Initially farmers earned Rs.150/- to Rs. 300/- per tree after 12-15 years. Trees in single rows grow faster than those in block plantations. These factors encouraged farmers to plant eucalyptus on a larger scale.

In the late 1980's, however, boundary planting of eucalyptus was discouraged because of the low market value of wood and competitive effects of eucalyptus on adjoining agricultural crops. Studies conducted at Punjab Agricultural University, Ludhiana indicated a 15-31% and a 6-20% loss in grain yields of wheat and paddy, respectively, due to boundary planting of eucalyptus.

The reduction in grain yield also depends upon the orientation of tree rows. Maximum loss was observed in wheat on the northern aspect (Sheikh *et al.*, 1984; Dhillon *et al.*, 1982), but the loss in paddy was towards the southern aspect. The magnitude of the loss increased with the increase in the age of the trees. Maximum loss (47% to 60%) in wheat yield, depending on the age of trees, was recorded at 0-5 m from the tree line. The loss in yield decreased significantly with the increase in distance from the tree line (Dhillon *et al.*, 1982; Dhillon, 1993). The loss can be minimised considerably by maintaining the distance between trees at not less than 3.0 m, orienting the tree line in the North-South direction, growing fodder crops near the tree line and following suitable agronomic practices in the tree-crop interface. Boundary plantation of eucalyptus also serves as a windbreak, providing protection from hot and chilly winds. The other tree species used for boundary plantation are poplar, dhak, mulberry, kikar and sissoo.

Block planting of poplar at 5.0 x 4.0 m spacing is becoming popular among the farmers in this zone. This type of planting is distributed over moderately productive to marginal lands and to 'bet' areas along river banks. The deciduous nature of poplar enabled the intercropping of wheat, berseem, oats, mustard and vegetables during the rabi season. But during the kharif, crop production is possible only during the first three years till the tree canopy closes over. Progressive farmers have harvested poplar plantations six years after planting, earning Rs. 16,000- 17,000 per acre per annum, excluding crop cultivation in the bet area. Moreover, leaf litter from trees help improve soil fertility.

Other important multipurpose tree species used for block planting are eucalyptus and subabul.

### **Western Semi-Arid Zone**

Sub-soil water in this zone is brackish and not suitable for irrigation. Sand dunes and waterlogged or saline soil which need to be reclaimed for sustainable production are the main problems of this area. Kikar, khejri, ber, neem and dhak are the common tree species on farm boundaries and as scattered trees in cultivated fields with different cropping systems.

### **Agri-Silvi-Horticulture System**

The total area under fruit trees in Punjab was 72,665 ha in 1991- 92. Mango trees are grown scattered or in clusters in the Kandi region in association with agricultural crops. In many fields, scattered forest and horticultural trees are retained to supplement the farm income, particularly during crop failure due to poor rainfall. Intercropping of agricultural crops is mainly practised in widely spaced horticultural crops like mango, litchi, gauva and ber. The wide spacing and coniferous canopy of pear enables the cultivation of agricultural crops because of better light infiltration. Moreover, deciduous horticultural crops like peach provide greater scope for growing rabi crops as intercrops. Intercropping in orchards helps protect fruit trees from weed competition and uses natural resources efficiently. Moreover, trees benefit from inputs like irrigation and nutrients applied to the crops. Windbreaks of eucalyptus trees around the orchards is a common sight in Punjab. But this has invited heavy criticism as eucalyptus competes with horticultural trees.

### **Constraints**

- Proper pruning and lopping is lacking in poplar and subabul which affects tree growth and increases competition with agricultural crops.
- High plant density of trees per unit area increases inter- and intra-species competition.
- Inadequate marketing facilities and unrealistic prices discourage tree growers from adopting agroforestry.
- Industrial units for processing wood and other forest products are limited.
- Management practices for different agroforestry systems/models in different environments have not been standardised.
- Conflicts between farmers to grow trees on common farm boundaries due to competition of trees with the crops of the neighbour.

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# MPTS in Agroforestry Practices in Chhattisgarh Region of Madhya Pradesh

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## ***Abstract***

*The paper outlines the results of a survey conducted during the period 1992-93 in Bilaspur district of Chhattisgarh region in Madhya Pradesh to gather information on multipurpose tree species (MPTS). Nearly 25 villages spread over the entire district (stratified random sampling method at 1% sampling intensity) were covered during the survey. Data collected from over 200 farmers in these villages regarding existing agroforestry practices, preference for various MPTS and their utilization, fuel and fodder requirements and constraints in tree farming are presented. The paper concludes that certain MPTS like Acacia nilotica, Butea monosperma, Terminalia arjuna, Albizia procera and Zizyphus mauritiana are an integral part of the rural agroforestry practices of the region and have tremendous importance in poverty alleviation and income generation in the predominantly rainfed agrarian economy of the region. While traditional models with Acacia nilotica and Butea monosperma, and homestead cultivation of horticultural crops have to be encouraged, extensive research inputs have to focus on increasing crop yields through better management of the tree crops and on minimizing competition for resources in the tree-crop interface.*

## **Introduction**

The utility of a single species to produce several products as well as service benefits are best illustrated by MPTS. Burley and Von Carlowitz (1984) defined MPTS in relation to agroforestry systems or other multipurpose land use systems. In the arid and semi-arid environments, MPTS provide social security and economic stability to farmers. Traditional, time-tested agroforestry practices revolving around locally available MPTS

are normally adopted by farmers even if they do not fulfill all their expectations and aspirations. Adoption of a new technology using introduced species may not succeed unless various social, economic and psychological constraints of the farmer are overcome. Survey of traditional practices in relation to MPTS and agroforestry may help in identifying actual field problems, and the needs of the farmers with respect to choice of tree species and provide a valuable data base for channelising further research inputs. Surveys conducted in various agroclimatic regions (Sheik 1991; Hegde, 1991; Jambhale *et al.*, 1992) have proved this point. The results of a survey on MPTS in agroforestry practices in Bilaspur district of Chhattisgarh region of Madhya Pradesh are highlighted in this paper.

## **The Region**

The Chhattisgarh region, known as the rice bowl of Central India, comprises of five districts in the south-eastern part of Madhya Pradesh covering an area of 72,940 sq. km. The region has a predominant agrarian-based economy with more than 80% of the rural population engaged in agriculture, mainly of the subsistence type. Farmers usually take a single rainfed paddy crop during the year. Common soil types known locally as 'kanhar' and 'matasi' are basically residual soils derived from shale and limestone parent materials and appear to be highly suited for paddy cultivation and natural regeneration of *Acacia nilotica*. Other common MPTS in the region include *Terminalia arjuna*, *T. tomentosa*, *Albizia procera*, *Mangifera indica*, *Butea monosperma*, *Zizyphus mauritiana* and *Gmelina arborea* grown on paddy field bunds.

## **Materials and Methods**

An extensive survey was conducted in Bilaspur district. Nearly 200 farmers categorised as marginal (less than 2.0 ha), small (2.0-4.0 ha), medium (4.0-6.0 ha) and large (greater than 6.0 ha) from more than 25 villages selected randomly from all over the district were covered in the survey. Stratified random sampling method at 1% sampling intensity was adopted. Details on cropping patterns, agroforestry practices, tree preferences and constraints were recorded in pre-tested proforma sheets.

## **Results**

1. Most of the respondents listed farming as their main occupation. Paddy was the main agricultural crop followed by some optional pulse crops during the rabi season.
2. Only 36% of the farmer respondents could be considered fully literate of which more than 70% were medium and large farmers.

3. The survey revealed that bund planting of trees and scattered trees on farmlands were the most common agroforestry systems in Chhattisgarh.
4. The prevalent agroforestry models / practices are :
  - a. *Acacia nilotica* - paddy model
  - b. *Butea monosperma* - paddy model
  - c. MPTS like *Albizia procera*, *Terminalia arjuna* and *Gmelina arborea* on field bunds as windbreaks or live hedges on boundaries.
  - d. *Zizyphus mauritiana*-based homestead gardens.
5. Babul (*A. nilotica*) was the most common MPTS in the district, maintained as scattered trees in crop lands and on field bunds. More than 56% of the farmers surveyed had maintained the tree either in a scattered manner inside the field or on field bunds, and there was no significant difference among the different categories of farmers in this regard.
6. Farmlands totally dependent on rains accounted for 61%. Among the others, 20% depended on canal irrigation while 80% had their own sources of irrigation like tubewells or ponds.
7. All the farmers surveyed had standing MPTS up to 62.5 per hectare on their farm lands.
8. *Butea monosperma* model was the second most popular system. Nearly 48% of the farmers maintained them. This practice was confined more to marginal tribal farmers. The trees were mostly maintained on paddy field bunds for lac cultivation.
9. Other common MPTS maintained or planted in farmlands include *Terminalia arjuna*, *Gmelina arborea*, *Leucaena leucocephala*, *Azadirachta indica*, *Zizyphus mauritiana* and *Tamarindus indica*. The first four species were mostly maintained on farm boundaries as shelterbelts/windbreaks or planted on field bunds for longer rotation for timber production. *T. indica* and *Z. mauritiana* (ber) were maintained near the household for their edible products. Ber was extensively lopped during summer and the loppings were used as fencing material or firewood.
10. The survey also indicated that farmers opt for eucalyptus, bamboo and mango in that order of preference, if given a choice to plant on their farms.
11. Among the farmers who preferred eucalyptus, 22% belonged to large, 30% to medium, 27% to marginal and the rest to the small farmer category.
12. More than 30% of the farmers were dependent on forests or forest-based sources for meeting their fuelwood requirements. Less than 25% of the farmers only could



meet their fuelwood requirements from their own farm. The annual firewood requirements varied from 0.5 to 10 t/year/family depending on the size of the family.

13. Majority of the farmers preferred to give crop residues as fodder to their livestock rather than tree fodder.
14. The major constraints in tree farming listed by farmers include (a) stray grazing, (b) erratic rainfall pattern and lack of proper irrigation facilities, (c) non-availability of inputs like superior planting stock, (d) lack of finance / capital, (e) inadequate marketing infrastructure to take up commercial tree planting of MPTS and (f) a low level of awareness regarding the profitability of several MPTS.

## Discussion

Among the traditional agroforestry models being practised by the farmers, the babul-paddy model appears to be the most popular and widely accepted. The temporal and spatial arrangements of this model have been described in detail (Vishwanath *et al.*, 1993). The importance of babul can be directly linked to the typical agrarian economy of Chhattisgarh where its wood is extensively used for making farm implements and for meeting requirements of small timber of the rural household. The economics of this model, worked out by Jena (1991), shows a net additional return of Rs. 5800/ha/yr during the 12-year rotation of the tree in the paddy field at a reciprocal loss of only 6000 kg/ha in terms of paddy yield.

The other popular agroforestry model with *Butea monosperma* has not been well-documented. Viswanath *et al.* (1994) have pointed out that the economic return from sale of lac was an incentive for the tribal practitioners of this model. About 7.0 kg of lac can be harvested from an average tree/year which may fetch about Rs. 150/- in terms of economic returns in addition to other tree products like fibre for rope making, leaf cups and plates.

The survey also revealed a subtle change in the attitude of farmers towards tree planting preferences. Farmers were more inclined to go in for eucalyptus for bund planting to meet fuel and small timber needs. A majority of them felt that eucalyptus would provide quick economic returns notwithstanding the long-term ecological implications in rainfed agro-ecosystems. Bamboo which was another highly preferred species could be encouraged for planting on field bunds, farm boundaries and in homesteads. Regarding choice of fruit trees, mango and ber were preferred but non-availability of improved planting stock was a major constraint. Jambhale *et al.* (1992) in a survey on the attitudes of farmers in rainfed regions of Western India reported similar

preferences by farmers regarding forest tree crops although the choice species for fuelwood and timber were neem, subabul and babul.

At present, there seems to be less emphasis on tree fodder. A lack of proper awareness and non-availability of planting material were two main reasons for this. Trees like subabul and *Sesbania sesban* can be grown on farm boundaries or as block plantations as fodder/protein banks to cater to livestock requirements in addition to meeting the fuelwood demand. This could reduce the dependence of the farmers on forests or forest-based sources for fuelwood.

## Concluding Remarks

Though traditional systems have been very successful, certain modifications or innovations for reducing competition in the tree-crop interface could make these systems more viable. The survey has emphasized that MPTS like *Acacia nilotica* and *Butea monosperma* have the potential to provide the much-needed economic and long-term ecological security to farmers of the Chhattisgarh region.

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# Performance of Multipurpose Tree Species in a Silvi-Olericultural System

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## Introduction

The availability and requirement of green and dry fodder by the end of the century shows a huge deficit. The need for meeting this deficit, especially of green fodder, is well recognised. Under these circumstances, a well planned strategy has to be evolved to bridge the gap between demand and supply of requirement and reduce our dependence on natural forests. Multipurpose tree species (MPTS), particularly legumes, enrich the soil through biological nitrogen fixation, addition of organic matter by plant leaf litter and recycling of nutrients. Vegetables are a dependable source of income to the growers. They are quick growing and yield immediate returns to the growers. Their cultivation as such occupies an important place in the agricultural development of the country. Results of a silvi-olericultural system where vegetables were grown in association with trees are presented in this paper.

## Materials and Methods

The present agroforestry model was studied at the Tropical Forest Research Institute campus situated at latitude 23°37' to 23°60' N and longitude 79°. The experimental site had sandy loam soil with a hard murram layer. The soil was deep and well drained with a pH varying from 5.3 to 7.3 in the surface and the organic matter and electrical conductivity were 1.19% and 0.78 mhos, respectively. It is a semi-arid environment with a mean annual rainfall of 1150 mm, a mean maximum temperature of 33°C and a mean minimum temperature of 18.6°C.

The experiment consisted of five main tree species: *Acacia nilotica*, *Albizia procera*, *Dalbergia sissoo*, *Gmelina arborea* and *Tectona grandis*. They were planted in a randomised block design and intercropped with seasonal vegetable crops at a spacing of 30 x 45 cm. This experiment had four replications with 15 treatments. In each block, there were 64 trees of one species and three vegetable crops every season as intercrops. The details of species combination are given in Table 1. Seedlings of *A. nilotica*, *A. procera*, *D. sissoo*, *G. arborea* and *T. grandis* were planted in July 1992. Seasonal

vegetable crops were directly sown in a strip between trees in a row. Seedlings of vegetables like *Lycopersicum esculentum* and *Solanum melongena* were raised in a nursery and transplanted in the field. The experimental field was flood irrigated every two days.

## Results

Results showed that the best performance of vegetables during the three seasons was under *A. nilotica* followed by *A. procera* (Table 1). In general, the lowest yield was under *T. grandis* and *G. arborea*. However, the yields of vegetables under trees were significantly higher than the sole vegetable crops (control). During the summer season, the maximum yield of *Lycopersicum esculentum* (cv. Pusa ruby), *Solanum melongena* and *Abelmoschus esculentus* were under *A. nilotica*. During the rainy season, when *Phaseolus vulgaris*, *L. esculentum* (hybrid), *Vigna sinensis* were the intercrops, the yield of *V. sinensis* was highest under *D. sissoo*. During the winter, yields of *Raphanus sativus*, *Daucus saroto* and *Spinacia oleracea* were highest under *A. nilotica*. At the end of two years (Table 2), *G. arborea* recorded significantly greater height (341.7 cm) and gbh (14.28 cm) than the other four species. The growth of *T. grandis* with respect to height (96.72 cm) and gbh (6.06 cm) was the lowest.

## Discussion

Studies on intercropping vegetables under trees such as *Acacia tortilis*, *Sesbania sesban* and *Leucaena leucocephala* (Anonymous 1989) showed that, in general, there was a complimentary effect on growth and yield of associated agricultural crops. Compatibility between different components of agroforestry depends on the growth stage because of shade effect and root competition. Studies at Dantiwada in Gujarat (Prasad *et al.*, 1985) showed no adverse effect of *A. tortilis* on intercrops during the first two years, but a detrimental effect was discernible subsequently. It is suspected that the responses under *A. nilotica* may be similar. Allelopathic effects on the growth of *Lycopersicum esculentum*, *Solanum melongena* and *Abelmoschus esculentus* under *A. nilotica* trees have been reported by Swaminathan *et al.* (1989). In the present experiment, since the performance of the seasonal vegetable crops was monitored when *A. nilotica* was only two years or less, the allelopathic effects might have been insignificant. Continuous observation can establish conclusively the vegetable crop combinations under these tree species during various stages of growth.

## Concluding Remarks

The indigenous agroforestry systems evolved in a particular socio-economic environment by farmers can be adopted with appropriate modifications in order to enhance income and employment potential. The study also provided an insight on how to obtain progressively increasing yields per unit area per unit time on a sustained basis and to standardise a specific tree-crop combination to suit local conditions.

**Table 1.** Yield of vegetables in a silvi-olericultural system monitored for three seasons (g/sq.m.) n=4.

Crop Combination	Summer (Feb-Apr 93)			Rainy (Jun-Sept 93)			SeasonWinter (Oct-Jan 94)		
	<i>Tomato</i>	<i>Brinjal</i>	<i>Bhendi</i>	<i>Beans</i>	<i>Tomato</i>	<i>Cowpea</i>	<i>Radish</i>	<i>Carrot</i>	<i>Spinach</i>
<i>Acacia nilotica</i>	1046	1014	1183	782	1644	830	1112	900	1236
<i>Albizia procera</i>	912	1010	838	1031	1139	821	1100	1025	1186
<i>Dalbergia sissoo</i>	626	818	811	894	960	1069	1022	793	1412
<i>Gmelina arborea</i>	855	969	782	468	738	659	639	1118	1050
<i>Tectona grandis</i>	844	750	739	672	1111	698	965	535	962
Control (No trees)	333	296	246	330	295	340	403	364	487
S E M $\pm$	281				229			217	
C D $\pm$ (at 0.5 level)	567				463			438	

**Table 2.** Growth performance of MPTS in a silvi-olericultural system at two years (1993). n = 24 (Mean Values in cm.)

Tree species	Height (cm)	G.B.H. (cm)
<i>Acacia nilotica</i>	282.3	9.99
<i>Albizia procera</i>	221.6	8.97
<i>Dalbergia sissoo</i>	298.2	9.40
<i>Gmelina arborea</i>	341.5	14.28
<i>Tectona grandis</i>	96.72	6.07
SEM $\pm$	21.99	0.867
CD (at 0.5 level)	47.94	2.41

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# Studies on Multipurpose Tree Species for Farm Forestry in Dryland Agriculture

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## *Abstract*

*Evaluation studies on twenty multipurpose tree species (MPTS) for fuel and timber on a medium soil (depth 30-60 cm) at Rahuri under rainfed conditions indicated that in the seventh year of growth, eucalyptus attained the maximum tree height (13.94 m) followed by leucaena (13.02 m) and casuarina (10.40 m). Albizia lebbeck, Azadirachta indica, Cassia siamea and Dalbergia sissoo were medium in growth and had attained a height in the range of 5.90 to 7.46 m. Acacia catechu, Acacia nilotica and Thespesia populnea were slow in growth. A trial on leucaena, eucalyptus and casuarina with three planting patterns (1.0 x 0.5, 1.0 x 1.0 and 2.0 x 1.0 m) was conducted on shallow (depth <30 cm), medium deep (30-60 cm depth) and low-lying (30-100 cm depth) soils at Rahuri in Maharashtra. Growth of trees was influenced by soil depth. In general, irrespective of the soil type, leucaena attained greater height (14.84 m), collar girth (54.2 cm) and gbh (38.6 cm) of bole than eucalyptus and casuarina at seven years. It was closely followed by eucalyptus. In a timber - fibre system on a marginal soil, fibre yield from three cuts of agave was 14.2 t/ha.*

## **Introduction**

Scarcity zone is the largest among the nine agroclimatic zones of Maharashtra. Agricultural crops in this zone are totally dependent on rainfall which is only about 75 cm, erratic and ill-distributed leading to partial or total failure of crops. About 40% of the soils of this zone are unsuitable for arable crops due to their shallowness and low moisture retentive capacities. Thus, under a given situation, soil depth plays a dominant role in deciding the success of crops under dryland conditions. The campus of Mahatma Phule Krishi Vidyapeeth, Rahuri is a typical location in the scarcity zone and receives

only 520 mm of rainfall annually. The rainfall during June to August is scanty and insufficient to sow kharif crops, but September receives a satisfactory rainfall of about 160 mm. The rainfall during June to mid-September is conserved in the soil and post-rainy season (rabi) crops are grown on medium deep and deep soils. Shallow soils (depth 25 cm) are more vulnerable to moisture stress and crop failure is more frequent, occurring usually every third year. These soils pose problems of low and unstable crop production and degradation due to soil erosion resulting from high and frequent cultivation of land for crop production. Obviously, these lands need permanent protection in the form of grasses and trees to avoid soil erosion.

## Methodology

Two permanent non-replicated trials on various MPTS on different soils and one trial on agave in association with MPTS on marginal soil in a split-plot design were laid out at Rahuri. The experimental details are given below.

**Experiment 1 :** To evaluate MPTS for fuel and timber on a medium soil (depth 30-60 cm), 19 species were planted at a distance of 1.0 x 1.0 m and *Gmelina arborea* was planted at 2.0 x 1.0 m in a randomised block design. Out of the 20 MPTS, depending upon availability of seedlings, 10 species were planted on 15 October 1984, four species on 14 August 1985 and the remaining six on 13 August 1986. A separate block plantation for each species was adopted with a plot size of 9.0 x 20 m.

**Experiment 2 :** The experiment was conducted on three different types of soil: shallow (depth < 30 cm), medium (depth 30-60 cm), and low lying (depth 30-100 cm). There were nine treatments in each soil type consisting of *Leucaena leucocephala*, *Eucalyptus* hybrid and *Casuarina equisetifolia* with three plant densities, high (20,000 plants/ha at 1.0 x 0.5 m), medium (10,000 plants/ha at 1.0 x 1.0 m) and low (5000 plants/ha at 2.0 x 1.0 m) in a randomised block design. In shallow and low lying soils, seedlings of MPTS were planted in plots of 14 x 14 m on 15 October 1984 and in the medium soil, planting was done on 6 November 1984 in 12 x 14 m plots.

**Experiment 3 :** In the experiment on timber-fibre system, agave (*Agave kantala*) in association with different MPTS was planted on marginal land (depth <30 cm) in 1985. There were sixteen treatment combinations consisting of four planting patterns of agave (1.0 x 1.0, 1.5 x 1.0, 2.0 x 1.0 and 1.3 x 1.0 m) as main-plot treatments and three MPTS (*A. indica*, *Leucaena leucocephala* and *A. lebbeck*) in association with agave plus one control as sub-plot treatments. The treatments were replicated twice in a split-plot design. The plot size was 12 x 10 m. The number of seedlings of each tree species planted in different planting patterns of agave were 110, 70, 50 and 30 per plot.



One-year old seedlings raised in polybags in the nursery of the Social Forestry Department were planted in all the experiments. The seedlings of agave were raised from bulbils. During the first year, tree seedlings were watered for better establishment and thereafter they were allowed to grow under rainfed conditions. In general, the soils of the experimental plots were calcareous and low in organic carbon, available N, low to medium in available P and fairly rich in available K content.

## Results and Discussion

Results of the evaluation studies of MPTS for fuel and timber in the third year are presented in Table 1 and data on growth parameters on various mature MPTS are presented in Tables 2 and 3. Survival of all the species under rainfed conditions was satisfactory except casuarina (31.66%), *Thespesia populnea* (45.55%), *A. auriculiformis* (48.89%), *Albizia saman* (28.65%) and *A. nilotica* cv. *cupressiformis* (46.11%) (Table 1). In the remaining species, survival was in the range of 66.67 to 100%. Initially, the maximum survival was in *Gmelina arborea* (100%) followed by *A. tortilis* (97.78%), leucaena (97.22%), melia (96.52%) and *A. indica* (95.00%).

**Table 1.** Establishment of MPTS under rainfed conditions at Rahuri.

Tree Species	Survival %	Tree Species	Survival %
Leucaena	97.22	<i>Acacia auriculiformis</i>	48.89
Eucalyptus	85.00	<i>Bauhinia variegata</i>	89.44
Casuarina	31.66	<i>Tectona grandis</i>	81.66
<i>Albizia lebbek</i>	79.44	<i>Acacia tortilis</i>	97.78
<i>Azadirachta indica</i>	95.00	<i>Gmelina arborea</i>	100.00
<i>Cassia siamea</i>	84.44	<i>Melia azaderach</i>	96.52
<i>Dalbergia sissoo</i>	80.00	<i>Albizia saman</i>	28.65
<i>Acacia catechu</i>	78.89	<i>Acacia nilotica</i>	46.11
<i>Acacia nilotica</i>	66.67	<i>Hardwickia binata</i>	82.46
<i>Thespesia populnea</i>	45.55	<i>Bambusa species</i>	--

Count was taken in the third year of growth.

In the 7th year of growth, eucalyptus attained the maximum height (13.94 m) followed by leucaena (13.02 m) and casuarina (10.40 m). *A. lebbek*, *A. indica*, *Cassia siamea* and *D. sissoo* showed moderate growth and attained heights in the range of 5.90 to 7.46 m. *A. catechu*, *A. nilotica* and *Thespesia populnea* were slow growing and attained heights of 3.14 to 4.78 m (Table 2). The collar girth of bole was maximum in *A. lebbek* (58.8 cm) with a gbh of 38.6 cm. Leucaena, eucalyptus, casuarina, *A. indica*,

*Cassia siamea* and *D. sissoo* also attained satisfactory collar girth. In slow-growing MPTS, the range in collar girth and gbh were 18-26 cm and 12-18 cm, respectively. The mean annual increment in height and gbh was highest in eucalyptus followed by leucaena.

**Table 2.** Mean height and bole girth of MPTS at seven years and fuelwood production at five years.

Species	Height (m)	GBH (cm)	Mean annual increment		Fuelwood yield (t/ha)
			Height (m)	GBH (cm)	
<i>Leucaena</i>	13.02	30.6	1.86	4.4	88.32
<i>Eucalyptus</i>	13.94	37.8	1.99	5.4	4.17
<i>Casuarina</i>	10.40	21.2	1.49	3.0	-
<i>A. lebbeck</i>	7.62	38.6	1.09	5.5	1.67
<i>A. indica</i>	5.90	29.1	0.84	4.2	2.44
<i>Cassia siamea</i>	6.04	22.6	0.86	3.2	2.56
<i>D. sissoo</i>	7.46	28.2	1.07	4.0	1.94
<i>A. catechu</i>	3.14	12.0	0.45	1.7	-
<i>A. nilotica</i>	4.78	18.0	0.68	2.6	-
<i>Thespesia populnea</i>	3.48	12.0	0.50	1.7	-

The increment in growth parameters was also satisfactory in *casuarina*, *A. lebbeck* and *D. sissoo* while the lowest increment in growth parameters was in *A. catechu* and *Thespesia populnea*. In the 5th year, 50% plants of *leucaena* and plants showing below average growth among the other five MPTS were harvested for fuelwood. The fuelwood yield from *leucaena* was 88.32 t/ha while it ranged from 1.67 to 4.17 t/ha in the other species.

In another group of 10 MPTS, *A. auriculiformis* attained the maximum tree height (6.76 m) followed by *A. tortilis* (5.84 m), *Bauhinia variegata* (5.56 m) and *Tectona grandis* (4.84 m) at six years. The collar girth and gbh was highest in *A. tortilis* and lowest in *Tectona grandis*. The average annual increment in height was high in *A. auriculiformis* (1.13 m) and *A. tortilis* (0.97 m). In the fifth year of growth, *melia* attained maximum growth. *Gmelina arborea* and *A. nilotica* also performed well in the scarcity zone. *Hardwickia binata*, an excellent fodder tree, can sustain well in the zone, but its initial growth was slow. Fuelwood production from 50% of the trees and below average growth plants was in the range of 6.60 to 15.54 t/ha (Table 3).

**Table 3.** Mean height and bole girth of MPTS at 6th year of growth and fuelwood production.

Tree species	Height (m)	GBH (cm)	Mean annual increment		Fuelwood (t/ha)
			Height (m)	GBH (cm)	
* <i>A. auriculiformis</i>	6.76	21.4	1.13	3.6	11.11
* <i>Bauhinia variegata</i>	5.56	14.2	0.93	2.4	-
* <i>Tectona grandis</i>	4.48	12.0	0.81	2.0	-
* <i>A. tortilis</i>	5.48	25.6	0.97	4.3	9.99
** <i>Gmelina arborea</i>	4.02	15.0	0.80	3.0	6.60
** <i>Melia azedarach</i>	4.80	21.2	0.96	4.2	12.22
** <i>Albizia saman</i>	3.60	18.0	0.72	4.6	12.20
** <i>A. nilotica var. cupressiformis</i>	3.58	8.4	0.72	1.7	15.54
** <i>Hardwickia binata</i>	2.86	5.2	0.57	1.0	-
** <i>Bambusa species</i>	-	-	-	-	-

\* 6th and \*\* 5th year of growth.

**Table 4.** Survival, tree height and bole girth of MPTS in different soils at the 7th year.

Species	Soil	Survival (%)	Height (m)	GBH (m)	Increment		Fuelwood (t/ha)
					Height (m)	GBH (cm)	
Leucaena	Shallow	96.95	13.58	36.0	1.94	5.1	43.10
	Medium	89.95	15.05	40.0	2.15	5.8	42.50
	Low-lying	94.76	15.88	38.9	2.27	5.6	83.59
	Mean	93.89	14.84	38.6	2.12	5.5	56.40
Eucalyptus	Shallow	93.70	13.43	33.1	1.92	4.7	3.79
	Medium	89.64	15.38	39.7	2.20	5.7	4.24
	Low lying	93.20	11.80	35.7	1.69	5.1	3.20
	Mean	92.21	13.54	36.2	1.94	5.2	3.74
Casuarina	Shallow	23.47	11.20	22.8	1.60	3.3	3.23
	Medium	32.99	13.79	28.1	1.96	4.0	4.51
	Low lying	33.19	13.46	27.0	1.92	3.9	6.79
	Mean	29.88	12.79	26.0	1.83	3.7	4.84

1. Survival count at 3rd year.
2. Fuelwood through 50% thinning of leucaena below average growth of eucalyptus and trimming lateral branches of casuarina.

Another trial on three MPTS with different planting patterns on different soils indicated that establishment of leucaena and eucalyptus was more than 90% in all the soils while in casuarina survival was only 23.47 to 33.19%. This suggests that casuarina may not be suitable for rainfed conditions in the scarcity zone. Irrespective of soil and planting pattern, the survival values of leucaena, eucalyptus and casuarina were 93.89, 92.21 and 29.88%, respectively (Table 4). Data reported in Table 4 also indicates that the growth parameters of MPTS were influenced by soil depth and type. Growth parameters such as tree height of leucaena and casuarina were better both in medium and low-lying soils than in shallow soil while eucalyptus had better growth in medium soil at seven years. Irrespective of soil and planting pattern, leucaena attained the maximum tree height (14.84 m), collar girth (54.2 cm) and gbh (38.6 cm). This was closely followed by eucalyptus with tree height, collar girth and gbh of bole of 13.54 m, 49.6 cm and 36.2 cm, respectively. The average increment in growth parameters was also more in leucaena than eucalyptus and casuarina.

In high and medium density plantings, 66 and 50% leucaena trees were harvested by felling alternate two and one rows at the 5th year, and finally 2.0 x 1.0 m spacing was maintained wherein average fuelwood production was 56.40 t/ha. In eucalyptus, by thinning below average growth plants and trimming lateral branches of casuarina, the fuelwood production was from 3.20 to 6.79 t/ha.

**Table 5.** Mean tree height and bole girth of MPTS at six years on marginal soil in Tim-Fib system.

Tree species	Height (m)	GBH (cm)	Mean annual increment		Fuelwood at 4th year (t/ha)
			Height (m)	GBH (cm)	
<i>A. indica</i>	5.21	20.5	0.86	3.4	-
<i>A. lebbeck</i>	7.63	34.3	1.27	5.7	-
Leucaena	13.69	40.1	2.28	6.7	52.65

\* Fuelwood production through 50% thinning of plants.

Irrespective of planting pattern of agave, leucaena species attained the maximum tree height (13.69 m), collar girth (55.2 cm) and gbh (40.1 cm) of bole at six years on the marginal soil (Table 5). The tree height of leucaena was 2.0 to 2.5 times higher compared to *A. lebbeck* and *A. indica*. Due to fast growth and presence of lateral branches, leucaena intercepted 70 to 80% light at four years. To minimise the shade

effect on the growth of understory agave, alternate trees of leucaena in association with agave were thinned in the 4th year. Fuelwood production of felled leucaena on dry weight basis was 52.65 t/ha.

**Table 6.** Fibre production from agave in Tim.-Fib system.

Treatment	Fibre production (g/ha)			Total
	I	II	III	
<b>A) Planting pattern of agave</b>				
1.0 x 1.0 m <sup>2</sup>	3.20	6.03	5.19	14.42
1.5 x 1.0 m <sup>2</sup>	3.47	6.28	5.94	15.69
2.0 x 1.0 m <sup>2</sup>	4.32	4.97	5.00	14.29
1.3 x 1.0 m <sup>2</sup>	3.78	4.06	4.55	12.39
S.E. ±	0.07	1.25	0.29	-
C.D. at 5%	0.22	N.S.	N.S.	-
<b>B) Effect of association of trees</b>				
Control (without tree)	3.76	5.49	5.10	14.35
<i>A. indica</i>	3.95	4.92	4.87	13.74
<i>A. lebbek</i>	3.75	5.17	5.60	14.52
Leucaena	3.33	5.17	5.11	13.61
S.E. ±	0.12	0.57	0.42	-
C.D. at 5%	0.37	N.S.	N.S.	-
Interaction	N.S.	N.S.	Sig.	-
Mean	3.69	5.34	5.17	14.20

The planting pattern of agave significantly influenced its fibre production. At four years, 2.0 x 1.0 m spacing produced significantly more fibre (4.32 kg/ha) than other treatments. Paired planting of agave (1-3 x 1.0 m) was significantly higher than 1.0 x 1.0 and 1.5 x 1.0 m spacings. Fibre production of agave in association with MPTS was significant only at first cut. The fibre yield of agave decreased more in association with leucaena than with other MPTS. This can be attributed to the stunted growth of agave due to the shade effect of leucaena and was overcome after the harvest of 50% of trees (Table 6). The total fibre production from three cuts of agave was 1420 kg/ha.

The interactive effects were significant only at the third cut at six years. At the third cut, the agave fibre production was maximum (677 kg/ha) in 2.0 x 1.0 m spacing in association with *A. lebbek*.

# Potential Role of *Dalbergia sissoo* in Agroforestry Systems for Sustainable Rainfed Agriculture

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## ***Abstract***

*A field trial was initiated in 1991 on red sandy loam soils at the student farm of the College of Agriculture, Hyderabad to study the potential role of Dalbergia sissoo (sissoo) in dry land agroforestry with arable crops under different nitrogen levels. Seed yields of sunflower and castor were not influenced when grown as intercrops with sissoo during the first two years. During the third year, the arable crops responded well to increased doses of nitrogen fertilization. Sissoo growth was not affected by the intercropped arable crops.*

## **Introduction**

The potential use of multipurpose tree species (MPTS) in various agroforestry systems is being increasingly emphasised. Among them, *Dalbergia sissoo* offers many possibilities by supplementing a part of nitrogen requirement of the associated crops through enrichment of site, providing fuelwood, off season fodder and small timber to cater to the basic needs of rural people for their sustenance in dry lands. Therefore, a field trial was initiated to study the effect of sissoo on the growth and yield of arable crops in dry lands.

## **Materials and Methods**

The experiment was initiated in 1991 on a red sandy loam soil at the student farm at the College of Agriculture, Rajendranagar, Hyderabad. It was a split-plot design with two replicates. The treatments consisted of three different crop management practices in sissoo plantation (continuous cropping, cropping after growing stylo for two years and cropping after two years of fallow), two intercrops (sunflower and castor) and three nitrogen levels (no nitrogen, 50% of recommended nitrogen and recommended nitrogen). Nitrogen treatments were imposed two years after planting sissoo under different crop management practices.

Four-month old seedlings of sissou were planted in pits of 30 cm<sup>3</sup> during the post-monsoon period of 1990 at a spacing of 4.0 x 3.0 m. Regular pot watering was done for sissou whenever required till the onset of the rainy season to ensure satisfactory establishment during the first year. The intercrops were sown during kharif season of every year of study since 1991 between the rows of sissou with recommended spacings. The crops were fertilized with a common dose of 60 kg each of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O per ha at the time of planting. Nitrogen was applied at the rate of 120 kg and 100 kg per ha to sunflower and castor, respectively, in two split doses at sowing and at flowering during 1991 and 1992. The three levels of nitrogen treatments were imposed in 1993. *Stylosanthes hamata* was sown as an understorey pasture crop in the year 1991 as part of the treatments.

## **Results and Discussion**

### **a) Performance of intercrops in sissou**

Mean seed yields of sunflower and castor (438 and 486 kg/ha) were not influenced by the growth of sissou when compared with seed yields of respective sole crops (448 and 477 kg/ha) during the initial two years of the study. This indicates the compatibility of this tree-crop association. Khattak *et. al.* (1980) observed higher yields of wheat in association with sissou than with *Eucalyptus camaldulensis*, *Populus deltoides* and *Bombax ceiba*. Similarly, maize fodder yields with sissou were higher than with other tree combinations on clayey soils of Karnataka (Anonymous, 1989).

### **b) Performance of intercrops under different nitrogen levels**

In 1993, the two crops responded well to nitrogen fertilisation under the different crop management practices in association with sissou. The mean seed yields of sunflower and castor (442 and 487 kg/ha) grown after two years of stylo in association with sissou were comparable to mean seed yields of respective sole crops (498 and 477 kg/ha). But the mean seed yields of sunflower and castor were reduced considerably under continuous cropping and fallowing in sissou plantations (Table 2).

In general, a positive trend was observed in seed yields of sunflower and castor with increasing level of nitrogen irrespective of the crop management practice. But the seed yields of both intercrops were better with 50% of recommended dose of nitrogen only when cropped after two years of stylo. Both stylo and sissou being leguminous species, they might have added organic matter and nitrogen to the soil, resulting in better crop performance at reduced level of nitrogen. This reduces the expenditure on cost of fertiliser by 50%.

### c) Performance of sissoo in association with intercrops

Tree growth determined by height and girth was greater in association with intercrops during the entire period of experimentation. During the first year, the increment in height of intercropped sissoo was almost double that of sole sissoo. It may be due to the availability of fertilisers applied for the intercrops. Misra and Prasad (1980), however, observed no significant difference in growth of intercropped and sole teak and sissoo during the first year. The increment in girth of sissoo was also not affected with growth of associated crops like sunflower and castor in all the evaluations.

### d) Nutrient status of soil in intercropping situation

During the first two years of the study, it was observed that the organic carbon and nitrogen contents in the soil were considerably increased in the sissoo planted plots compared to the open area (Table 4). This clearly indicates that addition of leaf litter and root biomass of sissoo might have helped in building up of soil nutrient status. This is similar to the observations of Misra and Prasad (1980) where N and P increased in the soil under sissoo. Thus, sissoo is a promising species for agroforestry systems for imparting stability and increasing crop yields through enrichment of soils especially in dry lands.

**Table 1.** Yields of arable crops in association with sissoo.

Treatments	Seed Yield (kg/ha)		
	1991	1992	Mean
Sissoo + Sunflower	494	383	438
Sissoo + Castor	672	300	486
Sole Sunflower	481	415	448
Sole Castor	644	311	477



**Table 2.** Yields of arable crops under different crop management practices and nitrogen levels in association with sissoo in 1993.

Treatments		Seed Yield (kg/ha)	
		Sunflower	Castor
Sissoo + After two years stylo	N <sub>0</sub>	197	192
	N <sub>1</sub>	554	655
	N <sub>2</sub>	580	617
Mean		443	488
Sissoo + Continuous cropping	N <sub>0</sub>	121	failed
	N <sub>1</sub>	365	508
	N <sub>2</sub>	500	604
Mean		329	371
Sissoo + After two years Fallow	N <sub>0</sub>	142	failed
	N <sub>1</sub>	298	531
	N <sub>2</sub>	442	608
Mean		294	380
Sole cropping	N <sub>0</sub>	192	104
	N <sub>1</sub>	611	642
	N <sub>2</sub>	694	688
Mean		499	478

**Table 3.** Growth of sissoo as influenced by arable crops.

Treatments	Increment in Height (cm)		Increment in Girth (cm)	
	1991	1992	1991	1992
	Sole sissoo	88.0	87.5	5.5
Sissoo + Sunflower	156.3	92.0	5.5	6.5
Sissoo + Castor	180.3	97.2	5.8	6.6

**Table 4.** Change in nutrient status of soil.

Nitrogen Treatments	Organic Carbon (%)		Available in Soil (kg/ha)	
	1991	1992	1991	1992
Open area	0.22	0.21	104	108
Sole sissoo	0.26	0.64	146	383
Sissoo + Sunflower	0.22	0.61	126	333
Sissoo + Castor	0.20	0.61	124	332

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# Planting System of Forages in *Leucaena leucocephala* under Nitrogen Management Conditions

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## **Abstract**

*An agronomic investigation was conducted to study the green and dry matter yield of forages when intercropped with *Leucaena leucocephala* (subabul) under nitrogen (N) fertilization. The study was conducted at the College of Agriculture, Dhule in Maharashtra during 1983-84 and 1984-85. The experiment was laid in a factorial randomised block design with three replicates. The experiment comprised of sixteen treatments, of which twelve were formed by the combinations of three forage intercrops (stylo, sorghum and cowpea) with four N levels (0, 50, 75 and 100%) applied to intercrops, while the remaining four treatments were of sole crops (subabul, stylo, sorghum and cowpea). Transplanting of subabul seedlings and sowing of intercrops was done in July during 1983 and 1984. The total green forage (57.5 t/ha) and dry matter production (18.6 t/ha) of sorghum was higher at 100% N during both years. Maximum green forage (75.28 t/ha) and dry matter production (29.1 t/ha) were obtained by intercropping sorghum with subabul at 100% level of N. The combined yields obtained in the intercropping systems were higher than sole cropping of forages during both the years.*

## **Introduction**

A great deal of interest has been generated in the production and use of multipurpose tree species (MPTS) and nitrogen fixing trees (NFTs) because they are often considered to be critical components of sustainable agroforestry systems. It is widely accepted that the N fixed by NFTs can be used to improve production of trees, crops and animals and to improve soil fertility. The production of green and dry fodder in Maharashtra is 84.3 million t annually whereas the total requirement is about 148.7 million t. This deficit of 64.4 million t of green and dry fodder can be overcome by systematically growing annuals and perennials in alley cropping. Association of annual cereal and legume forage

with leucaena can supply green fodder throughout the year. Gill and Paṭil (1984) indicated that a maximum green forage production of 5.05 t/ha was obtained when sorghum was intercropped with subabul under rainfed conditions at Jhansi. Maximum green fodder (82.7 t/ha) and dry matter (21.0 t/ha) were produced by applying 150 kg N and 60 kg P<sub>2</sub>O<sub>5</sub>/ha to sorghum at Kanke (Bhagat *et al.*, 1986). The present investigation was undertaken to determine suitable forage crops with subabul under N fertilization for the production of green forage and dry matter.

## Materials and Methods

The experiment was conducted in a factorial randomised block design with three replications at College of Agriculture, Dhule during 1983-84 and 1984-85. The experimental soil was a clay of about 1.0 m depth and slightly alkaline in reaction (pH 8.0). It was medium in available N (240 kg/ha) and P<sub>2</sub>O<sub>5</sub> (23.27 kg/ha) and rich in available K<sub>2</sub>O (495 kg/ha). There were sixteen treatments as detailed in Table 2. Subabul was planted in rows 2.0 m apart and annual cereal and legume fodder were cultivated in the alleys. Leucaena was pruned at 1.0 m height four times for fodder during 1983-84 and six times during 1984-85. The annual cereals and the fodder legume were cut at 15 cm height. Sorghum and cowpea were cut at 50% flowering and stylo at flowering. Sorghum and cowpea were harvested twice during the year while stylo was harvested four times in 1983-84 and five times in 1984-85.

The recommended levels of fertilisers (Table 1) were applied as per the treatments in kharif and rabi seasons. For sorghum, two thirds of the N was applied at sowing and the remainder 25 to 30 days after sowing in both years. All the N was given at sowing to other intercrops. P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O were applied at sowing for all the crops.

**Table 1.** Variety, seed rate and recommended dose of fertilisers.

Forage crop	Variety/ cultivar	Seed rate (kg/ha)	Fertiliser dose (kg/ha)		
			N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Leucaena	Peru	8	20	50	20
Stylo		8	10	60	30
Sorghum	M-35-1	50	120	30	20
Cowpea	E.C.4216	50	15	90	30

The rainfall received during 1983-84 and 1984-85 were 737 mm and 640 mm in 44 and 46 rainy days, respectively. The gross and net plot sizes were 10 x 4.5 m and 6.0 x 3.3 m, respectively.

## **Results and Discussion**

### **Green forage and dry matter yield**

Data pertaining to green forage and dry matter yields as influenced by different treatments are presented in Tables 2 and 3. Total green forage and dry matter production were generally higher in intercropping systems than in sole crops during both years of experimentation. The mean total green forage production was 23.85 t/ha in 1983-84 and 25.67 t/ha in 1984-85. The total dry matter yield was 7.57 and 8.26 t/ha in the first and second years, respectively. The contribution from subabul increased in the second year. This was similar to the results of Desai and Bhoi (1984). Green forage and dry matter yields increased by 55% in the second year. These results are in agreement with the results reported by Gill and Patil (1984 and 1985).

### **Effects of intercrops**

The effect on green forage production as a result of intercropping was significant during both years. Sorghum intercropped with subabul produced the maximum green forage and dry matter in 1983-84 and 1984-85, respectively. This was followed by cowpea and stylo. The lowest dry matter production was registered by stylo intercropped with subabul during both years.

### **Effect of N level**

N had a significant influence on green and dry matter yield of forages. However, green and dry matter yields of subabul were not significantly influenced by N application. There was almost linear increase in the total green forage and dry matter yield with increasing N. Highest green forage production was at 100% N. Dry matter production was 8.92 and 9.65 t/ha of dry matter in 1983-84 and 1984-85, respectively. Similar findings were reported by Chandrashekharan *et al.* (1980).

### **Effects of interactions**

The interaction between cropping systems and N was significant. Sorghum intercropped with subabul at 100% level of N produced the maximum green forage and dry matter during 1983-84 and 1984-85. However, the yield obtained with 75 and 100% levels of N were similar in the case of cowpea and stylo intercropping during both years of

experimentation. Therefore subabul and sorghum formed a suitable combination to produce maximum green (75.28 t/ha) and dry matter yields (29.1 t/ha) with 100% N application.

**Table 2.** Mean total green forage (t/ha) of subabul + forage intercrop as influenced by cropping systems and percent levels of N during 1983-84 and 1984-85.

Treatments	1983-84		1984-85	
	Subabul	Intercrops	Subabul	Intercrops
<b>Effects of Cropping Systems</b>				
Subabul + Stylo	5.48	9.80	8.16	10.95
Subabul + Sorghum	5.06	26.49	7.52	24.24
Subabul + Cowpea	5.37	18.04	8.94	15.39
S.E. $\pm$	0.06	0.21	0.05	0.25
C.D. at 5%	0.16	0.62	0.14	0.73
<b>Effects of N levels</b>				
0	4.74	15.28	7.33	14.37
50	5.14	17.88	8.01	17.21
75	5.47	20.51	8.56	19.32
100	5.83	21.92	8.91	20.80
S.E. $\pm$	0.07	0.24	0.06	0.29
C.D. at 5%	0.19	0.70	0.16	0.85
Interaction	N.S.	Sig.	N.S.	Sig.
Mean	5.30	18.55	8.20	17.47
<b>Sole crops</b>				
Subabul	6.53	-	10.63	-
Stylo	-	11.25	-	12.45
Sorghum	-	30.01	-	26.11
Cowpea	-	20.40	-	18.53

Sig. - Significant, N.S. - Not Significant

**Table 3.** Mean total dry matter yield (t/ha) of subabul + forage intercrops as influenced by cropping systems and nitrogen levels during 1983-84 and 1984-85.

Treatments	1983-84		1984-85	
	Subabul	Intercrops	Subabul	Intercrops
<b>Effects of Cropping Systems</b>				
Subabul + Stylo	1.87	2.84	2.78	3.18
Subabul + Sorghum	1.61	10.07	2.57	9.21
Subabul + Cowpea	1.85	3.96	3.10	3.39
S.E. $\pm$	0.08	0.08	0.03	0.13
C.D. at 5%	0.23	0.23	0.38	0.38
<b>Effect of N levels</b>				
0	1.58	4.69	2.49	4.39
50	1.75	5.52	2.73	5.33
75	1.87	6.36	3.09	6.05
100	2.05	6.87	Sig.	6.56
S.E. $\pm$	0.06	0.09	0.12	0.15
C.D. at 5%	0.17	0.26	0.44	0.44
Interaction	N.S.	Sig.	N.S.	Sig.
Mean	1.82	5.75	2.82	5.44
<b>Sole crops</b>				
Subabul	2.22	-	3.61	-
Stylo	-	3.26	-	3.61
Sorghum	-	10.68	-	9.92
Cowpea	-	4.49	-	4.07

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# Evaluation of Young Multipurpose Tree Species under Alley Cropping in the Tropics

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## ***Abstract***

*Seedlings of six multipurpose tree species (MPTS) were evaluated in association with raised cotton after twelve months of planting. Without watering, maximum survival (100%) was observed in Acacia nilotica cv. cupressiformis (ramkathi), Dichrostachys cinerea (nutan) and Leucaena leucocephala (subabul), and least (82%) in Sesbania sesban (sevari). Sevari (300 cm) was the tallest followed by subabul (267 cm) whereas the shortest among the trees was nutan (120 cm). Pruning yield was highest from sevari (2918 kg/ha), 532 kg/ha from Albizia lebbeck (siris). Best rainfed cotton yield, relative to sole crop, was in association with nutan (289%) and siris (285%). The preliminary growth results show nutan, sevari and subabul to be promising MPTS for agroforestry.*

## **Introduction**

West Nimar Valley of Madhya Pradesh which is in the Tropic of Cancer is inhabited predominantly by tribals. In this region, density of human and animal populations is very high. This has exerted immense pressure on existing vegetation cover for fuel, fodder and small timber. Additionally, the rolling and undulating topography with a high degree of slopes and sparse vegetative cover has resulted in moderate to severe erosion. Selection of appropriate MPTS suitable for alley cropping from among those common to West Nimar Valley is important to overcome the above problems. This paper discusses the results of a one-year evaluation study of six MPTS. Most of these species have traditionally been used as potential sources of energy, pulp, fodder and small timber, but their growth has not been systematically studied under alley cropping in this region.

## **Materials and Methods**

To identify suitable tree species for agroforestry, four-month old container seedlings of six MPTS - *Acacia nilotica* (babul), *Acacia nilotica* cv *cupressiformis* (ramkanthi),



*Albizia lebbek* (sirisi), *Dichrostachys cinerea* (nutan), *Leucaena leucocephala* (subabul) and *Sebania sesban* (sevari) - widely differing in their vegetative growth were transplanted at the Zonal Agril. Research Station (NARP), Khargone, Madhya Pradesh (21° 49' N, 75° 37' E, 251.5 m elevation) during the second week of July 1991 in a randomized complete block design with four replications. Seeds of the above species except sirisi were obtained from the National Research Centre for Agroforestry, Jhansi, Uttar Pradesh. The tree plot size was 10 m x 4.5 m (a row of trees 10 m long, 4.5 m apart) and the spacing within each tree row was 1.0 m. Each tree species had two rows and each row of species was randomized separately within a block. The annual crop in the alley was rainfed cotton sown at a spacing of 45 x 45 cm a few days before transplanting of tree species. Fertiliser was applied at the rate of 60 N: 40 P: 20 K kg/ha. The plots were rainfed and no irrigation was provided. Heights of ten plants of each tree row were measured at six month intervals after planting. Plants were pruned to 1/3 of total height approximately six and 12 months after planting. Alley crop yield was recorded before pruning.

## **Results and Discussion**

### **Climate**

Khargone has a tropical climate with three distinct seasons: rainy (mid-June to October), mild winter (mid-November to mid-February), and extremely hot summer (mid-February to mid-June). There are two distinct monsoons in a year, the southwest and the northeast monsoon. The rainfall in this area is mainly from the southwest monsoon which starts around the second week of June. The normal rainfall is 886 mm, of which 96% is received during the rainy season. During 1991-92 (753.5 mm), the rainfall was normal in July (404 mm), but below normal in August (44 mm) and thereafter.

### **Growth characteristics**

Survival count was made in January and July 1992. Tree survival without irrigation ranged from 98.7-100% and 82-100% in January and July, respectively (Table 1). Maximum survival after one year was in subabul, ramkathi and nutan (100%) followed by babul (96.2%), sirisi (93.7%) and the least in sevari (82.0%). Subabul, ramkathi and nutan did not exhibit any reduction in survival in July compared to that in January. Deb Roy (1989) reported comparable (98.3%) survival in these species when grown in association with crops in Jhansi. Analysis of variance indicated significant differences among the tree species for height, alley crop yield (Table 1) and pruning yield (Table 2) under rainfed conditions. After six months of planting (January 1992), sevari was significantly superior in height (276 cm) and height increment (223 cm) than the other five species. The next best height (199 cm) and height increment (132 cm) was in subabul while sirisi was the shortest (51 cm) and had the lowest height increment (19 cm).

**Table 1.** Survival, height and height increment of six MPTS at two dates after planting and effects on adjacent rainfed cotton crop.

Species	January 1992			July 1992			Rainfed cotton yield	
	Survival (%)	Plant height (cm)	Height increment (cm)	Survival (%)	Plant height (cm)	Height increment (cm)	Yield (kg/ha)	Average row yield of cotton relative to sole crop (%)
<i>Acacia nilotica</i>	100	128	61	96.2	145	17	222	219
<i>Acacia nilotica</i> cv.								
<i>Cupressiformis</i>	100	133	62	100	152	19	258	254
<i>Albizia lebbeck</i>	98.7	51	19	93.7	124	73	289	285
<i>Dichrostachys cinerea</i>	100	88	39	100	120	32	293	289
<i>Leucaena leucocephala</i>	100	199	132	100	267	68	227	224
<i>Sesbania sesban</i>	100	276	223	82	300	23	216	213
Grand mean		146	90		185	39	250	
SEM $\pm$		7.3	6.5		8.6	8.0	18.7	
CD at 1%		30.5	26.9		35.9	33.3	55.8	

Height increments of all the species except siris were lower in July than in January as the growing season was relatively hot and dry in the second half of the year. This reduction was more pronounced in fast-growing species than in slower growing ones. Nevertheless, fast-growing species like subabul maintained substantial height increments (132 cm and 68 cm) in January and July 1992. Sevari, ranked first (223 cm) in January, showed top drying which induced branching during the dry spell resulting in the lowest height increment. According to Allard and Bradshaw (1964), significant interactions suggest that appropriate selection programmes should allow for the identification of a number of species, each particularly adapted to one of the special environments. In the present context, this would mean that on the basis of height increment, a set of tree species may be selected for planting under high rainfall areas and a different set for planting under low rainfall areas like West Nimar Valley. This, however, does not exclude the possibility of selecting a tree species like subabul which may be equally suitable for planting under high as well as low rainfall areas. Thus, the height increment character seems to be of considerable value to the tree breeder for selection under high temperature and moisture stress conditions.

Pruning yield of all the species was lower in January 1992 compared to July 1992 (Table 2). In January, the yield of sevari (1096 kg/ha) was significantly higher than the other five species. But in July, sevari (1822 kg/ha), nutam (1597 kg/ha) and subabul (1258 kg/ha) were significantly higher yielding than the remaining species.

The rainfall received during 1983-84 and 1984-85 were 737 mm and 640 mm in 44 and 46 rainy days, respectively. The gross and net plot sizes were 10 x 4.5 m and 6.0 x 3.3 m, respectively.

## **Results and Discussion**

### **Green forage and dry matter yield**

Data pertaining to green forage and dry matter yields as influenced by different treatments are presented in Tables 2 and 3. Total green forage and dry matter production were generally higher in intercropping systems than in sole crops during both years of experimentation. The mean total green forage production was 23.85 t/ha in 1983-84 and 25.67 t/ha in 1984-85. The total dry matter yield was 7.57 and 8.26 t/ha in the first and second years, respectively. The contribution from subabul increased in the second year. This was similar to the results of Desai and Bhoi (1984). Green forage and dry matter yields increased by 55% in the second year. These results are in agreement with the results reported by Gill and Patil (1984 and 1985).

### **Effects of intercrops**

The effect on green forage production as a result of intercropping was significant during both years. Sorghum intercropped with subabul produced the maximum green forage and dry matter in 1983-84 and 1984-85, respectively. This was followed by cowpea and stylo. The lowest dry matter production was registered by stylo intercropped with subabul during both years.

### **Effect of N level**

N had a significant influence on green and dry matter yield of forages. However, green and dry matter yields of subabul were not significantly influenced by N application. There was almost linear increase in the total green forage and dry matter yield with increasing N. Highest green forage production was at 100% N. Dry matter production was 8.92 and 9.65 t/ha of dry matter in 1983-84 and 1984-85, respectively. Similar findings were reported by Chandrashekharan *et al.* (1980).

### **Effects of interactions**

The interaction between cropping systems and N was significant. Sorghum intercropped with subabul at 100% level of N produced the maximum green forage and dry matter during 1983-84 and 1984-85. However, the yield obtained with 75 and 100% levels of N were similar in the case of cowpea and stylo intercropping during both years of

experimentation. Therefore subabul and sorghum formed a suitable combination to produce maximum green (75.28 t/ha) and dry matter yields (29.1 t/ha) with 100% N application.

**Table 2.** Mean total green forage (t/ha) of subabul + forage intercrop as influenced by cropping systems and percent levels of N during 1983-84 and 1984-85.

Treatments	1983-84		1984-85	
	Subabul	Intercrops	Subabul	Intercrops
<b>Effects of Cropping Systems</b>				
Subabul + Stylo	5.48	9.80	8.16	10.95
Subabul + Sorghum	5.06	26.49	7.52	24.24
Subabul + Cowpea	5.37	18.04	8.94	15.39
S.E. $\pm$	0.06	0.21	0.05	0.25
C.D. at 5%	0.16	0.62	0.14	0.73
<b>Effects of N levels</b>				
0	4.74	15.28	7.33	14.37
50	5.14	17.88	8.01	17.21
75	5.47	20.51	8.56	19.32
100	5.83	21.92	8.91	20.80
S.E. $\pm$	0.07	0.24	0.06	0.29
C.D. at 5%	0.19	0.70	0.16	0.85
Interaction	N.S.	Sig.	N.S.	Sig.
Mean	5.30	18.55	8.20	17.47
<b>Sole crops</b>				
Subabul	6.53	-	10.63	-
Stylo	-	11.25	-	12.45
Sorghum	-	30.01	-	26.11
Cowpea	-	20.40	-	18.53

Sig. - Significant, N.S. - Not Significant

**Table 3.** Mean total dry matter yield (t/ha) of subabul + forage intercrops as influenced by cropping systems and nitrogen levels during 1983-84 and 1984-85.

Treatments	1983-84		1984-85	
	Subabul	Intercrops	Subabul	Intercrops
<b>Effects of Cropping Systems</b>				
Subabul + Stylo	1.87	2.84	2.78	3.18
Subabul + Sorghum	1.61	10.07	2.57	9.21
Subabul + Cowpea	1.85	3.96	3.10	3.39
S.E. $\pm$	0.08	0.08	0.03	0.13
C.D. at 5%	0.23	0.23	0.38	0.38
<b>Effect of N levels</b>				
0	1.58	4.69	2.49	4.39
50	1.75	5.52	2.73	5.33
75	1.87	6.36	3.09	6.05
100	2.05	6.87	Sig.	6.56
S.E. $\pm$	0.06	0.09	0.12	0.15
C.D. at 5%	0.17	0.26	0.44	0.44
Interaction	N.S.	Sig.	N.S.	Sig.
Mean	1.82	5.75	2.82	5.44
<b>Sole crops</b>				
Subabul	2.22	-	3.61	-
Stylo	-	3.26	-	3.61
Sorghum	-	10.68	-	9.92
Cowpea	-	4.49	-	4.07

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# Evaluation of Young Multipurpose Tree Species under Alley Cropping in the Tropics

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## *Abstract*

*Seedlings of six multipurpose tree species (MPTS) were evaluated in association with raised cotton after twelve months of planting. Without watering, maximum survival (100%) was observed in Acacia nilotica cv. cupressiformis (ramkathi), Dichrostachys cinerea (nutan) and Leucaena leucocephala (subabul), and least (82%) in Sesbania sesban (sevari). Sevari (300 cm) was the tallest followed by subabul (267 cm) whereas the shortest among the trees was nutan (120 cm). Pruning yield was highest from sevari (2918 kg/ha), 532 kg/ha from Albizia lebbeck (sirir). Best rainfed cotton yield, relative to sole crop, was in association with nutan (289%) and sirir (285%). The preliminary growth results show nutan, sevari and subabul to be promising MPTS for agroforestry.*

## **Introduction**

West Nimar Valley of Madhya Pradesh which is in the Tropic of Cancer is inhabited predominantly by tribals. In this region, density of human and animal populations is very high. This has exerted immense pressure on existing vegetation cover for fuel, fodder and small timber. Additionally, the rolling and undulating topography with a high degree of slopes and sparse vegetative cover has resulted in moderate to severe erosion. Selection of appropriate MPTS suitable for alley cropping from among those common to West Nimar Valley is important to overcome the above problems. This paper discusses the results of a one-year evaluation study of six MPTS. Most of these species have traditionally been used as potential sources of energy, pulp, fodder and small timber, but their growth has not been systematically studied under alley cropping in this region.

## **Materials and Methods**

To identify suitable tree species for agroforestry, four-month old container seedlings of six MPTS - *Acacia nilotica* (babul), *Acacia nilotica* cv *cupressiformis* (ramkanthi),

*Albizia lebbek* (siris), *Dichrostachys cinerea* (nutan), *Leucaena leucocephala* (subabul) and *Sebania sesban* (seviri) - widely differing in their vegetative growth were transplanted at the Zonal Agril. Research Station (NARP), Khargone, Madhya Pradesh (21°, 49' N, 75° 37' E, 251.5 m elevation) during the second week of July 1991 in a randomized complete block design with four replications. Seeds of the above species except siris were obtained from the National Research Centre for Agroforestry, Jhansi, Uttar Pradesh. The tree plot size was 10 m x 4.5 m (a row of trees 10 m long, 4.5 m apart) and the spacing within each tree row was 1.0 m. Each tree species had two rows and each row of species was randomized separately within a block. The annual crop in the alley was rainfed cotton sown at a spacing of 45 x 45 cm a few days before transplanting of tree species. Fertiliser was applied at the rate of 60 N: 40 P: 20 K kg/ha. The plots were rainfed and no irrigation was provided. Heights of ten plants of each tree row were measured at six month intervals after planting. Plants were pruned to 1/3 of total height approximately six and 12 months after planting. Alley crop yield was recorded before pruning.

## **Results and Discussion**

### **Climate**

Khargone has a tropical climate with three distinct seasons: rainy (mid-June to October), mild winter (mid-November to mid-February), and extremely hot summer (mid-February to mid-June). There are two distinct monsoons in a year, the southwest and the northeast monsoon. The rainfall in this area is mainly from the southwest monsoon which starts around the second week of June. The normal rainfall is 886 mm, of which 96% is received during the rainy season. During 1991-92 (753.5 mm), the rainfall was normal in July (404 mm), but below normal in August (44 mm) and thereafter.

### **Growth characteristics**

Survival count was made in January and July 1992. Tree survival without irrigation ranged from 98.7-100% and 82-100% in January and July, respectively (Table 1). Maximum survival after one year was in subabul, ramkathi and nutan (100%) followed by babul (96.2%), siris (93.7%) and the least in seviri (82.0%). Subabul, ramkathi and nutan did not exhibit any reduction in survival in July compared to that in January. Deb Roy (1989) reported comparable (98.3%) survival in these species when grown in association with crops in Jhansi. Analysis of variance indicated significant differences among the tree species for height, alley crop yield (Table 1) and pruning yield (Table 2) under rainfed conditions. After six months of planting (January 1992), seviri was significantly superior in height (276 cm) and height increment (223 cm) than the other five species. The next best height (199 cm) and height increment (132 cm) was in subabul while siris was the shortest (51 cm) and had the lowest height increment (19 cm).

**Table 1.** Survival, height and height increment of six MPTS at two dates after planting and effects on adjacent rainfed cotton crop.

Species	January 1992			July 1992			Rainfed cotton yield	
	Survival (%)	Plant height (cm)	Height increment (cm)	Survival (%)	Plant height (cm)	Height increment (cm)	Yield (kg/ha)	Average row yield of cotton relative to sole crop (%)
<i>Acacia nilotica</i>	100	128	61	96.2	145	17	222	219
<i>Acacia nilotica cv.</i>								
<i>Cupressiformis</i>	100	133	62	100	152	19	258	254
<i>Albizia lebbek</i>	98.7	51	19	93.7	124	73	289	285
<i>Dichrostachys cinerea</i>	100	88	39	100	120	32	293	289
<i>Leucaena leucocephala</i>	100	199	132	100	267	68	227	224
<i>Sesbania sesban</i>	100	276	223	82	300	23	216	213
Grand mean		146	90		185	39	250	
SEM $\pm$		7.3	6.5		8.6	8.0	18.7	
CD at 1%		30.5	26.9		35.9	33.3	55.8	

Height increments of all the species except siris were lower in July than in January as the growing season was relatively hot and dry in the second half of the year. This reduction was more pronounced in fast-growing species than in slower growing ones. Nevertheless, fast-growing species like subabul maintained substantial height increments (132 cm and 68 cm) in January and July 1992. Sevari, ranked first (223 cm) in January, showed top drying which induced branching during the dry spell resulting in the lowest height increment. According to Allard and Bradshaw (1964), significant interactions suggest that appropriate selection programmes should allow for the identification of a number of species, each particularly adapted to one of the special environments. In the present context, this would mean that on the basis of height increment, a set of tree species may be selected for planting under high rainfall areas and a different set for planting under low rainfall areas like West Nimar Valley. This, however, does not exclude the possibility of selecting a tree species like subabul which may be equally suitable for planting under high as well as low rainfall areas. Thus, the height increment character seems to be of considerable value to the tree breeder for selection under high temperature and moisture stress conditions.

Pruning yield of all the species was lower in January 1992 compared to July 1992 (Table 2). In January, the yield of sevari (1096 kg/ha) was significantly higher than the other five species. But in July, sevari (1822 kg/ha), nutan (1597 kg/ha) and subabul (1258 kg/ha) were significantly higher yielding than the remaining species.



Rainfed cotton yields in association with nutan (293 kg/ha), siris (288.89 kg/ha) and ramkathi (258 kg/ha) were significantly higher than other associations. Cotton yield was lowest (216 kg/ha) in association with sevari. The control plot (without trees) yielded 101 kg/ha. Due to late sowing and early withdrawal of monsoon, the establishment of cotton was unsatisfactory. As a result, the yield was low. Under alley cropping, rainfed cotton yield was distinctly higher than sole rainfed cotton (control). Highest cotton yields relative to the sole crop were obtained in association with nutan (289%) and siris (285%).

The preliminary growth results show nutan, sevari and subabul as promising MPTS for agroforestry in West Nimar Valley with the potential to provide fuelwood and fodder under rainfed conditions.

**Table 2.** Pruning yield (kg/ha) of six MPTS at two dates after planting.

Species	Pruning dates		Total yield after one year
	January 92	July 92	
<i>Acacia nilotica</i>	146	575	721
<i>Acacia nilotica cv.</i>			
<i>Cupressiformis</i>	144	592	736
<i>Albizia lebbbeck</i>	18	514	532
<i>Dichrostachys cinerea</i>	189	1597	1786
<i>Leucaena leucocephala</i>	396	1258	1654
<i>Sesbania sesban</i>	1096	1822	2918
Grand mean	331	1060	1391
SEM $\pm$	147	202	273
CD at 1%	613	842	1140

### Acknowledgements

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# ***Hardwickia binata* - a Promising MPTS for Agroforestry in Dryland Areas**

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## ***Abstract***

*Farmers in dry areas need tree resources for the supply of fodder, fuel, timber and cash. When trees are grown with crops in dryland areas, competition for water cannot be avoided. Therefore, the best alternative would be to select a multipurpose tree species (MPTS) which competes least with crops and has multiple utilities. Hardwickia binata is one such species which is slow growing, erect and competes least with companion crops. Under dryland conditions, the tree may take 20-25 years to attain a diameter at breast height (DBH) of 30 cm. In studies at Bijapur, eight-year old trees spaced at 5.0 x 2.0 m had a standing biomass of 9.9 kg/tree (dry weight) in which the stem constituted 75%. Leaf yield from loppings was 0.9 kg/tree/yr. At eight years, trees recorded a height and DBH of 4.5 m and 7.7 cm, respectively. In intercropping studies, rabi sorghum yielded 52% of no-tree control when the trees were 6-7 years. However, if only the area sown to sorghum is taken into account, the yield under this tree was 100% of no tree control. This was significantly superior to the other tree species tested. Apart from arable lands, this tree also has the potential for being planted along bunds, farm roads and other soil and water conservation structures. In Hyderabad, trees planted on either side of a 6.0m wide farm road at 6.0 m intra-row spacing attained a DBH of 25 cm at 20 yrs of age.*

## **Introduction**

Tree populations in dry areas have been dwindling. Introduction of trees into dryland cropping systems resulted in competition for moisture between trees and crops. Therefore, the selection of tree species and their management are important for growing trees in drylands without adversely affecting crop growth significantly.

## Materials and Methods

*Hardwickia binata* seedlings were planted in an East-West direction at 5.0 x 2.0 m spacing in June 1983 at the Agricultural Research Station, Bijapur (16° 49' N latitude and 75° 42' E longitude). The soil is a shallow (<30 cm) black vertisol. The average annual rainfall at the station is 644 mm. The trees were intercropped with grass from 1983 to 1988.

During 1988-89 and 1990-91, the trees were subjected to four levels of management, namely control (no management), root pruning only, lopping only and root pruning plus lopping. Root pruning was achieved by ploughing close to the tree rows on either side to a depth of 30 cm with tractor-drawn MB-plough during the mid-kharif season. The lopping treatment consisted of removing branches from the lower 2/3 height before sowing the rabi crop. Rabi sorghum was intercropped with the trees during 1989-90 and 1990-91. Sole sorghum was also grown in the no-tree control plot.

## Results and Discussion

Grain yield of sorghum was significantly influenced by tree management during both the years (Table 1). Sole sorghum produced significantly higher yield during both years, followed by sorghum grown with root pruned plus lopped trees, lopped trees, root pruned trees and control trees. Root pruning and lopping reduced the competition for moisture and light, respectively, thereby decreasing the adverse effect of trees on the arable crop. Beneficial effects of root pruning on associated crops have been reported (Dhadwal *et al.*, 1986; Korwar and Radder, 1994). Similarly, benefits of tree lopping have also been reported (Hocking and Rao, 1990; Muthana and Arora, 1974). Of the two factors tested, root pruning was more beneficial than lopping. Similar results have been reported by Verinumbe and Okali (1985).

At six years, trees recorded an average height and DBH of 2.9 m and 4.2 cm, respectively; the corresponding figures at eight years were 4.5 m and 7.7 cm (Table 2). Tree height and DBH were not significantly influenced by tree management treatments. It appears that even though the lateral spread of the roots is contained, the trees extract moisture through their vertical roots from deeper layers. Similarly, light lopping of the canopy did not have adverse effects on tree growth. Dry matter increment (Table 3) in the trees between 6-8 years was 3.92 kg/ha/yr. It was not significantly influenced by tree management treatments. At eight years, the average standing biomass (DW basis) was 9.9 kg/tree.

**Table 1.** Grain yield of sorghum as influenced by tree management.

Treatment	Grain Yield (kg/ha)		
	1989-90	1990-91	Mean
Control (no management)	255	195	225
Root pruning only	300	250	275
Lopping only	435	330	383
Root pruning plus lopping	440	375	408
Sole Sorghum	698	554	626
SEM $\pm$	29.4	6.8	
CD (5%)	116	27	

**Table 2.** Height and DBH of trees as influenced by their management.

Treatment	DBH (cm)			Height (m)		
	June	June	June	June	June	June
	1989	1990	1991	1989	1990	1991
Control (no management)	4.2	5.8	7.6	2.85	3.85	4.65
Root pruning only	4.2	6.2	7.7	2.80	3.65	4.35
Lopping only	4.3	6.1	7.8	2.90	3.80	4.50
Root pruning plus lopping	4.3	6.0	7.6	3.00	3.60	4.35
SEM $\pm$	.36	.51	.51	.24	.29	.29
CD (5%)	NS	NS	NS	NS	NS	NS

**Table 3.** Dry matter increment during 6 to 8 yrs. (June 1989 to June 1991) as influenced by tree management treatments.

Treatment	Dry matter increment (kg/tree/yr)			
	Leaf	Branch	Stem	Total
Control (no management)	.65	.34	2.91	3.90
Root pruning only	.60	.34	3.03	3.96
Lopping only	.75	.29	2.93	3.97
Root pruning plus lopping	.69	.28	2.86	3.83
SEM $\pm$	.234	.132	.846	1.183
CD (5%)	NS	NS	NS	NS

Mean data of the two years showed that grain yield of sorghum with root pruned plus lopped trees was 65% of sole sorghum. Considering the fact that within tree stands, sorghum can be sown only in a 3.0 m strip, out of the 5.0 m space between two tree rows, the yield obtained with trees on area occupied basis is same as that in sole sorghum.

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# Studies on Non-Wood Produce of *Hardwickia binata* and *Madhuca latifolia*

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## ***Abstract***

*Phenological observations like leaf fall, new leaf emergence, deciduous or evergreen habits, crown shape and crown size, availability and yield of leaves, flowers and fruits are very important parameters of species yielding non-wood produce. These parameters were recorded in Hardwickia binata (anjan) and Madhuca latifolia (madhuca). The present study collected information regarding periods of leaf fall, flowering and fruiting in these species and average leaf yield in anjan and flower and seed yields in madhuca. This study also identified the safe limit of lopping intensity in anjan. Local variations in leaf fall and flower initiation were also observed.*

## **Introduction**

Man has always been dependent on trees for his needs like food, fodder, fuel and fibre. The knowledge of periodical variations in the life cycle of tree species and the estimation of produce is of great importance in this regard. Phenological studies on many species have been conducted (Krishnaswamy and Mathanda, 1954), but not much emphasis has been placed on the potential of non-wood produce. Considering the current importance, studies on *Hardwickia binata* (anjan) and *Madhuca latifolia* (madhuca) were initiated.

## **Materials and Methods**

### ***Hardwickia binata***

The studies were confined to the area in compartment numbers 330, 331 and 332 in Jimalgatta Range of the Pranhita Forest Division in Maharashtra. Observations were recorded from 100 mature trees. Since different shapes of the crown were observed, the diameter of the crown in two opposite directions and height of the crown were measured to determine the volume of the crown. For each girth class, crown volume was determined with 10 selected trees. Lower 0.25 to 0.33 of the crown of one sample tree from each girth class was lopped at two different periods to study the optimum intensity

of lopping and period of lopping. The weight of the leaves and twigs (fresh and dry) in the lopped crown and the weight of the collected leaf litter were measured.

### ***Madhuca latifolia***

Girth class-wise trees were selected in compartment number 195 in Tadgaon Range of Bhamragarh Division, Maharashtra. Diameter and height of the crown were measured to determine the crown volume. Leaf litter, flowers and seeds collected were weighed to calculate the average yield. Observations on leaf fall, flowering and fruiting were made periodically.

## **Observations**

### ***Hardwickia binata***

The frequency of occurrence of different crown shapes was as follows : conical - 64%, irregular - 16%, cylindrical - 14%, double pyramidal - 4% and mushroom - 2%. Highest volume of 1505 m<sup>3</sup> was in mushroom-shaped crown followed by cylindrical 1253 m<sup>3</sup>, irregular 1186.5 m<sup>3</sup>, conical 620 m<sup>3</sup> and double pyramidal 501 m<sup>3</sup>.

Crown volume increased with girth and this was also reflected in the quantity of leaf litter and twigs and leaves obtained from the lower 0.25 of the crown. Observations on lopping of crown showed that lopping in December takes about 10 months for recouplement whereas lopping in May required only about six months for recovery.

### ***Madhuca latifolia***

There were four different shapes of crown: irregular, cylindrical, spherical and conical. In general, crown volume increased with increase in girth. The bole was reported to be invariably shorter with maximum average bole height being 8.5 m (Troup, 1985). Leaf litter, flower and seed quantity increased with girth and crown volume (Table 2). On an average, 12.9 kg of flowers (dry) and 2.7 kg of seed (dry) per tree were obtained. The ratio of sun dried flowers to fresh flowers is 0.276 as against 0.377 reported by Awasthi (1971).

Maximum leaf fall was observed during March. Leaf initiation occurred towards the end of March whereas flower initiation started in the beginning of March. The full bloom period was from 12-31 March and total flowering period extended from 1st March to mid-April. Fruits matured in May-June and dropped immediately.

## **Discussion and Conclusion**

The lopping studies on anjan showed that an average of 20 kg leaves per tree can be obtained by lopping the lower 0.25-0.33 part of the crown every year. Lopping in May takes less time for recouplement than in December. However, previous studies show that

lopping in winter results in recovery during the next season. Lopping should be restricted to lower two-third of the crown and lopped trees should be rested for two seasons (Deb Roy *et al.*, 1980).

Narayan and Dabadghao (1972) demonstrated that anjan leaves are better than grass fodder in nutritive value. Therefore, when grasses dry up and perish, generally from January onwards, leaves of anjan can be used as high-value fodder during summer or can even be mixed with grasses to increase the nutrient value of fodder. In a plantation of anjan, maximum fodder can be obtained from trees of gbh class 121-135 cm having 156 trees/ha which can yield 5148 kg of fodder. But 400 trees/ha of gbh class 76-90 will be economical as waiting period will be short and the yield of about 4000 kg of leaf fodder is higher than the yield of many fodder grasses.

The study on madhuca showed that average production of mahua flowers (dry) and seeds per tree are 13 kg and 3.0 kg, respectively. The maximum quantity of flowers obtained was 20 kg and that of seed was 4.3 kg. This may be a lower estimate because 1992 was not a good seed year as fruiting in alternate years is not uncommon in madhuca (Anon. 1962). The study also showed that flower and seed production increases with the size of crown and girth of the tree. Local variations in leaf fall period and flower initiation are reported (Troup, 1985; Krishnaswamy and Mathanda, 1954).

The collection and sale of mahua flowers and seed is done by the Tribal Development Corporation and covered under the Monopoly Act. Sale figures show that average prices of mahua flowers and seed per kg were Rs. 1.75 and Rs. 3.85, respectively. Though the commercial rates of flowers and seeds do not appear very attractive, considering the high nutritional value and fatty oil content, it has an important place in the life of tribals. If a plantation of madhuca is thought of for its flowers and seed, the number of trees per ha to be planted depends upon the crown spread. The maximum yield of 1500 kg of flowers and 400 kg of seed can be obtained with 100 trees per ha when trees attain 176-190 cm gbh followed by 125 trees/ha yielding 1230 kg of flowers and 125 kg of seeds when the trees attain 91-105 cm gbh. The respective per hectare economic returns from these two girth classes were Rs. 4165/- and Rs. 2635/-, respectively. The latter is economical since the gestation period is short compared to the former. Records indicate that mahua trees start flowering at the age of 10 years and mature for the purpose of flower and fruit collection at 15 years of age and have a productive life span of 85 years (Awasthi, 1971).

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# **Poplar Introduction for Agroforestry in Maharashtra**

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## **Introduction**

Poplars are among the world's fastest growing industrial softwoods and can be harvested within a reasonably short period of 8-10 years depending on the end use. Poplar wood is excellent for manufacturing matches, veneers, fibre boards, paper pulp and light packaging. Consequently, it enjoys a large-scale demand.

## **Special Features of Poplars**

Poplars can be grown in pure or mixed tree plantations or can be combined with agricultural crops under agroforestry practices. Because of their leaf-shedding habit, it is possible to grow intercrops during winter. Thus, poplars are well suited for agroforestry. They have already been recognised as an important component of agroforestry in the North Indian Tarai belt. Poplars being comparatively little known in the country, a brief introduction on their salient features would be useful.

Poplars naturally occur interspersed throughout the forests of temperate and cold regions of Northern Hemisphere between 30° to 45° latitude. Indigenous poplars do well in areas having a temperature range from 6° to 18°. Poplars are generally sensitive to high temperatures, hot summer winds, fire and frost. This is particularly so at the seedling stage. Poplars thrive well in near-alkaline soils, though most species tolerate moderate acidity. Soils with a pH of 6-7 support poplars well.

Though poplars grow on a variety of soils from clayey to sandy, growth is slow on extreme soil types. Fertile loam or silty loam soils with high water tables and rich in organic matter are best for poplar cultivation. Poplars cannot withstand waterlogging. They are drought susceptible. Good soil aeration is an important requirement as they have a very high rate of root respiration compared to other woody species. Thus, poplars prefer deep, well-drained and nutrient-rich soils.

Poplars are dioecious : male and female flowers appear on different trees. Reproduction of poplars is primarily by vegetative propagation. An important characteristic of poplar is that hybridisation between trees of different types is relatively common, rendering evolution of genetically superior variations easy.

### **Nursery and Planting**

Plants can be raised from seeds and branch cuttings. Best cuttings are obtained from the main stem of one-year old healthy and vigorous plants. The cuttings should be 1.0-5.0 cm in diameter, 18-25 cm in length and should contain three to five live buds.

Cuttings of poplar should preferably be planted in January in the nursery. Planting should not be delayed beyond February. The cutting should be vertically inserted in prepared nursery soil. Sandy loam is best suited for this purpose. Heavy clays and acid soils should be avoided. Poplars being fast-growing species, frequent enrichment of the nursery soil by the application of fertiliser, farmyard manure or compost is necessary.

The ideal site for poplar is a fertile loamy soil with a summer water table not lower than 1.0-2.0 m below the soil surface. Poplars can be grown on many other soils as well, but growth will be less vigorous. However, shallow and extremely clayey and sandy soils are unsuitable.

Poplars are light-demanding trees and lose their vigour if crowns are suppressed or shaded. To accommodate the fast rate of growth, planting is usually done at spacings from 3.0 x 3.0 m to 6.0 x 6.0 m depending upon the enduse and intercrops desired. Usually one-year old naked rooted entire transplants (ETPs) raised in irrigated nursery beds are planted in the field in January/February.

### **Field Management**

Weeding and mulching enhance growth. A mulch of vegetation, straw or other suitable material effectively suppresses weeds. Pruning is necessary in order to get knot-free timber, but this should not be done unless the trees are well-established. Pruning can be done at 2-3 year intervals as the objective is to cut branches when they are small. Since excessive pruning stimulates epicormic branches, care should be taken not to remove too many branches at a time.

The initial growth of poplars can be boosted by the application of fertilisers and irrigation. Poplar requires adequate protection against insect pests and fungal diseases, particularly in the early stages.

## Introduction Trials in Site Districts

It was generally believed that poplars would not grow in areas outside their natural habitat, especially south of 28°N latitude, but its promising growth prompted introduction trials in Maharashtra. Poplars were first tried in the Western Ghats plateau of Maharashtra during 1979-80. But these trials met with limited success, probably due to the incorrect method of planting.

Poplars belong to family Salicaceae which also includes willows. The occurrence of well grown willows (planted by the then Maharaja of the erstwhile Kolhapur State) along riverbanks in Kolhapur and Satara districts prompted the author (then Conservator of Forests, Nasik) to re-examine the potential of poplars for their introduction around Nasik during 1985 to 1987. Poplars being fast-growing and producing softwood for the packing-case industry, their cultivation in Western Maharashtra would be complimentary to the flourishing grape and other horticultural crop production in this part of the state.

The reintroduction trials (1985-87) conducted at Gangapur Nursery, Nasik were broad-based and included cultivars from various sources as detailed in Table 1.

**Table 1.** Poplar species included in introduction trials.

Source	Species	Cultivars	
1. Silviculturist, Southern Region, Uttar Pradesh, Kanpur	<i>Populus deltoides</i>	Australia	G-3, G-48
		U.S.A.	D-61, D-121, D-181, S-701 S-704, S-708 S-7015, S-7020
	<i>Populus euramericana</i>		IC-69/55
			IC-72/58
2. Director (Silvicultu- rist), F.R.I., Dehra Dun	<i>Populus deltoides</i>	Netherlands	3287, 3298 3678, 3686 Tr-56/52
		Turkey	
	<i>Populus nigra</i>		
	<i>Populus deltoides</i>	Australia	28/8, 28/13 61/58, 74/24

The trials showed that the performance of cultivars supplied by the Silviculturist, Kanpur, U.P. was more encouraging compared to recent introductions from Australia, the Netherlands and Turkey (Table 2).

**Table 2.** Performance of poplar cultivars in 1991 and 1994.

Cultivar	Survival	Sept. 91	March 1994	
	(%)	Average Height (cm)	Average Girth (m)	Average Height (cm)
G-3	18.22	39	12.80	43.00
—	14.04	39	7.10	43.26
D-181	43.85	46	10.60	52.21

These trials of more than nine years show that poplars can thrive well in selected areas of Maharashtra. Subsequently, enterprising individuals and farmers planted poplars on farmlands in Nasik and Pune districts. However, these plantations lacked regular monitoring and feedback.

### **Introduction Trials in Pune District**

Encouraged by the success of the reintroduction trials, small-scale trials were initiated by the Forest Research wing of Maharashtra during 1992. The sites include the campus of College of Agriculture, Hadapsar, Theur, Manjri and Daund. The trial at the College of Agriculture campus site is discussed below.

Pune is situated at 18° 30'N latitude. The average rainfall is 640 mm and the temperature ranges between 6° to 41°C. The summer period is from February to May. Climate is more or less equable. Soil of the trial site is medium black, about 1.0 m deep and well-drained. An area of 0.28 ha was selected in the campus and site preparation included criss-cross ploughing. Each of the six cultivars was replicated twice.

Entire transplants of five cultivars of poplars of L & S series, supplied by the Silviculturist, Uttar Pradesh, Haldwani and Tata Energy Research Institute, Delhi were planted in pits of 0.60 x 0.60 x 0.60 m, dug at an espacement of 3.0 x 3.0 m in February 1992. Each plot contained 24 transplants. Cuttings of poplars brought from Nashik and planted in two plots served as control. Watering was done once in two weeks from February till the onset of the monsoon. Casualties were replaced in June 1992. Weeding and cultural operations for soil and moisture conservation were carried out. Fertiliser and farmyard manure were applied in small doses.

During the first year, fodder maize and French beans were successfully intercropped. Maize yielded about 1400 kg of fodder valued at Rs. 700/-. The avoidable delay in transporting ETPs from Haldwani and Delhi resulted in comparatively poor survival of ETPs at the initial stage. However, ETPs thought to be dead showed regrowth

when cut back in March, 1992. Table 3 gives the performance of ETPs which survived from the beginning as well as those cut back in March 1992. Assessment in both cases was done in September 1992.

**Table 3.** Average height and girth measurement 26 months after planting.

Clone	Girth (cm)	Height (m)
L-12	23.43	7.19
L-13	22.33	8.49
L-29	23.36	3.51
S-701	23.08	8.38
S-748	23.42	8.50
N	15.72	4.27

**Table 4.** Average girth and height of different clones seven, and 26 months after planting.

Clone	Sept. 92		Dec. 93		April 94	
	Girth	Height	Girth	Height	Girth	Height
L-12	15.5	3.75	22.96	8.28	23.53	7.19
L-13	15.0	4.85	22.30	8.47	22.33	8.49
L-29	12.5	4.44	24.70	10.44	23.36	13.51
S-701	14.8	5.10	22.42	9.53	23.08	8.38
S-748	12.15	3.37	23.94	9.88	23.42	8.50
N			17.27	4.92	22.64	4.27

The apparent inconsistency in some of the average girth and height values is due to subsequent mortality or top breaking.

### **Yield Estimates**

It is premature to forecast the probable yield from poplar in Maharashtra where the climatic, edaphic and other factors are not optimum for this species. However, available data pertaining to poplar cultivation in North India under more favourable conditions indicate that spacing has a marked influence on volume. Yield estimates on poplar stands indicate a mean annual increment of 20-25 m<sup>3</sup> per ha and in field bund planting an annual increment of 1.5 to 3.0 m<sup>3</sup> per ha at the age of eight years. However, in more productive stands, yields range from 25 to 28 m<sup>3</sup> per ha. Farmers in Punjab have achieved yields as high as 46.92 m<sup>3</sup> per ha per year from a seven-year old plantation with a mean height of 23.44 m. Poplars are fast-growing trees capable of producing mean annual increments of 15-20 m<sup>3</sup> per ha.

# Multipurpose Tree Species for Agroforestry

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## ***Abstract***

*Development of interactive constituent elements that are mutually complimentary in the vertical and horizontal compositions for maximising the production potential of land and other natural resources constitutes agroforestry. It is important to identify the most profitable model and integrate the constituents. Due to the long gestation period of the tree component, development of scientifically-tested agroforestry models is time consuming. Traditional agroforestry practices, though crude and partial, provide the basis for evolving new and desirable models. Considering the prevailing conditions, community or cooperative approach is the solution for the promotion of agroforestry in India.*

## **Introduction**

It is said '*nasti ekopi vanspati na vanaushadhi*', which means all plant species on earth have medicinal value. This implies that every plant species is multipurpose. This is particularly true in the case of tree species. In addition to producing timber, fuel, fibre, fruit and other tangible products, trees regulate water movement in nature, offer physical protection to the land and provide shade. Thus all the trees are multipurpose and should merit inclusion in planned agroforestry models.

Integrated management of mutually complimentary productive components, namely the tree species, agricultural crops and cottage-level economic activity based on raw materials from agroforestry production, could be achieved through manoeuvring the vertical and horizontal compositions of tree and crop communities. The correct blending of these elements is crucial in agroforestry.

## **The Tree Component**

In an integrated system, trees are grown to extract nutrients and water from deep soil layers. There is continuous recycling of the organic matter in the soil by way of leaf fall and humus formation. Trees help in the stabilization of fragile ecosystems, particularly

in dry and arid regions. Growth rates of trees is generally slow compared to herbaceous agricultural crops. Moreover, the long gestation period required by trees results in the unpredictability of market rates. Therefore, the rate of generation of interest by tree-based systems do not compare favourably with agriculture or industry. Therefore, the tree component in agroforestry should be viewed as an investment for social security and environmental stabilization and an insurance for sustainable development.

The order of priority in the selection of tree species is given below.

1. Local species acceptable to the grower.
2. Species having a deep root system, a vertically growing crown and preferably nitrogen fixing ability.
3. Species yielding fodder, fuel, fruits and small timber and raw material for generating supplementary economic activity.
4. Fast-growing species with good coppicing ability.

### **The Crop Component**

The second important component in agroforestry is the agricultural crop. Raising the most suitable crop in an agroclimatic region is of foremost importance. The annual crop in agroforestry is grown in the inter-spaces between tree rows. To maintain fertility and productivity, it is advisable to use a compatible crop. The burden of economic return in the short-term falls heavily upon this component in the integrated agroforestry management.

### **The Economic Activity**

The third component in an agroforestry system is the supplementary economic activity for income generation during the idle time. Some such activities are dairy, sheep and goat rearing, horticulture, sericulture, apiculture, shellac cultivation, bamboo handicraft, basket making and rope making. It is expected that the product from agroforestry should support and sustain supplementary activities by way of raw material, source of energy, fodder for dairy and other animals or serve as host for silkworms, apiculture or shellac cultivation. The system adopted should be such that it utilizes the spare time and generates supplementary income to the farmer.

### **Development of Agroforestry Models**

It is essential to convince farmers that agroforestry can maximise production. In this context, it should be noted that agriculture started with jungle clearance, and progressed through under-cultivation, jhum cultivation and agrisilviculture to pure agriculture and forestry. Cultivation of agricultural crops and perennial tree species separately is undesirable; agricultural lands devoid of trees are often impoverished by the mechanical



overuse while forests are falling prey to pilferage due to the fuel crisis. It is imperative to educate, demonstrate through model farms and propagate agroforestry practices.

Development of scientifically-tested agroforestry models is time consuming and arduous because of the long gestation period of the tree component. In the meantime, traditional agroforestry practices, though crude and partial, can provide the basic information to evolve systematically-designed improved models. A survey of diagnosis and design in arid and semi-arid regions identified many traditional models (Table 1).

**Table 1.** Traditional tree-based models.

Species Combination	Remark
<b>A. Agroforestry models</b>	
1. <i>Prosopis cineraria</i> + bajra	Study reveals that the average economic returns from these models is Rs.4000-5000 per ha more than the sole crop when a 20 year rotation is assumed.  These models generate an additional revenue of Rs.6000-7500 compared to sole crop in a 20 - year rotation  Rs. 7000/- more than solecrop.
2. <i>Prosopis cineraria</i> + mung bean + cluster bean	
3. <i>Tecomella undulata</i> + bajra	
4. <i>Acacia nilotica</i> + bajra + wheat	
5. <i>Acacia nilotica</i> + bajra + mustard	
6. <i>Acacia nilotica</i> + mung bean + mustard	
7. <i>Acacia nilotica</i> + cluster bean + wheat	
8. <i>Acacia nilotica</i> + cluster bean	
9. <i>Acacia nilotica</i> + sorghum + wheat	
10. <i>Acacia nilotica</i> + sorghum + mustard	
11. <i>Acacia nilotica</i> + sorghum + gram	
12. <i>Acacia tortilis</i> + pearl millet	
13. <i>Acacia tortilis</i> + cluster bean	
14. <i>Acacia tortilis</i> + mung bean	
15. <i>Ailanthus excelsa</i> + pearl millet + wheat	
16. <i>Ailanthus excelsa</i> + pearl millet + mustard	
17. <i>Ailanthus excelsa</i> + cluster bean + mustard	
<b>B. Silvo-pastoral Models</b>	
1. <i>Prosopis cineraria</i> + grass	
2. <i>Prosopis cineraria</i> + grass	
3. <i>Tad/Phoenix</i> + grass	
<b>C. Agri-silvopastoral Models</b>	
1. <i>Prosopis cineraria</i> + bajra + grass	
2. Anar + bajra + grass	
3. Ber + bajra + grass	

Based on the traditional agroforestry practices, models could be evolved for various agroclimatic conditions with the advantage of including economically valuable species given below.

**Zone I:** Arid to semi-arid zone, very hot climate, erratic 100 to 500 mm precipitation.

**On the bund:**

*Agave cantala, Saccharum munja, Eulaliopsis binata, Capparis decidua, Eucalyptus camaldulensis, Calligonum polygonoides, Phoenix sylvestris, Acacia senegal, Acacia tortilis, Salvador oleoides.*

**In the field:**

**a. Woody Perennial :** *Azadirachta indica, Prosopis cineraria, Acacia nilotica, Acacia tortilis, Acacia senegal, Cordia myxa, Ailanthus excelsa, Melia azaderach, Leucaena leucocephala, Tecomella undulata.*

**b. Fruit Trees:** *Punica granatum, Zizyphus mauritiana, Moringa oleifera, Annona squamosa, Jatropha curcas.*

**Zone II:** Very dry climate, drought prone with precipitation between 500-750 mm.

**On the bund:**

*Agave sisalana, Calligonum polygonoides, Caesalpinia bonducella, Semicarpus anacardium, Phoenix sylvestris, Phoenix dactylifera, Azadirachta indica, Melia azedarach, Eucalyptus tereticornis, Tamarindus indica, Pithecellobium dulce, Terminalia bellerica, Carissa cunjeta, Melincara hexandra, Holoptelia integrifolia, Feronia elephantum, Chloroxylon swietenia, Butea monosperma.*

**In the field:**

**a. Woody Perennial:** *Acacia nilotica, Casuarina equisetifolia, Dalbergia sissoo, Hardwickia binata, Dendrocalamus strictus, Santalum album, Tectona grandis.*

**b. Fruit Trees:** *Punica granatum, Zizyphus mauritiana, Emblica officinalis, Moringa oleifera, Psidium guajava, Citrus medicalemona, Ricinus communis, Sesbania grandiflora, Annona reticulata, Carica papaya.*

**c. Crop/Grass:** sorghum, wheat, red grass, cotton, soyabean, groundnut, moth mustard, lentil, til, linseed.

**Zone III:** Dry to semi-moist, precipitation between 750-1250 mm.

**On the bund:**

*Agave sisalana, Azadirachta indica, Eucalyptus citriodora, Tamarindus indica, Feronia*

*elephantum, Semicarpus anacardium, Caesalpinia bonducella, Bombax mulbaricum, Thespesia populnea, Phoenix sylvestris, Terminalia bellerica, Carissa congesta, Madhuca latifolia, Holoptelia integrifolia, Albizia lebbek, Soymoda febrifuga and Pongamia pinnata.*

**In the field:**

**a. Woody Perennial:** *Tectona grandis, Hardwickia binata, Ougenia dalbergioides, Chloroxylon swietenia, Dendrocalamus strictus, Bambusa polymorpha, Casuarina equisetifolia, Dalbergia latifolia, Pterocarpus marsupium.* .

**b. Fruit Trees:** *Emblica officinalis, Annona reticulata, Morus alba, Moringa oleifera, Citrus medica (lemona), Citrus medica (citratu), Carica papaya, Psidium guajava, Achras sapota, Ricinus communis.*

**c. Crops/Herbs:** wheat, cotton, peanut, pigeonpea, pea, gram, sunhemp, ambadi, potato, onion, tomato, soybean, French bean, chilly, tumeric, ginger, flower species.

**Zone IV:** Semi-moist to moist, hot and selubrous, precipitation between 1250-2500 mm.

**On the bund:**

*Agave sisalana, Bromelia annus, Sterculia foetida, Aegle marmelos, Bambusa arundinacea, Mangifera indica, Azadirachta indica, Syzygium cumini, Anthocephalus cadamba.*

**In the field:**

**a. Woody Perennials:** *Tectona grandis, Gmelina arborea, Dalbergia latifolia, Oxytenanthera monostigma, Bambusa vulgaris, Acacia catechu, Eucalyptus tereticornis, Casuarina equisetifolia.*

**b. Fruit Trees:** *Emblica officinalis, Anacardium occidentale, Morus alba.*

**c. Crop/Cash Crop/Grass:** Tumeric, bitter bean, soybean, paddy, wheat, sorghum, sweet potato.

**Zone V:** Moist, hot and humid, precipitation more than 2500 mm.

**On the bund:**

*Bromelia annanus, Carissa congesta, Artocarpus integrifolia, Garcinia indica, Bambusa arundinacea, Bambusa gigantea, Borassus flabellifer, Calophyllum inophyllum, Sterculia foetida, Aegle marmelos.*

**In the field:**

**a. Woody Perennials:** *Tectona grandis*, *Dalbergia latifolia*, *Pterocarpus santalinus*, *Gmelina arborea*, *Hevea brasiliensis*, *Eucalyptus grandis*, *Casuarina equisetifolia*, *Cinnamomum zeylanicum*.

**b. Fruit Trees:** *Anacardium occidentale*, *Cocos nucifera*, *Areca catechu*.

**c. Crop/Cash Crop/Grass:** paddy, tapioca, cardamom, black pepper.

Resource-rich farmers can overlook the initial adverse effects of trees on adjacent crops and await overall enhanced and sustained production. But marginal and small farmers have to be cautious in their approach. For example, those who ventured into eucalyptus planting without thinking about the long gestation period and marketing avenues found a glut at the time of harvest and prices had fallen considerably. Agroforestry models suitable for resource-rich farmers need not be the best for small farmers. Constraints to practising agroforestry in smallholdings could be overcome by community or co-operative farming. In addition, beneficial effects of agroforestry such as sustained production, sizeable marketable produce, marketing, social security and insurance can be highlighted in the larger interest.

# Genetic Improvement of Multipurpose Tree Species for Agroforestry

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## ***Abstract***

*High-yielding varieties and improved cultural practices of crops have revolutionized agricultural production and have made cultivation of many crops economically viable and popular among farmers of our country. However, lack of improved planting material and cultural practices for trees have hampered the adoption of agroforestry systems. Genetically improved material for high productivity would make agroforestry systems economically viable and popular among farmers. Multipurpose Tree Species (MPTS) are grown under agroforestry systems in different agroclimatic zones with different objectives. The genetic improvement of MPTS involves different selection criteria and standards to meet the objectives of agroforestry plantations. These objectives identify the comparative economic importance for each trait which helps in fixing the minimum selection standards. This will be useful in objective-based selection of superior MPTS for each agroforestry system. Genetic testing of selected MPTS and the use of genetically superior MPTS in seed production or vegetative propagation, and the role of genetically superior planting stock in popularising agroforestry among farmers have been discussed.*

## **Introduction**

Agroforestry, the mixing of agriculture and forestry, has been recognised internationally as a scientific venture. It is a land use system which maintains the sustainability of land and enables the grower to meet all his agriculture and forestry-based needs from the same unit of land. Though agroforestry has great potential as a land use system, it has not been exploited fully so far. Agroforestry as a science is quite young compared to its parental sciences, agriculture and forestry. Standardised cultural practices and high-yielding

-varieties for every agroecosystem have been developed for the cultivation of agricultural crops. As a result, agriculture has become economically viable and has been adopted as a profession by farmers.

Agroforestry research, however, has not reached a stage to recommend suitable tree-crop combinations, their package of practices and genetically improved planting material for a given situation. Lack of information on these aspects has become a limiting factor in the adoption of this land use system. MPTS well suited to an agroecosystem and meeting the needs of local people and/or industrial needs of the area will encourage its adoption under agroforestry systems. Further, genetically improved high yielding clones within such species which may accomplish specific agroforestry system-based objectives will enhance the popularity of agroforestry among farmers. The present paper deals with the perspectives of genetic improvement of MPTS and its role in popularising agroforestry among farmers.

## **Genetic Improvement of MPTS**

The objectives of planting MPTS are quite variable with respect to their providing tree products, services to humanity and rehabilitation of degraded lands. Before the start of any tree improvement programme, the breeder must understand the problem and identify the objectives of a breeding programme. Tree breeding plans are then formulated to rectify the problem and achieve the objectives. MPTS are mainly associated in agroforestry to:

- a. meet the farmers needs such as small timber, housing, fodder, fuelwood, fruit and minor tree products;
- b. supplement crop productivity through moisture conservation, addition of organic matter and maintaining the sustainability of soil;
- c. provide economic gains to farmers by supplying raw material to wood-based industries in the area.

For each agroforestry system, species should be selected based on the site, agroclimate and products and services to be obtained. Once the MPTS with major economic value have been identified, attempts should be made to explore the total genetic resources through selection, crossing and progeny testing.

### **Selection**

Selection of superior provenances and genotypes in a species is the first and most important step in any tree breeding programme. In any MPTS, the breeder attempts to manipulate several characteristics simultaneously. Thus there is a need to develop the

minimum selection standards for each agroforestry species for the selection of trees having superiority in objective-based traits. Each economic trait has its own significance which determines minimum selection standards for it. The character of highest economic significance must have highest selection standards and vice versa. These selection standards are used to select the superior trees for many traits.

The area of species distribution should be surveyed and data on best phenotypes (candidate trees) should be recorded. Observations should also be recorded on comparison of trees or baseline trees. Only those candidate trees which meet the minimum selection standards for all traits are selected as plus trees. Banks and Van Vuuren (1976) selected plus trees in eucalyptus against splitting in sawn timber through minimum selection standards. Selection of plus trees has been reported in many MPTS such as *Tectona grandis*, *Dalbergia sissoo*, *Bombax ceiba*, *Acacia catechu*, *Casuarina equisetifolia*, *Pinus petula*, *Gmelina arborea* and *Santalum album* (Rai and Parthasarathi, 1989). Sidhu (1993) has selected plus trees in *Eucalyptus tereticornis* by using the minimum selection standard method.

### **Progeny Testing**

Superiority of selected trees may be either due to desirable gene combinations or better environment or both. The breeder's objective is to select the parent that transmits its superiority to the next generation. Progeny testing (genetic testing) is used to identify the cause of superiority in the selected parents. Progeny testing is conducted by collecting the seeds from different parents and growing their progenies under similar environmental conditions. The superior performance of a progeny indicates the superior gene combinations in its parent.

Progeny testing provides information on the type of genetic control for a trait, that is, the amount of additive and non-additive genetic variation. Genetic analysis of the progenies is used to quantify the amount of heritability in any population, family or individual. The heritability is used to find out the expected gains from selections.

Many studies on progeny testing have been reported. In *Eucalyptus tereticornis*, the progeny of a selected tree was 51.3% taller in the nursery than the control (Sidhu, 1993). Significant variation among the progenies of *Prosopis cineraria* and *Tecomela undulata* for tree height and diameter was recorded by Kackar *et al.* (1993). In half-sib progenies of *Terminalia arjuna*, Srivastava *et al.* (1993) reported high heritability for leaf size and seedling size. The trees selected on the basis of progeny testing are used either in seed production or in vegetative propagation for raising commercial plantations.

## **Seed Orchard**

Seed orchard is the main source for the collection of genetically improved seed. It is a plantation of genetically superior trees, isolated to reduce pollination from genetically inferior outside source, and intensively managed to produce frequent, abundant and easily harvested seed crop (Zobel *et al.*, 1958). Seed orchard development is the ultimate objective of all tree breeding programmes on MPTS. The amount and type of genetic variability (additive and non-additive) determines the nature of seed orchard to be developed. Trees high in additive genetic variation are concentrated in a multiclonal seed orchard and those showing non-additive genetic variation are used in a biclonal seed orchard. Either seeds (seedling seed orchards) or vegetative propagules (clonal seed orchards) are used for this purpose. The latter provides more genetic gains than the former because of the use of true copies of the tested clones. Seed bearing also occurs at a comparatively earlier stage in the clonal seed orchard.

Trees selected are planted in the seed orchard in a specific design. Seedlings/ramets should be planted in such a way that no two seedlings/ramets of the same clone are next to each other. The minimum separation by two other clones is obligatory to avoid in-breeding. The tree to tree and row to row spacing in the seed orchards should be sufficient to admit sunlight for crown development and to permit easy seed collection. A pollen dilution zone of 125-150 m all round the first generation seed orchard was recommended by Faulkner (1975). The orchard ground should be managed either as clean cultivation or by growing cash crops. Application of fertiliser, weedicides and irrigation helps in the satisfactory establishment of trees for seed production. The first experimental seed orchard in India was established from grafted material in teak using 20 clones at New Forest, Dehra Dun (Kedharnath, 1983). Rai and Parthasarathi (1989) reported the establishment of seed orchards in species like teak, casuarina, *Eucalyptus tereticornis* and *Gmelina arborea*.

## **Clonal Breeding**

Seed orchard technology is able to exploit only a part of the genetic variation. The use of total genetic variability provides comparatively better gains. The total genetic variability can be exploited in MPTS through the use of vegetative multiplication of superior genotypes. A cost effective technique for vegetative propagation has been developed for many tree species. In recent years, vegetative propagation has been integrated with all tree breeding programmes to realise extra gains. The foremost aim of the clonal breeding strategy is to produce new opportune genotypes which can exploit both additive and non-additive genetic variability.



Although clonal breeding has become popular among breeders, not much effort has been made to produce opportune genotypes. The methods of sub-line breeding (Baker and Curnow, 1969) and multiline breeding (Chaperson, 1984) have been reported to produce opportune genotypes. Burdon (1986) suggested controlled crosses between intensively selected parents and Sam Foster (1986) reported an approach of positive assortive mating for obtaining opportune genotypes to exploit total genetic fidelity. Very high genetic gains have been achieved through clonal breeding in many MPTS. In eucalyptus, through selection, crossing and vegetative multiplication, genetic gains have been increased from 12 m<sup>3</sup>/ha/yr to 34 m<sup>3</sup>/ha/yr in Congo (Delwaulle *et al.*, 1983) and from 15 m<sup>3</sup>/ha /yr to 100 m<sup>3</sup>/ha/yr in Brazil (Shyam Sunder, 1988). A significant gain has been achieved for stem straightness in *Gmelina arborea* in Malaysia, Cameroon and Solomon Islands (Leakey, 1987).

### **Popularising Agroforestry**

Tremendous developments in agriculture have been made by India since early sixties. There was a significant increase in the area under grain crops, area under high yielding varieties, and production of foodgrains. However, the development in the field of forestry has not been encouraging. The main reasons for the growth in agriculture are :

- a. development of cultural practices;
- b. development of high yielding varieties;
- c. well organised marketing and remunerative prices.

The above aspects have not been developed so far with respect to forestry/ agroforestry. Planners and forestry scientists must work on these aspects to make tree growing profitable under agroforestry systems. Indian Council of Agricultural Research institutes and State Agricultural Universities are working hard to develop cultural practices for different agroforestry systems. They should be provided with sufficient resources to work on the constraints faced by farmers. However, only a few institutions are involved in the genetic improvement of MPTS. An All-India Coordinated Tree Breeding Programme for MPTS should be planned and sponsored in different agroclimatic zones. Cultivation of high yielding clones of MPTS with improved technology would increase the tree output per unit area and per unit time. The government should ensure an organised wood market on the pattern of foodgrains so that farmers can get remunerative prices. All these steps will make the agroforestry profession economically viable and popular among farmers.

## Examples

With the consolidation of landholdings and ushering in of the green revolution in Punjab, there was a great setback to tree wealth on farmlands. The trees were cut out of fear of change in ownership and of causing reduction in adjoining crop yields. For sometime thereafter, farmers did not plant any trees on farmlands. During the mid-seventies, eucalyptus became popular among farmers as an agroforestry tree. Many farmers planted it on farm boundaries, water channels and even as solid blocks on farmlands. However, because of lack of cultural practices and uniform and improved planting material, the harvest was lower than the expectations of farmers. Low prices of eucalyptus timber and the fear of soil degradation had compelled many farmers to uproot young eucalyptus plantations in the mid-eighties. On the other hand, eucalyptus has been a boon as far as wood production is concerned. Scientists in Brazil and Congo have developed tree breeding programmes and cultural practices for *E. grandis* resulting in tremendous genetic gains (Delwaulle *et al.*, 1983; Shyam Sunder, 1988).

Poplar (*Populus deltoides*) is another fast-growing species that made its entry as an agroforestry tree in the early eighties. It can grow in the state only in some pockets. Its cultivation with agricultural crops is quite easy. Its rotation age is 6-8 years. Its cultivation has become economically profitable and many progressive farmers have adopted it as an agroforestry tree. Because of its deciduous nature, it causes less damage to adjoining crops during winter. Plantlets of poplar are always in demand. Because of the planting of a single clone, problems are expected in the future. Clonal introduction and evaluation work is already in progress in the Department of Forestry and Natural Resources at Punjab Agricultural University, Ludhiana. Many high-yielding clones are under evaluation (Sidhu, 1994). Poplar wood is being used by sports goods and plywood industries. A national sports industry is already available in Jalandhar and many plywood industries are expanding in the area.

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# Impact of Bee Flora in a Plantation-Based Ecosystem

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## ***Abstract***

*In the Kodagu region of Karnataka, the Coorg mandarin is grown as an intercrop in coffee with pepper on silver oak or erythrina. At the Central Horticultural Experiment Station at Chettalli in Kodagu, the Soapnut (*Sapindus emarginatus*) and drumstick (*Moringa oleifera*) were introduced in a stand of Coorg mandarin plants as shade and bee foraging plants. Bee flora plants like *Schefflera wallichiana* (tree type), *S. vermulosa* (vine type), *Pongamia pinnata* and *Syzygium jambos* (jamun) are planted along the periphery of the station. In addition to these, three varieties of perennial pigeonpea, ICP 8094, ICP 11298 and ICPL 88040, obtained from ICRISAT in Hyderabad, are also grown as a source of nectar<sup>3</sup> for bees. These multipurpose tree species (MPTS) need to be popularised.*

## **Introduction**

Kodagu is situated in the Malnad region of Karnataka which is characterised by hilly terrain with heavy rainfall. The main commercial crop is coffee with pepper as a creeper on silver oak and erythrina trees and Coorg mandarin as intercrops. At the Central Horticultural Experiment Station (CHES) in Coorg, mandarin is grown as a sole crop at a spacing of 6.0 x 6.0 m. Efforts were made to introduce soapnut (*Sapindus emarginatus*) and drumstick (*Moringa oleifera*) as shade and bee foraging plants between Coorg mandarin in order to study the effect of these plants on crop and honey production.

In addition to soapnut and drumstick, other bee foraging plants *Schefflera* spp., *Pongamia pinnata*, *Syzygium jambos*, *Leucaena leucocephala* and *Grevillea robusta* were also planted along the periphery. Three varieties of perennial pigeonpea ICP 8094, ICP 11298 and ICPL 88040 obtained from ICRISAT at Hyderabad were also grown as bee foraging plants.

## Survey of Bee Flora

Details of a survey conducted to study the flowering periods of different bee foraging plants in Coorg are given in Table 1.

**Table 1.** Flowering periods of bee foraging plants.

Species	Flowering time
Citrus	Feb - March & Sept - October
Coffee	March - April
Drumstick	Jan - April
Jaman	March - April
Karanji	Jan - April
Pigeonpea	Nov - April
<i>Schefflera</i> spp.	March - June
Silver oak	Oct - March
Soapnut	Nov - Dec
Subabul	Jan - Dec

## Utility of Bee Flora in the Prevailing Cropping System

### a. As shade trees in citrus orchards

#### 1. *Moringa oleifera*

This species is widely cultivated in south India. Plants were raised by stem cuttings and introduced as foraging plants in the year 1990 at CHES. After their establishment, Coorg mandarin plants were interplanted in 1992. The leaves and flowers of drumstick are used as fodder while tender leaves and fruits are used as vegetables. All parts of the tree are used in native medicine (Rajan, 1983).

#### 2. *Syzygium jambos*

This is an indigenous minor fruit of commercial value grown for shade and as windbreak along roads and avenues. It is a tall, evergreen cross pollinated tree. It is also reported to enhance soil fertility (Bose, 1986). It is used as a standard for pepper and a shade in coffee estates in Coorg. Jamun trees were planted along the periphery at CHES in 1992.

### **3. *Sapindus emarginatus***

Soapnut is a tall evergreen tree which grows to a height of 10 m in most parts of tropical Asia. It is a major source of honey in south India and is grown as a shade tree in coffee plantations, wastelands and farm borders for its fruits and timber in Coorg. It was planted in 1990 at CHES.

### **4. *Grevillea robusta***

This species is used as a standard for pepper in coffee estates in Coorg. It is used for furnitures and shed and hut construction (Rajan, 1983).

## **b. Cultivated bee flora**

### **1. *Pongamia pinnata***

A medium size, evergreen tree, karanja is grown on roadsides throughout the country (Chadha, 1991). These trees were planted in 1990 all along the periphery at CHES. Its leaves are used as green manure, and the oil is used in soap manufacture and for the control of red scale in rose (Shivaramu and Jhansi, 1993).

### **2. *Leucaena leucocephala***

Subabul is an evergreen plant which grows into a bush and attains a height of 5.0-6.0 m. If the lower branches are pruned, it appears like a short tree. The leaves and pods are a good source of fodder for cattle (Rajan, 1983). It is grown for live fencing at CHES.

### **3. *Cajanus cajan***

Pigeonpea provides food, fuelwood, fodder and material for shelter to marginal and small farmers. It is a species of interest in agroforestry in hedgerow intercropping experiments at the International Institute of Tropical Agriculture (IITA) in Nigeria. It is well adapted to tropical and sub-tropical conditions. This hardy leguminous nitrogen fixing species contributes to soil fertility (Ong and Daniel, 1990).

Three varieties of perennial pigeonpea, ICP 8094, ICP 11298 and ICPL 88040 were grown on marginal land at CHES. Though it is a self-pollinated crop, yield increase was noticed due to activities of honeybees. Its green pods are used as a vegetable, dried seeds as a pulse and leaves as fodder. Studies conducted at CHES revealed that fruit set and pod filling was superior in open pollination than in closed pollination. In open pollination, three seeds/pod were recorded as against one seed/pod in controlled pollination.

### c. Natural bee flora

Four species of *Schefflera* grow naturally in south Indian forests. Seedlings of *Schefflera* spp. planted under shade of erythrina trees during 1990 to study bee forage value at CHES are doing well. *Schefflera wallichiana* (tree type) and *S. vermulosa* (vine type) flower in the months of March to June in Galibeedu and other areas of Kodagu district and serve as major sources of honey during the honey flow season. In addition to producing honey, bees act as major pollinators in increasing yields in crop plants. Ramani and Bhumannavar (1991) reported an increase of 45-50% in fruit set with bees as pollinators compared to only 4-5% in controlled pollination.

Soapnut and *Schefflera* species are the major sources of nectar for honeybee in the Coorg area. In addition to bee foraging value, these trees serve as standards for pepper and need to be popularised.

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# **Cloning of *Dalbergia sissoo*, *Dalbergia latifolia* and *Faidherbia albida***

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## **Introduction**

Raising trees, crops and animals on the same farm enables farmers to meet most of their basic needs. Crops provide foodgrains and fodder while trees yield timber, firewood and fodder. Agroforestry is defined as a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to farmers. Agroforestry includes a combination of agriculture and forestry in a physical and functional relationship. This provides greater benefits than agriculture or forestry alone. It results in the maintenance of soil fertility, soil conservation, increased yield, diminished crop failure, ease of management, pest and disease control and/or greater fulfilment of the socio-economic needs of the local population. Based on the composition of species, agroforestry systems such as agrisilviculture, agrisilvipasture and silvipasture have been recognised.

## **Vegetative Propagation**

Vegetative propagation of three economically important leguminous tree species was tried by the Maharashtra Van Sanshodhan Sanstha, Chandrapur. The species were *Dalbergia sissoo* (sissoo), *Dalbergia latifolia* (shisham) and *Faidherbia albida*.

### **1. Sissoo**

Sissoo is a large deciduous tree of about 30 m tall, 2.4 m in girth and has a stem with high crown. It grows very well on alluvial soils in riverbeds. It is a strong light demander, forms plenty of suckers and coppices well. Natural regeneration of sissoo can be through seed, shoot cutting and stump. It fixes nitrogen and is a good host for sandal.

### **2. Shisham (Rosewood)**

Shisham is a large deciduous or nearly evergreen tree with a rounded crown growing up to 40 m in height and 6.0 m in girth. Its stem is cylindrical with a fairly clear bole. It



grows naturally in Uttar Pradesh, and central and peninsular India. Natural seed germination occurs during the early rainy season. Emergence of root suckers on exposed roots is also profuse. Artificial regeneration is possible by direct sowing of shoot or root cuttings and stump planting or by nursery raised seedlings. It can be grown on poor, dry or waterlogged soils. Shisham is recommended for shelterbelts, windbreaks and for shade. It fixes nitrogen and is a good host for sandal (P.I.D., 1990).

### **3. *Faidherbia albida***

This species is suitable for arid or semi-arid conditions and can be planted on farm bunds. It grows well in areas where rainfall ranges between 300 to 650 mm. The oldest plantation of *F. albida* in India is in Haryana where it reached a height of 7.5 m and girth of 20.6 cm within four years. *F. albida* develops profuse root suckers on sand dunes.

### **Materials and Methods**

Branch cuttings of sissoo, shisham and *F. albida*, 15 cm in length and 3-5 cm in girth, were collected from pre-marked and comparatively vigorous plants. Sissoo cuttings were procured from Chandrapur, shisham cuttings from different clones of plus trees and *F. albida* from Haryana (Pinjore).

These cuttings were treated with different hormone concentrations of Rootex, Indole Acetic Acid (IAA), Indole Butyric Acid (IBA) and Naphthelene Acetic Acid (NAA). The lower end of cuttings were kept in the fungicide Bavistin for 15 minutes and then treated with the hormone of required concentration mixed with ordinary talcum powder for 24 hours. Cuttings of *F. albida* were kept in root trainers containing pre-soaked vermiculite as a rooting medium. These root trainers were kept in a mist chamber. It was automatically adjusted for sprinkling of mist for 18 seconds at six minute intervals at a constant temperature of 30 ( $\pm 5$ )°C and a humidity range of 70 to 90%.

Rooted cuttings, determined by 5-10 roots with a length of 5.0 cm or above, were carefully removed from the root trainer and transferred to polythene bags by following the regular procedure for further growth.

**Table 1.** Vegetative propagation through branch cuttings of different clones of shisham.

Name of clone	Type of treatment ppm	No. of cuttings	Period of sprouting of shoot and initiation of root		Rooting %
			No.	Days	
MHAL AR7	IBA 4000	400	180	20	45.0
MHAL AR9	IBA 4000	270	185	19	68.5
MHAL AR10	NAA 4000	450	395	20	88.6
MHAL AR10	NAA 1000	320	242	18	75.6
MHAL AR11	NAA 1000	246	134	46	50.0
MHAL AR12	NAA 1000	170	22	55	12.9
MHAL AR12	NAA 4000	335	250	21	74.9
MHAL AR14	NAA 4000	305	125	18	41.0
MHAL AR14	IBA 4000	250	207	23	82.8
MHAL AR16	IBA 4000	300	45	21	15.0
MHAL AR17	NAA 4000	200	190	21	95.0
MHSC JR1	IBA 4000	383	155	20	40.5
MHAL AR14	IAA 1000	80	46	45	57.5
MHAL AR8	IBA 500	80	68	35	85.8
MHAL AR12	NAA 1000	70	15	13	21.4
MHAL AR14	NAA 1000	246	132	15	54.2
MHAL AR17	NAA 1000	80	64	56	80.0
MHAL AR17	NAA 500	80	34	56	42.8
MHAL AR10	NAA 500	80	75	65	93.8

**Table 2.** Vegetative propagation through branch cuttings of sissoo.

Type of treatment	No. of cuttings	No. of shoots and initiation of root		Rooting %
		No	Days	
NAA 1000	240	130	30	54.2
NAA 1000	458	440	23	96.1
NAA 1000	183	112	18	61.2
IBA 1000	100	83	21	83.0
NAA 1000	240	193	17	80.4
NAA 1000	458	378	13	83.2
IBA 1000	100	83	47	83.0

**Table 3.** Vegetative propagation through branch cuttings of *Faidherbia albida*.

Type of treatment	No. of cuttings	No. of shoots and initiation of root		Rooting %
		No	Days	
Rootex	112	73	14	66
Rootex	187	114	12	61
	(Below 3.0 cm in girth)			
Rootex	970	320	26	33
Rootex	245	68	12	28

## Results and Discussion

NAA and IBA at 4000 ppm were the best for shisham as 95% of the cuttings sprouted and rooted within the shortest period (21 days) in all the clones (Table 1). This is in agreement with the results obtained by Gurusurthy *et al.* (1985) for eucalyptus. Sprouting of branch cuttings of sissou was maximum (96%) at a concentration of 1000 ppm NAA followed by 1000 PPM IBA (83%) at 23 and 21 days, respectively (Table 2). Direct application of Rootex induced root initiation in 66% of the cuttings of *F. albida* in 14 days (Table 3).

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# Relationship between Biochemical Changes and Rooting of Cuttings of *Dalbergia Sissoo* Roxb.

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## ***Abstract***

*Stem and branch cuttings of Dalbergia sissoo treated with 100 ppm of NAA and TBA were planted in a mist chamber at the Department of Agroforestry at Haryana Agricultural University, Hisar in the spring and monsoon seasons of 1991-92. Biochemical changes (proteins, starch and sugar) were estimated and correlation values between the rooting percentage and biochemical changes (proteins, starch and sugars) were determined. These were found to be highly correlated with rooting of cuttings. It was found that starch was negatively correlated and proteins and sugars were positively correlated with rooting of cuttings. The results are discussed in relation to the findings of other scientists.*

## **Introduction**

*Dalbergia sissoo* Roxb. (sissoo) is an excellent multipurpose tree species (MPTS) for agroforestry. Its timber is highly valued for construction and general utility purposes. It can be propagated through seeds, but to produce the true to type trees, vegetative propagation technique is employed (Verma, 1992; Puri, 1992; Nanda and Kochhar, 1985). Vegetative propagation of cuttings is the cheapest and preferred method (Bhatnagar, 1974; Puri and Shamet, 1988). During the rooting of cuttings, some important biochemical changes take place (Verma *et al.*, 1993). Nanda and Dhaliwal (1974) reported that rooting response of cuttings is controlled by a balance between nutrition and auxins. Therefore, a study was undertaken to determine the relationship between the biochemical changes (protein, sugar, starch) and rooting.

## **Material and Methods**

Stem and branch cuttings of sissoo were planted in spring and monsoon seasons in the mist chamber in the Department of Agroforestry at the Ch. Charan Singh Haryana

Agricultural University, Hisar in 1991-92. The cuttings were treated with 100 ppm of Naphthaleine Acetic Acid (NAA) and Indole 3-Butyric Acid (IBA) for 24 hours by dipping their lower 1/3 portion in auxin solutions. The biochemical parameters studied were proteins, starch and sugars. Data on rooting and biochemical changes were collected one month after planting of cuttings. Proteins were estimated by the method of Lowry *et al.* (1951) while starch and sugars were estimated by Clegg (1956) and Dubois *et al.* (1951) methods, respectively. The correlation coefficient (r) among rooting and biochemical changes (protein, starch, sugar percentage) were calculated.

## Results and Discussion

Proteins and sugars increased after rooting, but starch decreased (Table 1). In the monsoon season, maximum (100%) rooting was observed in stem cuttings (both NAA and IBA treatments) and branch cuttings (IBA treatment) (Table 1). Starch and sugars were highly correlated with rooting of cuttings (Table 2). However, protein and sugars were positively correlated and starch was negatively correlated after root formation (Tables 1 and 2). Maximum correlation ( $r=1.00$ ) between proteins and rooting was found in stem and branch cuttings treated with IBA (Table 2). The same trend was found with starch and sugar. The lowest correlation was found in branch cuttings treated with NAA during the monsoon season (Table 2).

**Table 1.** Biochemical changes and percentage rooting of cuttings of sissou treated with 100 ppm of NAA and IBA in spring and monsoon seasons.

Season	Type of cutting	Protein		Starch		Sugar		Rooting %	
		NAA	IBA	NAA	IBA	NAA	IBA	NAA	IBA
Spring	Stem	6.78 (1.48)	6.56 (1.48)	1.00 (4.5)	1.10 (4.5)	4.00 (1.34)	3.78 (1.34)	66	66
	Branch	6.59 (1.44)	6.50 (1.44)	1.10 (4.2)	1.25 (4.2)	3.98 (1.27)	3.86 (1.27)	66	66
Monsoon	Stem	6.02 (1.41)	5.99 (1.41)	1.20 (4.01)	1.36 (4.01)	2.62 (1.29)	2.82 (1.29)	100	100
	Branch	6.01 (1.35)	5.50 (1.35)	1.20 (4.00)	1.32 (4.00)	3.89 (1.27)	3.89 (1.27)	66	100

Data in parentheses represent the respective value of protein, starch and sugars before planting of cuttings.

**Table 2.** Correlation values (r) of proteins, starch and sugars with percentage of rooting obtained in cuttings of sissou treated with 100 ppm of NAA and IBA in spring and monsoon season.

Season	Type of cutting	Protein vs Rooting		Starch vs Rooting		Sugar vs Rooting	
		NAA	IBA	NAA	IBA	NAA	IBA
Spring	Stem	0.95	1.00	-0.94	-0.96	0.95	0.98
	Branch	0.92	1.00	-0.86	-0.93	0.99	0.98
Monsoon	Stem	0.95	0.97	-0.90	-0.94	0.98	0.98

Starch reserves in the cuttings disappeared with the onset of rooting (Table 1). The disappearance of starch was closely related to the activity of a hydrolysing enzyme causing mobilization of reserved food material. The rooting response of cuttings is positively related with mobilization of reserved food material as is apparent from changes in contents of total sugars and proteins, the trend being markedly different and opposite to starch which was negatively correlated. Both sugars and proteins were low prior to planting, but increased during rooting which indicates the mobilization of starch into soluble carbohydrates.

The continued loss of starch from cuttings is attributed to the export of carbohydrates to develop roots. Several workers have pointed out that synthesis of fresh proteins is required before adventitious root formation (Nanda and Jain, 1972; Dhaliwal *et al.*, 1979; Harisingh, 1971). Influence of auxins on initiation and development of adventitious roots have been mediated through qualitative and quantitative changes in protein (Kaminek, 1967; Mitsuhashi *et al.*, 1969).

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# Root Trainers - An Improvisation in Nursery Technique

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## ***Abstract***

*Large-scale tree planting, which is becoming increasingly important in India for both commercial as well as environmental reasons, requires healthy seedlings for success. The traditional system of raising seedlings in polythene bags has many disadvantages, the most important being root coiling and the recurring expenditure. Moreover, seedlings raised in polythene bags are likely to perform poorly on outplanting. The use of root trainers is an improvement over the polythene bag system and is a recent introduction in India. This system is said to avoid root coiling inside the container and is cost effective in the long run as the container is reusable. This paper, while explaining the concept of root trainer, compares various aspects of this system, particularly the economic aspects with the traditional system of polythene bags.*

## **Introduction**

Large-scale tree planting is becoming increasingly important in India both for commercial and environmental purposes. Government programmes such as wasteland development, social forestry, leasing of government wastelands to individuals, commercial complexes and societies aim at effective restoration of such lands through planting of tree seedlings of various species. Though genetic constitution of seedlings is very important, physical attributes of seedlings at nursery stage is also equally important for improved survival and healthy plantations to achieve better financial and ecological gains.

Nurseries in developing countries depend upon labour-intensive polythene bag seedling production systems which are expensive, difficult to transport and restrict large-scale tree seedling distribution and timely planting. With the availability of root trainers, there is a need for reexamining the advantages and disadvantages of existing nursery practices.



## **Disadvantages of Polythene Bags**

Though various locally made containers are being used for raising seedlings, the most common container at present in use in India is the polythene bag. The local manufacture of polythene bag is comparatively cheap requiring very small infrastructure. Because it is easy to handle and survival is satisfactory, raising polythene bag plants has been an established practice. However, as a nursery container, polythene bag has a number of technical and logistical disadvantages:

- a. Commonly used polythene bags often require large quantities of growing medium, making it difficult to handle due to the size and weight. Bags also require more space in the nursery and seedlings may be damaged in transit.
- b. It is mostly poorly aerated. If the polythene bag lacks holes at the base, a perched water table may be formed in the bag. Uneven wetting and drying occurs in the container.
- c. Lateral fibrous root system development is not encouraged. Roots commonly come out of the polythene bag and get anchored in the soil, causing damage to the roots at the time of shifting. As cultural activities are labour intensive, costs are increased. Roots that do not escape the polythene bag often spiral inside, resulting in root strangling and poor growth after planting in the field.
- d. There is a possibility of seedlings getting planted with polythene bag causing poor root growth. Polythene bags are not reusable and require new purchases every season.

## **Root Trainers - An Effective Alternative**

A root trainer is a container which utilizes vertical ribs on its inner wall to prevent root spiralling and to guide root growth to the drainage hole at the base of the container. This containerised seedling production system is a comparatively recent introduction in India. There are a number of claims about its utility and advantages in comparison to the polythene bag system.

- a. Lateral root growth and orientation which are highly correlated with planting success are excellent. Root morphology is biologically correct as root spiralling is avoided. As a result, there is better outplanting survival and growth.
- b. Disease and pest management is simplified with root trainers as they are supported off the ground on racks, frames or stretchers.
- c. Smaller size and volume requires less quantities of media which is easy to fill.
- d. Smaller, lighter root trainer seedlings are less labour intensive, cheaper and easier to transport and occupy less space.
- e. Varied types are available to suit local needs.

## **Types of Root Trainers**

Though all types of seedling containers are not yet available in India, block type root trainers are available. Root trainer containers are of two types: (a) containers planted with seedlings and (b) containers removed before planting. Variations of the above two types are briefly described below.

### **A. Container planted with seedlings**

The best known are the paper pot and the jiffi pot. Paper pots are bottomless, hexagonal in shape and connected in a honeycomb fashion. The jiffi pot is a compressed pear pellet contained within a plastic mesh netting. The pellets expand upon watering and fit in a plastic tray.

### **B. Containers removed prior to planting**

This type of containers have varying designs and mostly use vertical ribs for root training. In individual cells with trays, each seedling is grown in its own independent and mobile unit arranged in a rack.

#### **a. Book and sleeve container**

This is made of relatively thin, flexible plastic arranged in two halves connected by a hinge, allowing the containers to be opened and closed at will. This arrangement helps in checking root development as well as soil moisture.

#### **b. Block container**

This is usually made of a single unit composed of many holes or cells arranged in the block.

#### **c. Winstrip container**

This is a relatively new and innovative root trainer system used in forest and horticultural industries. It is a block composed of a series of zigzag, high-density polythene plates clamped together ridge to ridge to form blocks of diamond shaped cells. Winstrips are extremely durable lasting more than 10 years.

## **Experimentation with Root Trainers**

The World Bank-aided Maharashtra Forestry Project envisages replacement of traditional polythene bag seedling production with 'root trainer' system. However, adoption of new technology in a country like India with varied socio-economic differences is a difficult task. Verification of facts through experiments under local conditions before recommending the technology for large-scale adoption is a must.

# Agroforestry for Land Resource Mobilization

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## ***Abstract***

*Ownership of degraded forest lands and wastelands is not clearly marked. Encroachment in such lands and marginal or small holdings are some of the impediments to the greening programme, particularly through woody perennial species. Poverty, landlessness, unemployment and anti-social elements are some other impediments of a socio-economic nature. However, building a sense of belonging, sharing profits for mutual benefits, self-help, a coordinated community and a cooperative approach through a proposed work model would enable the mobilization of waste and idle land resources for national well being.*

## **Introduction**

A more realistic assessment of wasteland resources is needed to determine alternative activities that meet the demands of local communities. The National Wastelands Development Board has already initiated a survey in collaboration with the National Remote Sensing Agency to identify such lands. Tenurial status is an important administrative issue related to the promotion of social forestry in India. A long-term activity such as tree planting cannot be undertaken without security of tenure. While executing social forestry programmes, problems are faced because of inadequate security of tenure.

## **Agroforestry Co-operatives**

Land use patterns of community-owned lands have evolved over a long period of time. Any attempt at awarding "tree patta" or the utilization of these lands for woodlot plantations is likely to face resistance. It is often said that prior to initiating any rehabilitation work, systematic identification of the extent, location, tenure and nature of wastelands is essential. There should be no hesitation in openly confirming "Bhoomidhari" tenurial status collectively to wasteland possessors forming an

agroforestry cooperative society. It can bestow a sense of belonging and boost production efforts. Nominal tenurial charges should be fixed until a final settlement is reached on disputed land. This approach would mobilize an idle productive resource in the national interest.

Agroforestry cooperatives may be constituted with the population of four adjoining villages. The area within the village limits, on an average, is approximately 4800 ha. This should constitute the area of operation. Each village should have proportional representation in the working committee based on its population. The committee with the help of local talathi, gram sewak and other officers should identify the forest area in charge of the Forest Department; grassland and waste or fallow land in charge of the Revenue Department or Gram Panchayat and other forms of land use in the operational area.

For government land available for planting, a nominal rental of Re. 1.0 per ha should be paid by the society. A forester should help the society identify suitable land and raise trees. All the expenses should be borne by the government through the Forest Department at the prevailing cost structure. The entire cost should be reimbursed to the Government by the society after 10 years in one installment at 5% plain rate of interest. The standing tree growth and usufructs should belong to respective owners. The ownership of land should continue to be as per the records. If the land under agroforestry belongs to small and marginal farmers, besides expenses for raising crops, additional amount to make good the losses should be paid to the land owner in the form of food grains up to the end of the half rotation period which is normally five years. By that time, the tree component will start producing to compensate the losses.

If medium and large landholders willingly bring their farm under agroforestry, then expenses on establishment should be borne by the government. Maintenance and protection should be the responsibility of the land owner. Entire expenses should be reimbursed to the government in the tenth year. If the government land is involved under the scheme, one ha per landless family should be allotted by the society for raising agri-silviculture up to 3-5 yrs. During this period, the beneficiary can harvest agricultural crops and usufructs from the trees. Harvest from trees at the end of the rotation period should be distributed equally between the society and the government.

In the case of government forest land already well covered with tree growth, the society should undertake harvesting and tending operations under the guidance of the forest department. A work plan for this should be drawn up and 25% of the harvest should be allowed to the cooperative society. By the end of the first rotation after 10 years, the society is likely to become financially sound and self sustaining. Thereafter, it should continue planting and harvesting operations under the technical guidance of the forest department.

## **Benefits**

If the scheme is implemented, a 10 ha tree cover would be raised in each village annually and the entire waste/idle land would be brought under tree cover in 40 yrs. This period of raising tree cover could be shortened to 20 yrs or 10 yrs if more funds become available for this programme. Depending upon the rate of expanding tree cover, between 10-40 yrs, a tree cover of 33% or even more envisaged in our National Forest Policy of 1988 would be achieved.

The proposed programme has the potential to generate 10 x 600 mandays of work in every village annually for plantation activities. Raising nurseries and tending operations of plantations will result in a substantial rise in local work generation. It will help arrest the exodus of villagers to nearby cities.

Bestowing "Bhumidhari" tenurial rights would help in developing a secure life for the villagers possessing land. Acceptance of "Bhumidhari" tenurial right would also mean surrendering of encroachments for common good and ego satisfaction of custodian officials. Investments of loan on easy terms for development work on lands belonging to rich, poor and common property would secure participation of village elite and generate work security to landless poor.

Sharing profits would build mutual trust and encourage participation, thereby boosting development and protection of common property. Voluntary involvement, coordinated community cooperative efforts for a secured life and sustainable development through agroforestry alone would enable mobilisation of potentially productive waste and idle land resources for the benefit of the nation.

# **Experiences in Mixed Tree Farming**

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## **Introduction**

A society was formed by a team of social workers in 1981 to promote cooperative farming in Tamil Nadu with the aim of creating egalitarian communities. Initially, the feasibility of the objective was questioned by many. The process of change the social workers have undergone, the approach they adopted and their experience in mixed tree farming are highlighted in this paper. The two concrete approaches adopted were (a) tapping underground water for agriculture and (b) raising commercial forestry.

## **Tapping and Recharge of Ground Water**

Initial attempts to establish 10 cooperative units were not successful because the ground water source proved to be very poor and the moisture holding capacity of the land was low. It became clear that an appropriate ground cover to improve recharge of water was necessary before tapping water. Because of this realisation and the interaction with Action for Food Production (AFPRO) and Agriculture Man Ecology (AME), organisations with similar experience, a watershed approach was adopted. Thus, the Chettikulam Watershed Project was initiated in 1990 with technical and financial support from AFPRO.

## **Chettikulam Watershed**

This watershed had more than 50% forest cover which was removed by the government when the land was allotted to repatriates from Sri Lanka. Eventually, the land lost the top soil and only thorny bushes were growing. Only 40% of the land was under traditional agriculture. There were only a few bunds. The native species on the legal boundaries were the saviours of the soil.

## **Present Land Use**

Our programme at present is attempting to recreate a balanced ecosystem. In one type of land use, drought-tolerant horticultural species like cashew, tamarind and amla were

planted within the bunds. On the bunds, trees like *Albizia lebbeck*, *Cassia siamea*, *Azadirachta indica*, *Ailanthus excelsa*, *Pithecellobium dulce*, *Albizia amara*, *Leucaena leucocephala*, *Borassus flabellifer*, *Acacia nilotica*, *Acacia leucophloea*, *Delonix elata*, *Delonix regia*, *Dalbergia sissoo*, *Tectona grandis* and *Pterocarpus marsupium* were planted. Because the trees have to survive extreme drought conditions, importance was given to local species. Trees commonly found in field bunds in the area are *Albizia lebbeck*, *Cassia siamea*, *neem*, *Albizia amara*, *Acacia leucophloea*, *Borassus flabellifer*, *Delonix elata*, *Chloroxylon swietenia*, *Wrightia tinctoria* and *Odina wodier*. In the programme implemented at present, species which have fodder and nitrogen fixing values are given importance. Though *Cassia siamea* does not serve these purposes, it grows very well and is useful as a green manure and firewood, and hence is planted in plenty.

In the second type of land use, there are certain areas where trees dominate, but horticultural species are few or none. In this uneven area, natural vegetation is encouraged. There is another land use type where trees are on bunds with a few fruit trees in the field where agriculture predominates. Satisfactory interception and percolation of rain water is effected by bunding, planting trees on bunds and deep ploughing. This type of dryland agriculture is expected to be more productive. The horticultural species thrive better because of greater recharge of rainwater.

### **Monoculture Tree Farming to Mixed Horticulture**

It was found that a commercial plantation with a single tree species was not viable. Eucalyptus planted in 3.0 acres generated an income of only Rs. 3,000 - Rs. 4,000 after four years. Besides, it had a negative effect on land, mainly through heavy soil erosion, outweighing the little profit it brought. Even cashew as a pure crop is not very profitable or ecologically sound. When cashew was inter-planted with multipurpose trees, especially nitrogen fixing trees, yields of cashew improved. Native species break the soil and enable roots of orchard trees to penetrate deep down.

Therefore, in the Chettikulam Watershed Programme, mixed tree planting on the borders of cashew orchards is encouraged. Other important species are tamarind, amla, mango and jackfruit. When cashew yield decreases, these trees will be removed. This type of mixed horticulture with multipurpose trees on bunds will be more sustainable than any single species orchard. In certain areas of this orchard, fodder species like *Cenchrus ciliaris* and stylo are grown. Native grasses growing in other areas are used as fodder for cattle. Participants in the programme plan to raise legumes like pigeonpea and cowpea within this mixed orchard in future.

## **Importance of Mixed Tree Stands**

Establishment of mixed tree stands is advocated in the watershed programme to increase the biodiversity. A large number of species is found in the temple groves in the area. People of this area love trees and are saving the area from ecological degradation. The conservation area within the watershed has a rich diversity of species. An area of seven acres is set aside for natural vegetation. So far 25 native tree species have been identified and there are likely to be more.

Multipurpose trees in the watershed provide protection from soil erosion, improve infiltration of the rainwater, enrich the soil, raise the water table and yield fodder and fuel. When the watershed is ecologically protected, people dwelling there will be economically protected as well.



# **Awareness and Knowledge of Farm Forestry among Farmers of Karnataka**

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## **Introduction**

It is essential to study the farmers' attitude towards and knowledge of farm forestry for the rapid and successful promotion of farm forestry, particularly in dry regions. Planners and policy makers should be equipped with this data while formulating objectives and strategies. Such data could be a yardstick for researchers in the evaluation and monitoring of ongoing projects. An attempt in this direction has been made as a prelude to an economic evaluation of the various components of social forestry, of which farm forestry is one.

## **Methodology**

Three Social Forestry Divisions - Bijapur, Dharwad and North Kanara - with distinct agro-climatic conditions, were selected for the study. Each of these divisions is under the respective zilla parishads and each taluka represents a Social Forestry Range. Within each division, two ranges having the highest number of Kisan nurseries were selected for the study. Bijapur and Hungud ranges from Bijapur division, Dharwad and Savanur ranges from Dharwad division and Sirsi and Siddapur ranges from North Kanara division were selected.

Selected Social Forestry divisions differed substantially in forest area, land available for tree cultivation, population density, bovine population and geographical features. Bijapur is a drought-prone district of the Northern dry zone, Dharwad is a transitional belt and North Kanara is a heavy rainfall area.

From the lists of beneficiaries under Social Forestry provided by the State Forest Department, 180 respondents were selected. From each division, 20 farmer beneficiaries belonging to each of small, medium and large categories were selected randomly to obtain primary data. Detailed data and information from each of the respondents were collected by direct interview method. For this purpose, a pre-tested and stratified questionnaire was used.

## Results and Discussion

For a majority of the respondents (75.28%), farm forestry meant planting trees on farm bunds, while for 59.17% and 3.33% of the respondents, it meant planting trees in waste/marginal land of the farmer and growing trees and crops together, respectively. It was an activity where cultivated land was diverted for growing trees, according to 4.44% of the respondents, while 24.72% had no idea about it at all.

Majority of the respondents (75.83%) from North Kanara division equated farm forestry with planting trees on waste/marginal lands of farmers. This view was shared by 68.33% and 33.33% of the respondents in Dharwad and Bijapur divisions, respectively. More than 46% of the respondents in Bijapur division were unaware of the concept of farm forestry which was the highest among the three divisions; the corresponding figures for Dharwad and North Kanara divisions were 18.33% and 9.17%, respectively.

When eight objectives of farm forestry were listed, 76.01% of the respondents felt that the introduction of farm forestry was to maintain the ecological balance in the region. Supply of fuelwood, fodder, timber and poles was another important objective of farm forestry (75.28%), followed by efficient land utilization (67.16%), supply of green manure (56.83%), checking soil and water erosion (56.09%), establishing shelterbelts (49.08%), maintaining soil fertility (34.32%) and creating employment opportunity (2.58%).

Among the different sub-components of farm forestry, planting trees on farm bunds, wastelands, and/or in marginal lands of a farmer were found to be more popular with 75.28 and 59.17% of respondents accepting them as synonymous with farm forestry. This could be easily defended and justified on the following grounds: firstly, farm forestry is not a new concept to farmers. Since time immemorial, farmers have been growing trees in their farms to meet their requirements of fuelwood, fodder, fruits, green manure, timber and gums. Trees are also grown in farms for aesthetic purposes and to provide shade and shelter to animals and human beings. Usually, multipurpose trees were preferred on farmlands. The farmers also knew very well that trees could prevent soil and water erosion effectively, thus maintaining the soil fertility. Trees are even worshipped in many parts of the country. When compared to the awareness and knowledge of other components of social forestry, farm forestry was well understood and conceived by farmers.

The objectives of farm forestry like efficient utilization of land, creation of employment opportunity and maintenance of the ecological balance appeared new to a majority of the farmers initially. But they were receptive to the concept when explained by the researcher. Among the divisions, Bijapur had 46.67% of respondents who had no

idea of farm forestry, followed by Dharwad with 18.33% and North Kanara with 9.17% of the respondents. The reason may be that trees in farmlands have either been sold to ward off financial crisis by many small and medium farmers or cut to feed the ever increasing number of sheep and goats. Respondents reported instances where trees belonging to species like *Acacia nilotica*, *Ficus bengalensis* and *Ficus religiosa* were felled to avoid loss of crop yields due to their shade effect or to deny shelter to birds that feed on crops. In many other cases, land reforms (Land Ceiling Act) resulted in extensive felling of trees in the farms before transferring the land ownership to others (tenants).

Division of landholdings also resulted in felling of a large number of trees in farmlands. Due to these reasons, many young farmers may not have seen trees on their farms at all. This may have made them unaware of the benefits of trees in farms. Adverse climatic conditions, illicit feeling and indiscriminate grazing may have further discouraged them from adopting farm forestry. But respondents in Dharwad and North Kanara divisions were more receptive to modern ideas.

## **Agroforestry Experience at Kadus Village in Maharashtra**

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Development of wastelands and marginal lands through afforestation is fast becoming a primary facet of many rural development activities. Although farmers are convinced about the benefits of growing trees on field bunds and marginal lands, the non-availability of good quality seedlings is a major constraint in promoting afforestation in rural areas. Therefore, the BAIF Development Research Foundation (BAIF) in Pune initiated a scheme in 1986.

The scheme envisaged raising of seedlings of multipurpose tree species by involving farmers around Kadus village of Rajgurunagar taluka in Pune district. These seedlings were distributed to interested farmers in surrounding areas. The initial response for tree planting was mild. Though the seedlings of different fodder, fuel, timber and fruit species were distributed free of cost at the farmers' fields, they were reluctant to plant trees on their land.

BAIF, therefore, conducted village-level meetings and group discussions to determine the reasons for non-participation. Farmers expressed their doubts about the feasibility of growing crops with trees and legal complications involved in felling trees under the existing tree felling act.

Suitable remedial measures such as pruning of roots and tree branches and orienting of tree rows in the north-south direction were suggested to avoid competition with crops in adjacent fields. Fear about government restrictions on tree felling were removed by explaining the relevant rules and regulations. The potential income generation from different tree species was detailed. Posters highlighting different uses of trees and their economics were displayed at village panchayats and schools. Film and slide shows highlighting the benefits of agroforestry were also organised. In addition, demonstration plantations at farmers' fields were established.

Initially, subabul seedlings were raised in the nurseries. Subsequently, species preferred by farmers such as custard apple, ber, melia and teak were raised in Kisan Nurseries. A large number of farmers came forward to collect and even buy these seedlings for planting on their field bunds.

The climate in Kadus area is sub-humid with an annual rainfall of 800 mm. Farmers provide irrigation from open wells till January-February. These conditions favour the growth of melia in this region. Therefore, farmers demanded melia seedlings in large numbers for planting on field bunds. To ensure that the main stem is straight and to reduce the shade effect on arable crops, side branches of melia trees were pruned regularly.

There is a demand for melia poles in the local market. Normally trees are harvested at 3-4 years when the basal diameter of the trunk reaches 8-10 cm. Melia coppices very well and the stems can be harvested every three years. A melia pole of 3-4 years fetches more than Rs. 40/- at the farm. Poles are purchased by users in surrounding areas and merchants from Rajgurunagar which is about 15 km from Kadus. Some farmers have also planted melia around orange and guava orchards, on field bunds and also as a sole plantation on marginal lands. Most of the farmers prefer to plant melia on field bunds as holdings are small. Since these plants do not require any care, except lopping branches to avoid shade on the adjacent crop, they are very popular. Trees are normally planted at a spacing of 1.0 m.

Melia poles are mainly used for rural housing, cattle sheds and for hitching bullocks to farm implements. Recently, melia wood is being used for making boxes to pack industrial products. The foliage is used as fodder and the thin branches are useful for propping up vegetable crops and as fuel. This melia model is highly profitable.

Since 1986, more than 1100 farmers in the Kadus area have planted about 450,000 melia seedlings on their farms. Many of them have harvested trees for their own use or for sale. Some farmers have earned up to Rs. 30,000/- or more per ha in 3-4 years by planting melia on field bunds. This is in addition to the regular income from agricultural and horticultural crops.

### **Planting on Field Bunds**

A typical case is that of Mr. Ramarao Balasaheb Dhaibar who planted about 2000 melia seedlings on his field bunds. He grows onion, potatoes, groundnut and other agricultural crops. In 1991, he harvested three-year old melia trees. The coppice will be ready for harvest shortly. According to him, a three-year pole, which is about 5-6 m in length and 8-10 cm in diameter, fetches Rs. 50-60/-. He uses the terminal portion as fodder and fuel. The branches and tops are sold as fuel to the villagers at the rate of Re. 1.0/kg. He has earned about Rs. 30,000/- from melia so far. He is also of the opinion that no special cultivation efforts are required except pruning of side branches.

## **Farm Forestry with Melia**

Mr. Hanif Papabhai Momin owns one acre of land in Kadus. He has a shop in the village and therefore is unable to manage the agricultural activities in his farm. He decided to grow melia on his land. Being a tree crop, he finds that the labour and attention required by melia is low.

He planted the entire area with melia in 1988. At a spacing of 1.5 x 1.5 m, there were about 2000 seedlings in his one acre land. The field was irrigated as and when required. In 1992, he harvested the trees and retained half of the poles for constructing an onion storage shed and the remainder was sold. He earned Rs. 40,000/- from the sale. Deducting the cost of cultivation which was less than Rs. 10,000/-, he has earned Rs. 30,000/- in addition to the poles used for the onion storage shed.

# Species Diversity in Coconut Gardens in Tiptur Region of Karnataka

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## Introduction

Coconut is an important crop in Tiptur taluka of Karnataka. Situated at an elevation of 900 m, Tiptur taluka receives an annual rainfall of about 600 mm. It is not known when coconut was introduced to this area, but at present it is planted in 15,550 ha in the taluk.

The coconut palm, popularly known as the kalpataru, meets the requirements of the local population in the form of cash, food, firewood, broom sticks and timber. Coconut is planted all along the valleys and low-lying areas. It used to be rainfed till recently. Due to over-exploitation of ground water, the water table has receded and people are increasingly adopting irrigation with water from borewells. Coconut is usually grown as a monocrop, but sometimes a fodder crop like sorghum is grown as an intercrop.

Clean cultivation of coconut gardens is normally practised. Both rainfed and irrigated gardens are ploughed 5-6 times a year and are maintained very clean. This repeated ploughing, farmers believe, increases percolation of rainwater and also gives a cushioning effect to falling coconuts which are plucked using a bamboo pole. It is also believed to check the rodent menace in coconut gardens. Because farmers believe that live fencing results in rodent infestation, there is a tendency to replace them with barbed wire fencing. The case study reported here tried to probe the influence of this change in practice on the species diversity in coconut gardens.

## Methodology

Data were collected from 60 coconut farmers belonging to all categories of landholding using a pre-designed format/questionnaire. Many more farmers were also informally interviewed to elicit their views on the subject. The personal observations of the authors during the last several years in this area were also used to draw conclusions.

## Results

**Table 1.** Salient features about the farmers contacted.

Landholding (ha)	Irrigated Area (ha)						Type of Fencing		
	0	< 1	1-2	2-4	4-7	Nil	Barbed hedge	Live	Thorn
< 1	4	10	-	-	-	4	3	4	3
1-2	3	7	12	1	-	-	6	16	3
2-4	3	3	6	2	1	1	8	4	2
4-7	-	-	1	5	6	-	5	3	-

The commonest species for live hedges are *Agave*, *Euphorbia*, *Lantana camara* and *Ipomea species*. Normally they are interspersed with *Acacia nilotica* and *Pongamia glabra*. The change in fencing pattern in the last 20 years is given in Table 2.

**Table 2.** Change of fencing pattern in the last 20 years.

Fencing	Old	Present
Barbed	-	22
Live	11	27
Thorn	7	6
No Fence	42	5
Total	60	60



**Table 3.** The preference of farmers for growing species in coconut gardens.

Species	Species found at present	Species preferred
<i>Azadirachta indica</i>	+++	++
<i>Pongamia glabra</i>	+++	+++
<i>Artocarpus heterophyllus</i>	+	+
<i>Acacia nilotica</i>	++	+
<i>Albizia lebbek</i>	+	+
<i>Madhuca indica</i>	+	+
<i>Mangifera indica</i>	+++	++
<i>Tamarindus indica</i>	+	++
<i>Syzygium cumini</i>	+	
<i>Ficus spp.</i>	+	
<i>Tectona grandis</i>	+++	++++
<i>Sapota</i>		++
<i>Dalbergia spp.</i>		++

**Table 4.** Species found in coconut gardens as influenced by fencing pattern.

Species	Garden with Live hedge	Garden with Barbed wire
<i>Acacia nilotica</i>	+++	+
<i>Azadirachta indica</i>	+++	+
<i>Pongamia glabra</i>	+++	+
<i>Tamarindus indica</i>	+++	+
<i>Santalum album</i>	+++	+
Mango	+	+++
Sapota	+	+++
Guava	+	+++
Banana	+	+++
Arecanut	+	+++
Teak	+	+++

## Discussion

Irrespective of the size of the holding, people in Tiptur taluka have the tendency to grow coconut as a major cash crop. People recollect that coconut gardens used to have a large number of other species in the fence a few years ago. But there is a tendency among the farmers, particularly those with large holdings, to replace the live hedges with barbed wire fencing.

The reasons quoted for replacing the live hedge with barbed wire fencing are that they promote rodent infestation, require regular maintenance, affect the yield of coconut trees and have a shade effect whereas barbed wire has value as a status symbol and is easy to maintain. The strong preference for clean cultivation in barbed wire fenced coconut gardens seems to strengthen this concept. Of late, a number of young farmers adopt zero cultivation practices in coconut gardens.

There is a strong linkage between fencing pattern and other species naturally established. Live hedge practice seems to promote natural propagation of species such as *Acacia nilotica*, *Tamarindus indica*, *Azadirachta indica* and *Santalum album*. All these species are normally found in fences with rare exception.

Large landholders who have increasingly gone in for barbed wire fencing raise horticultural species such as sapota, guava, mango, arecanut and banana. Naturally propagated species are rare in intensively cultivated gardens with barbed wire fencing. There is also a belief that species like neem, pongamia, eucalyptus and madhuca have coconut pest-repellent properties.

## Conclusion

It is observed that the population of naturally propagated plants have been reduced with the change in fencing pattern from live hedge to barbed wire. However, there is a conscious effort to include species like mango, sapota, guava, teak and coconut in coconut gardens. But there is no effort to grow species such as neem, *Acacia nilotica* and pongamia though farmers in general feel that they are helpful in pest control. Since coconut provides more than the required quantity of firewood, there was no interest to grow firewood species. Because farmers raise a fodder crop as an intercrop within the coconut gardens during the kharif season in rainfed coconut and 2-3 crops in irrigated coconut, there was no need to promote fodder trees.

# Socio-Economic Aspects of Community Forestry

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## Introduction

A study was initiated in 1989 and follow up surveys were conducted in subsequent years. The main objective of the study was to assess the role of social forestry from a systems research perspective and to study the linkages between social forestry and rural development.

## Methodology

The study was conducted in 12 villages of Maharashtra state where social forestry projects were started. Further, 10 farmers from each village were interviewed in an in-depth study. The linkages were studied by undertaking interviews with sarpanches, chairmen of cooperatives, village leaders, farmers, government officers and connected organisations.

## Profile of the Respondents

The profile of the respondents is discussed in terms of level of education, percentage of irrigated land and livestock ownership (Table 1). The numerical strength of milch cattle favourably influences adoption of social forestry to ensure a reliable source of supply of fodder.

**Table 1.** Profile of the Respondents

Particulars	Non-Adopting farmers	Adopting farmers	Small marginal farmers	Medium and big adopting farmers	Dairy farmers adopting	Farmers without irrigation
<b>Education (%)</b>						
None	28	19	23	12	8	9
Up to Primary	68	70	37	29	32	41
Above Primary	4	11	40	59	60	50
Up to 10th Standard	4	11	30	42	39	38
Above 10th Standard	-	-	10	17	2	12
<b>Irrigated Land (%)</b>	30	42	50	41	41	-
<b>Number of Livestock</b>						
Number of Livestock	4	9	4.7	13.1	18.6	3.6
Milch cattle	1.5	3	1.5	4.1	8.2	1.8
Bullocks	0.5	1.5	1	1.2	2.3	1
Poultry	1	2	1	5.2	1.5	0.7
Sheep/Goats	1	2	1	2.5	1	0.1

## **Backward Linkages**

A few of the important linkages which further the cause of social forestry are guidance and information; help in the form of inputs; extension meetings; and provision of credit and protection.

As regards the guidance on social forestry, an interesting pattern emerges. Forest Department and Social Forestry Department (SFD) are two distinct entities in the field with a common Secretary of Government. This is different from many other states where the Principal Chief Conservator of Forests or the Chief Conservator of Forests looks after both wings. The medium/large farmers (with or without irrigation) and the dairy farmers have identified the Forest Department as the single most important source of guidance on social forestry (not that SFD can be excluded from the section). This could be expected since such plots are few and those that exist do not stress short-term products while the wood yield is some distance away. In some places, leaders, agriculture extension officers and bank officials have also been active.

Interaction with various institutions is an important forward linkage through which the participants of social forestry are expected to benefit. In turn, hopefully, the village economy also stands to benefit. It is clear that social forestry has resulted in an increased interaction with gram panchayats. Gram panchayats are, therefore, very important links which need to make special efforts to solicit participation of non-adopters.

## **Forward Linkages**

The forward linkages of social forestry are not easily discernible as the tangible benefits in the shape of wood are yet to materialise. The yield of fodder has not been stressed and even when the fodder is produced, the general method of disposal by annual sale leads the common man to believe that the plantation does not yield anything worthwhile. The available feedback is, therefore, rather limited and the role of social forestry in rural development has so far not been prominent in the public mind.

It is clear that tangible benefits like procurement of fodder/ grasses from private lands is reported by a very small percentage of respondents. Yet, a very high proportion of them have a liking for the programme. It is seen that the benefits from minor forest produce have not been projected prominently so far.

The concept of people's participation has to be associated with the idea of meeting the basic requirements of fuel, fodder and timber with a promise of economic returns. The programme must be designed so as to take into account the local/trade/processing needs of all forest products to the extent possible. The linkages of local importance need to be carefully identified with a view to assign specific targets and responsibilities.

The strength of backward and forward linkages too have been depicted in relation to each of the five respondent categories. Social forestry, a dynamic process, presupposes people's participation which in turn would be greatly affected by the quality and quantity of the output and the benefits that will accrue to the participants. The sensitivity of the outputs as a function of the linkages can be easily analysed and tested if adequate empirical data is gathered on those aspects. This exercise could not be undertaken in the present report for lack of data and its documentation.

In order to undertake a sensitivity analysis, the data generation needs to be participant specific. The effectiveness of various linkages can be measured by the level of outputs which need to be properly documented.

In conclusion, we recommend that a very detailed plan specific to a village may be formulated by the SFD in consultation with participants, village leaders, village-level institutions, related government departments and non-government organisations. The Gram Panchayat should coordinate this effort and activities at the village level. A model may be initially drafted as a basis for preparing specific village level plans. This should form the cornerstone of future rural development effort. The approach would be to allow villagers to opt for participation on a voluntary basis as targets based on geographical units may not be appropriate. It would be advisable to select a few typical villages for various agro-climatic zones in the state and draw up detailed plans for each. Such plans could then be adopted for similar villages in the neighbourhood.

# Cashew Cultivation in Maharashtra : A Case Study in Retrospect and Prospect

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## ***Abstract***

*The potential of cashew, a multipurpose tree that yields cashew apple, nut and shell oil besides its role in soil and moisture conservation, has not been fully exploited despite the efforts of the Government of Maharashtra. Cashew cultivation was practised on a limited scale on forest lands by the Forest Department, but cashew has been planted on private lands too since 1977. During the period 1964-1972, the Department of Agriculture planted about 52,000 ha of private lands in the Konkan Region with cashew. The Forest Department planted an area of 350 ha of private land as part of the special Western Ghat Development Programme in Ratnagiri District. A similar scheme is in operation under the Employment Guarantee Scheme (EGS) since 1990. Cashew did not receive the priority it deserves as a horticultural crop; Forest Department considered it to be an extension activity which was confined mainly to the supply of seedlings and the establishment of plantations at subsidised rates. The role of the Department of Agriculture was limited to the establishment of the plantation and supply of inputs for three years. A comprehensive package offered by the Government of India did not succeed, primarily due to the longer lease period and lack of intermediate returns; establishment of plantations alone through EGS is inadequate as little thought has been given for aftercare. Success of this multipurpose tree species will be a trendsetter for cultivation of similar tree species on private lands.*

## **Introduction**

Cashew, introduced by the Portuguese in Goa about 400 years ago, is a multipurpose tree species as it produces cashew apple, nut and shell oil. The liquor distilled from the cashew apple, popularly known as 'feni', is used as a household medicine in Goa. Cashew nut is a widely consumed dry fruit. A naturally-occurring phenol extracted from

the kernel is used as an underwater preservative for ships. Because of their wide use and marketability, these products have great potential as a source of foreign exchange. The multiple use potential and role in soil and moisture conservation of cashew have not been fully harnessed despite the efforts of the Government of Maharashtra.

### **Efforts of the Forest Department**

Early efforts of the Forest Department were confined only to reserve forests where cashew was used mainly for providing a vegetative cover in afforestation programmes of degraded areas. Efforts to introduce cashew as an extension activity on private lands was also tried by the Forest Department on a limited scale since 1977 under the Integrated Rural Development programme. During 1981-1989, the Forest Department tried to introduce a comprehensive package of cashew cultivation on private lands taken on lease from the owners for a period of 30 years. This was under the Western Ghat Development Programme in about 350 ha of land in 10 villages in the catchment areas of Kajali and Muchkundi rivers in Lanja taluka of Ratnagiri District.

The package consisted of planting grafted plants of an improved variety developed by the Cashew Research Centre at Vengurla and its aftercare for 30 years, including application of fertilisers and insecticides as well as marketing of the produce on behalf of the farmers. This scheme envisaged incurring expenditure on inputs by the Forest Department and giving a 50% share in the net profit to the owner after fully recovering the costs incurred. The accounts were to be settled at the 10th, 20th and 30th years of the scheme.

### **Efforts of the Agriculture Department**

The Agriculture Department embarked upon a programme of cashew cultivation on private lands in 1964 offering a 50% subsidy. About 52,000 ha in the Konkan Region were included under this programme, but the incentives provided are only up to three years and that too not at the optimum level. Though this scheme tries to involve voluntary participation of people without any encumbrances of loans and their recoveries by the government as provided in the Forest Department's schemes, the burden of providing proper and timely intensive inputs is that of the beneficiary farmers who are definitely not in a position to afford this, being either marginal or small landholders belonging to economically weaker sections of the society. The whole exercise, therefore, is not expected to result in optimum production of cashew.

### **Suggestions**

Improved planting material, intensive fertilisation, irrigation, application of insecticides and effective protection are necessary for increasing the cashew yields. Since the gestation period for sustainable returns from cashew is about ten years, alternate sources

of intermediate return through intercrops like grasses, fodder or bamboo is necessary. Processing facilities like distillation units for liquor from cashew apples, roasting plants for cashew nuts and oil expellers for extraction of oil from cashew kernels are meagre in Maharashtra at present. Developing such facilities will enhance the marketability of these products.

Private entrepreneurs should be encouraged in a big way. Non-governmental organisations can play a leading role in motivating the rural population to take up cashew cultivation. As cashew is only one in the whole array of multipurpose tree species, its successful cultivation would definitely be a trendsetter for the introduction of other tree species on the otherwise non-productive lands in the Konkan region of Maharashtra.



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