TRAINING MANUAL: 2022

Training Manual for Refresher Training Program (RTP) on Agroforestry and Opportunities in Value Addition For Established Agripreneurs Under AC&ABC Scheme

TROPICAL FOREST RESEARCH INSTITUTE
(Indian Council of Forestry Research & Education) Jabalpur- 482021
In Collaboration with
National Institute of Agricultural Extension and Management (MANAGE)
Rajendra Nagar Hyderabad-500030

Training Manual

for

Refresher Training Program (RTP)

On

"Agroforestry and Opportunities in Value Addition"

For

Established Agripreneurs under Agri-Clinic and Agri-Business Center

(AC&ABC), Scheme

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Compiled

By

Dr.Nanita Berry
Dr.G.Rajeshwar Rao
Dr. P Chandra Shekara

Coordinated

By

Dr. Nanita Berry, Scientist 'F' Tropical Forest Research Institute,Jabalpur(MP)
Dr. Shahaji Phand, Principal Coordinator, AC&ABC, MANAGE, Hyderabad
Dr. Sagar Deshmukh, Training Associate, AC&ABC, MANAGE, Hyderabad
Muhammed Suhail TC, Consultant, AC&ABC, MANAGE, Hyderabad

Organized

By

Forest Extension Division, Tropical Forest Research Institute,
Jabalpur- 482021 (MP)

In collaboration with

National Institute of Agricultural Extension and Management-MANAGE
(An organization of Ministry of Agriculture and Farmers Welfare, Government of India)
Rajendra Nagar, Hyderabad-500030, Telangana, India

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Dr. Nanita Berry
Training Coordinator

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ADAPTATION AND MITIGATION TO CLIMATE CHANGE THROUGH AGROFORESTRY

Dr. G. RAJESHWARA RAO, ARS

Director
Tropical Forest Research Institute, P.O. R.F.R.C. Mandla Road, Jabalpur (M.P.)

1.0 Introduction

Climate change is linked to internal variability of the climatic system and external natural factors but much more to human activities. The potential fallouts of this phenomenon have been identified to include rise in temperature, much more erratic rainfall regimes, increased frequency and intensity of extreme events, and general unpredictability of agricultural operations among other effects. These have grave economic, social, and ecological consequences for agriculture and food security in many countries particularly, where agriculture is largely rain-fed. Climate change will affect developing countries more severely because of their low capacity for adaptation (IPCC, 2001). Within these countries, the agricultural sector is particularly vulnerable, putting rural populations at risk. Furthermore, climate change is an additional threat that might affect a country's ability to meet urgent rural development demands including the improvement of food security, poverty reduction, and provision of an adequate standard of living for growing populations. In the quest to provide food and fibre to an expanding human population, the provision of agriculture-based ecosystem services that help to moderate climate change is increasingly under threat (FAO, 2007).There is a real risk of losing the gains of the Green Revolution, which has largely eliminated the danger of famines such as those seen in the 1950s and 1960s.

The discussion on the potential synergies between adaptation and mitigation measures is just starting and is all too often reduced to a discussion of the costs of global adaptation vs global mitigation. A practical understanding of the link between adaptation and mitigation measures, particularly with respect to land use and management does not yet exist. Yet agricultural research in the last few decades has been addressing the need to cope with adverse and irregular climatic conditions including rainfall variability or shifting weather patterns. Similarly, there has been a major emphasis on improving the productivity of agricultural systems, leading to the understanding that increasing soil carbon stocks in degraded lands is essential for enhanced productivity. Agroforestry provides a unique opportunity to reconcile the objectives of mitigation and adaptation to climate change. A wide range of studies (Albrecht and Kandji, 2003; IPCC, 2000; Palm et al. 2005) have substantiated the fact that agroforestry systems, even if they are not primarily designed for carbon sequestration, present a unique opportunity to increase carbon stocks in the terrestrial biosphere (Table 1).

Table.1. Potential carbon (C) storage for agroforestry systems in different ecoregions of the world

Region	Ecoregion	System	Mg C ha^{-1}
Africa	Humid tropical high	Agrisilvicultural	29–53
South America	Humid tropical low dry low lands	Agrisilvicultural	39–10239–195
Southeast Asia	Humid tropical dry low lands	Agrisilvicultural	12–22868–81
Australia	Humid tropical low	Silvipastoral	28–51
North America	Humid tropical high humid	Silvipastoral	133–15
Tropical low	Silvipastoral	4104–198	
Dry lowlands	Silvipastoral	90–175	
Northern Asia	Humid tropical low	Silvipastoral	15–18

Based on assessments of national and global terrestrial carbon sinks, two primary beneficial attributes of agroforestry can be identified. The first is direct nearterm carbon storage in trees and soils through accumulation of carbon stocks in the form of live tree biomass, wood products, soil organic matter and protection of existing products. The second involves potential to offset greenhouse gas emissions through energy substitution (e.g. fuelwood from woodlots) and fertilizer substitution (through biological nitrogen fixation and biomass production). Agroforestry can also have an indirect effect on carbon sequestration when it helps decrease pressure on natural forests, which are the natural sinks of terrestrial carbon. Carbon is particularly useful in agricultural systems, making agroforestry a quantitatively important carbon sink. Agroforestry systems in the humid tropics are part of a continuum of landscapes ranging from primary forests and managed forests to row crops or grasslands.

They are mostly perennial systems such as homegardens and agroforests in which the tree component can stay in the field for more than 20 years. While agroforestry systems contain less carbon than primary or managed forests, the fact that they contain significantly higher carbon stocks than row crops or pastures suggests that the introduction and proper management of trees in crop lands has a great potential for carbon sequestration, in

addition to rehabilitating degraded land. Unlike simultaneous systems, improved fallows are tree–crop rotation systems where fast growing, often leguminous, trees are cultivated for a period of 8 months to 3 years to enhance nutrient depleted soils and degraded lands in the sub- humid tropics. However, several studies on soil carbon dynamics have indicated that soil organic matter increases after a few seasons of tree planting on degraded soils.

2.0 Enhancing farmer adaptive capacity through agroforestry

As adaptation emerges as a science, the role of agroforestry in reducing the vulnerability of agricultural systems (and the rural communities that depend on them for their livelihood) to climate change or climate variability needs to be assessed more effectively (Verchot et al., 2007). Rainfall variability is a major constraint in the semi-arid regions and to the upland farms in Southeast Asia that do not have access to irrigation. However, the effects of variable rainfall are often exacerbated by local environmental degradation. Therefore, curbing land degradation can play an important role in mitigating the negative impacts of climate change and variability, and that is where agroforestry can be a relevant practice. Successful and well-managed integration of trees on farms and in agricultural landscapes often results in diversified and sustainable crop production, in addition to providing a wide range of environmental benefits such as erosion control and watershed services. Optimizing the use of increasingly scarce rainwater through agroforestry practices such as improved fallow could be one way of effectively improving the capacity of farmers to adapt to drier and more variable conditions. Under many of the different farmer practices in Africa, crops still fail completely or yield very little in drought years. Results from improved fallow trials were used to model these various systems. The model suggested that it would be possible to produce an acceptable amount of food in low rainfall years if practices such as improved fallows were pursued. In low-rainfall years, water availability to crops is paramount and seems to be the dividing factor between absolute crop failure and reasonable food production. Buffering agricultural crops against water deficiencies is, therefore, an important function agroforestry would have to play in the adaptation battle. There are other mechanisms such as improved microclimate and reduced evapotranspiration through which agroforestry practices may improve the adaptive capacity of farmers. In the African drylands, where climate variability is commonplace, farmers have learned to appreciate the role of trees in buffering against production risk (Ong and Leakey, 1999). The parkland farming system, in which trees are encouraged to grow in a scattered distribution on agricultural land, is one example. One of the most valued (and probably most intriguing) trees in the Sahel is Faidherbia albida. Thanks to its reversed phenology (the tree sheds its leaves during the rainy season), F. albida significantly contributes to maintaining crop yield through biological nitrogen fixation and provision of a favourable microclimate while minimizing tree–crop competition. A study on an F. albida–millet parkland system in Niger demonstrated that shade-induced reduction of soil temperatures, particularly at the time of crop establishment, is critical for good millet growth (Vandenbeldt and Williams, 1992). This type of reversed phenology

is not observed in other parkland trees such as the shea butter tree (Vitellaria paradoxa) and néré (Parkia biglobosa), which have a negative shading effect that may reduce millet yield under the tree by 50 to 80 percent in some cases (Kater et al., 1992). Farmers are well aware of this loss in yield, but do not mind it since the economic benefits from harvesting marketable tree products largely compensate for the loss of crop yield. However, in extremely hot conditions (which we may have to face in the future), the shading effect of these evergreen trees could compensate for the yield losses due to excess heat in the open areas of the field. Such a hypothesis has been validated by the work of Jonsson et al., (1999), who measured variables including temperature, photosynthetically active radiation (PAR is the light in the 400–700 nm waveband of the electromagnetic spectrum that is useful for photosynthesis) and millet biomass under and away from tree canopies in a parkland system. The results showed that despite the heavy shading, similar amounts of millet biomass were obtained from the areas under these trees and in the open. This absence of yield penalty under trees was, to a great extent, explained by the fact that millet seedlings under tree canopies experienced only 1–9 hours per week of supra-optimal temperatures (> 40°C) compared with 27 hours per week in the open. In other words, the shorter exposure to extreme temperatures compensated for the millet biomass loss that would otherwise have occurred as a result of shading. This underscores the important role trees could play in mitigating the negative effects of extreme temperatures on crops, especially in semi-arid regions. Pests, diseases and weeds already stand as major obstacles to crop production in many tropical agroecosystems and there are strong reasons to believe that their prevalence and deleterious effects on crops may increase with a warmer climate (Rosenzweig et al., 2000). It is strongly believed, yet not sufficiently tested, that enhancing plant biodiversity and mixing tree and herbaceous species in agricultural landscapes can produce positive interactions that could contribute towards controlling pest and disease outbreaks. The potential of agroforestry to control both ordinary weeds and parasitic weeds such as Striga hermonthica has also been demonstrated.

3.0 Income generation through tree products

Besides the biophysical resilience, which allows the various components of the agro-forestry systems to withstand shocks related to climate variability, the presence of trees in agricultural croplands can provide farmers with alternative or additional sources of income, so strengthening the socioeconomic resilience of rural populations. Tree products (including timber, fodder, resins and fruits) are normally of higher value than maize or hard grains such as millet and sorghum, and can buffer against income risks in cases of crop failure. The Sahelian Eco-Farm (SEF) provides an eloquent example of how an agroforestry-based integrated natural resource management regime can help to improve the livelihood of the rural poor in vulnerable regions such as the Sahel (Pasternak et al., 2005). The SEF is an integrated land-use system that incorporates high-value multipurpose trees/shrubs with soil and water conservation structures. The value produced is in the form of food, fuelwood and forage (which can all be converted into cash), plant nutrients,

biomass for mulch (which contributes to increased infiltration of rainfall, and addition of organic matter to the soil), and protection from wind erosion. The first on-station test of the SEF took place at the Sahelian Center of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger during 2002. The estimated income from a 1-ha farm was US$600, some 12 times the value of a typical millet crop. The estimated costs of establishing the SEF are not high; the plant material costs about US$60 per ha, and the one-time application of fertilizer about US$10. The labour requirements for land preparation and tree planting are met by farmers and their families.

In the semi-arid zone of Kenya, the park-land system is showing similar success. The fast-growing indigenous species Melia volkensii is highly compatible with crops and can provide high-value timber in 5–10 years. A study by Ong et al., (2002) in the Kitui district of Kenya showed that in an 11-year rotation period, the accumulated income from tree products exceeds the accumulated value of crop yield lost through competition. This income difference is worth US$10 or 42 percent during average years, and US$22 or 180 percent if a 50 percent rate of crop failure owing to drought (reasonable for Kitui) is assumed. In such a hostile environment, where crops normally fail every other year, good and secure financial returns from M. volkensii even in drought years can provide significant relief for farmers. This will be all the more necessary as extreme climate events (droughts and floods) are likely to increase in frequency and in magnitude in the near future.

4.0 Conclusions

The impact of climate change will be felt at several levels in the agricultural sector. Most of the effects will hit the rural poor in developing countries, who are the most vulnerable because of their poor ability to adapt. The adaptive capacity of farmers in developing countries is severely restricted by their heavy reliance on natural factors and a lack of complementary inputs and institutional support systems. The concepts of resilience and sustainable productivity are well established in agriculture and can be linked directly to the discussions about adaptation and mitigation to climate change. Thus, policy makers can draw upon a substantial body of knowledge in this respect. However, the adaptation and mitigation synergies of agroforestry management systems warrant further investigation. Within international fora, there is much talk about bringing adaptation into the mainstream of planning processes. We have shown above, through the specific case of agroforestry, that some mitigation measures simultaneously provide opportunities to increase the resilience of agricultural systems. It is suggested that such synergies ought to be promoted more intensively through the channels of the UNFCCC such as the CDM. However, if agroforestry is to be used in carbon sequestration schemes including the CDM, several areas need to improve, for example, we need better methods of assessing carbon stocks and non-CO emissions. Furthermore, the debate on durable wood products is ongoing, but what is known is that farmers will need provisions to allow them to market wood products from their agroforestry systems, and we should develop methods to account

for the lifetime of the carbon sequestered in agroforestry products. As small-scale farmers are enrolled in carbon-offset projects, we will need to develop a better understanding of the implications of these for carbon sequestration by agroforestry and what it means to livelihoods. Finally, the CDM has very stringent rules for participation that may be beyond the reach of small-scale farmers to understand or to provide evidence of compliance. There is a need for institutional support by national, regional and international centres of excellence to facilitate effective participation of small-scale farmers in the CDM. In their attempts to develop adaptation strategies for the agricultural sector, scientists and policy makers must consider the complex interactions of constraints created by changing climates in the light of other stress factors. Government and international support in terms of research, education, and extension will be required to help farmers in developing countries cope with the additional stresses created by climate change and increased climate variability. Agroforestry can very likely contribute to increasing the resilience of tropical farming systems. However, our understanding of the potential of agroforestry to contribute to adaptation to climate change is rudimentary at best. Better information is required on the role of agroforestry in buffering against floods and droughts from both the biophysical (e.g. hydraulic lift or soil fertility) and financial (e.g. diversification and income risk) points of view. Agroforestry promises to create synergies between efforts to mitigate climate change and efforts to help vulnerable populations adapt to the negative consequences of climate change. The research agenda in this area is fairly well defined; much is already known and putting these ideas into practice on the ground with small-scale farmers will allow us to learn important lessons.

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PROMISING AGROFORESTRY MODELS FOR CENTRAL INDIA DEVELOPED BY TFRI

Dr. NANITA BERRY

Scientist 'F' & Head
Forest Extension Division
Tropical Forest Research Institute, Jabalpur (M.P.)

Evolution of agroforestry

Agroforestry is a relatively new term, although it is as old as the farmer's practice. Agroforestry is rapidly evolving as a science and a practice. It is increasingly seen as an approach to improve the livelihood of the rural poor and to protect the natural resource base by growing trees on farmlands Agroforestry science came into prominence only in the late 1970s. Subsequently, there has been progressive development in concept, philosophy, research, education and implementation approaches in agroforestry. Agroforestry promises to help farmers in increasing productivity, profitability and sustainability of production from their land.

What is agroforestry?

AF is an ancient land use practice of growing trees in association with crops for meeting some of the household needs Integration of trees with the crops and/or animals with the main objective of reducing risk and increasing total productivity. Agroforestry can be defined as both simple and complex definitions since the system has two or multiple components.

NEED AND SCOPE OF AGRO-FORESTRY

Agro-forestry, in true sense, has been realized as a need of the day. It does not confine to the regional, geographical or agro-climatic boundaries. Agro-forestry concept is a universal application . Agroforestry can provide a range of products and services that contribute to both rural development and environmental conservation. This section deals with the products generated from agroforestry systems. Products include food-fruit, fuel , fibres , wood . Agroforestry is proved as a source of employment and income generation for poor farmers as well as women SHGs. Agroforestry systems can thereby contribute to food and nutritional security and increased rural income and employment opportunities. The agro-forestry has both productive and protective potential and it can play an important role in enhancing the productivity of our lands to meet the demand of ever growing human and livestock population.

The protective functions (protecting and maintaining production systems) of agroforestry systems are given below:

Food

1. Enhanced sustainability of cropping systems through soil and water conservation by arrangements of trees to control soil run-off and erosion.
2. Enhanced food and feed production from crops associated with trees through nitrogen fixation, better access to soil nutrients brought to the surface from deep tree roots, improved availability of nutrients due to soil organic matter and mycorrhizal associations.
3. Food for human being in the form of fruits, seeds , cereal substitutes and fodder for livestock
4. Micro-climate improvement due to trees, particularly shelter-belts and wind-breaks rows.

Water

1. Improvement of soil-moisture retention in rainfed croplands and pastures through improved soil structure and micro-climate effect of trees.
2. Regulation of stream flow, reducing flood hazards and a more even supply of water through reduction of run-off and improvement of interception and storage in infiltration galleries.
3. Improvement in drainage from waterlogged or saline soils by trees with high water requirements.

Energy

1. Fuel-wood for direct combustion.
2. Pyrolytic conversion products such as charcoal, oil and gas.
3. Ethanol produced from fermentation of high-carbohydrate fruits.
4. Oils, latex and other combustible saps and resins.

Shelter

1. Building materials for shelter construction.
2. Shade trees for people, livestock and shade-loving crops.
3. Wind-breaks and shelter-belts for protection of settlements, crop lands, pastures and roadways.
4. Fencing: live fences and fence posts.

Raw Material for Industries

1. Raw material for pulp and paper industry.
2. Tannins, essential oils and medicinal ingredients.
3. Wood for agricultural implements and various crafts.
4. Fibre for weaving.

Cash

1. Direct cash benefits by multiple products.
2. Indirect cash benefits from increased soil productivity and maintain its fertility.

Classification of Agro-forestry Systems

On the basis of nature of components the following are common agro-forestry systems prevailing in different agro-ecological regions of India :

1. Agri-silviculture (trees+crops)
2. Boundary plantation (tree on boundary + crops)
3. Block plantation (block of tree+ block of crops)
4. Energy plantation (trees+crops during initial years)
5. Alley cropping (hedges+crops)
6. Agri-horticulture (fruit trees+crops)
7. Agri-silvi-horticulture (trees+fruit trees+crops)
8. Agri-silvipasture (trees+crops+pasture or animals)
9. Silvi-olericulture (tree + vegetables)
10. Horti-pasture (fruit trees+pasture or animals)
11. Horti-olericulture (fruit tree + vegetables)
12. Silvi-pasture (trees+pasture/animals)
13. Forage forestry (forage trees+pasture)
14. Shelter-belts (trees+crops)
15. Wind-breaks (trees+crops)
16. Live fence (shrubs and under- trees on boundary)
17. Silvi or Horti-sericulture (trees or fruit trees+sericulture)
18. Horti-apiculture (fruit trees + honeybee)
19. Aqua-forestry (trees + fishes)
20. Homestead (multiple combination of trees, fruit trees, vegetable etc).

Criteria for selection of tree in Agroforestry system

Selection of the tree species is made on the basis of their ability to generate higher cash income. Farmers generally do not like to change their old farming system due to strong link with their socio-cultural traditions. Such changes can take place gradually, when the income level of the farmers increases and they start generating cash.

The tree must have the following characters:

1. Suitable for agro-climatic conditions,
2. Multipurpose to fulfill the multiple needs of farmers (timber, fodder, fuel, fruit and fibre),
3. Fast-growing with short rotation and Narrow crown with nitrogen-fixer,
4. Non interference with arable crops ,
5. Easy to establish ,

3. Non-allelopathic effects with companion crops,
4. Easy to decompose leaf litter ;
5. Ability to withstand lopping ;
6. Easy marketable produce which have ability to generate employment.
7. Familiar with policies related to land use, soil and vegetation, and socioeconomics, including trade and market policies,

Associated Agricultural Crop must have following charactristics:

1. Small size & short duration crop usually less than one year.
2. Height of crop should be less then 1mt.
3. Root depth is 20 – 50 cm & lateral spread is - 25 to 100 cm
4. Crown size .25 to 1.0 m
5. Less Nutrient requirement of crop.
6. Does not transmit the disease to the trees.

CRITERIA FOR GOOD AGRO-FORESTRY DESIGN

A good agro-forestry design should fulfill the following criteria:

1. **Productivity :** There are many ways to improve productivity with agroforestry: increased out-put of tree products, improved yield of associated crops, reduction of cropping-system inputs, increased labour efficiency, diversification of production, satisfaction of basic needs .
1. **Sustainability :** By seeking improvements in the sustainability of production systems, agro-forestry can achieve its conservation goals while appealing directly to the motivations of low income farmers, who may not always be interested in conservation for its own sake.
2. **Adoptability** : No matter how technically elegant or environmentally sound an agro-forestry design may be, nothing practical is achieved unless it is adopted by its intended users. This means that the technology has to fit the social as well as environmental characterstics of the land-use system for which it is designed.

Tree-crops-soil interactions

For a learner of agroforestry it is important to understand how trees, crops and animals interact. In simultaneous agroforestry systems, trees and crops can share above-ground and below-ground space. Trees and crops interact in many ways, leading to both positive (facilitation) and negative (interference) effects on the growth of both trees and crops. These processes, which are very complex, are related to light, water, nutrients and wind. These processes also affect the soil. There are also indirect interactions, for instance related to pests and diseases. Cycling of soil organic matter, nutrients and water are processes that

are central to understanding the interactions in agroforestry systems. With a thorough knowledge of these cycles, the tree-crops-soil interactions are then explored.

Interactions: Principles of component interactions in an agroforestry system, in relation to the nutrient and water cycles and light capture. The interactions are both it may be positive and negative between both the components in the agroforestry systems:

Positive interactions (below and above-ground):

- Nutrient and water recycling
- Role of tree root systems as:

(1) a 'safety-net' for nutrients that have been leached down the soil profile, below the crop roots (and which would otherwise have been lost from the system)

(2) a 'nutrient pump' for weathered minerals in deep soil layers.

- Role of old tree-root channels in improving water infiltration and reducing soil erosion
- Nitrogen supply by tree roots, due to root decay or by nitrogen fixation
- Mycorrhizal associations to enhance phosphorus availability
- Litter production, functions and quality of litter
- Maintaining soil organic matter content
- Mulching, soil moisture and soil biological activity
- Shading
- Microclimate improvement such as temperature, relative humidity, etc. (for example, coffee needs shading)
- Maintaining carbon stock and above- and below-ground diversity

Negative interactions (below and above-ground*)* that may be involved:

- Above-ground competition for light
- Below-ground competition for water and nutrients
- Pests and diseases (for example, intercropped cassava may introduce
- white root disease to rubber)
- Allelopathic effect
- Tree-crops-soil interactions and farmers' priorities

Management strategies of complex agroforestry systems

To manipulate the growth of components in agroforestry systems,management options to achieve increased growth are:

(i)microclimate amelioration, (ii) fertilization, (iii) application of mulch or manure, (iv) irrigation, (v) soil tillage, (vi) adapted species and (vii)supplemental feeding; and for decreased growth are: (i) pruning, (ii) pollarding, (iii)root pruning, (iv) trenching, (v) excessive shading, (vi) herbicide and (vii) grazing or browsing.

Innovative Agroforestry system which have ability to enhance income by establishing:

1. Bamboo based enterprises
2. Paper and pulp industry
3. Fruit processing unit
4. Plywood mills.
5. Leaf cup-plate units.
6. Fuel wood depots**.**
7. Lac Processing units
8. Medicinal Plant processing unit.
9. Fibre extractions and rope making unit.

Successful Agroforestry systems in India

- Adoption of *Eucalyptus, Casurina Poplar,Leucaena* (MPTs) by ITC,Wimco etc in large scale plantation(5 million ha).
- West coast paper Mills- *Acacia Mangium and A.auriculiformis*
- Hindustan paper Mills- Bamboo plantation - Short rotation species preference
- 3o million trees of poplar producing 1.125 million m^3 industrial wood annually in U.P., Haryana,Punjab with wheat-paddy traditional agriculture crops.
- 25000ha under poplar (north-west area) and Eucalyptus in 5000ha (A.P.) under agri-silvi system at the 6-8 year rotation.
- Silvi-pastoral system over a period of 10 year could generate 120 man days/ha/year employment.(*D.sissoo,Allbizia with Cenchurus ciliaris,ginny,dinanath grass*)
- Rehabilitation of >3 million ha salt affected wastelands through Agroforestry**.**

Constraints

In spite of significant impact of Agroforestry on country's economy there are certain limitations with this land use systems:

- Farmers in generals are reluctant to grow trees as block plantation on their farm field.
- Proven agroforestry technologies are available only for limited regions.
- Limited knowledge about choice of tree species.
- Non-availability of assured market and support price of AF produced.
- Rigid legal laws restricting harvesting, transporting and sale of trees.
- Lack of Quality Planting Material
- Shortage of adequate irrigation facilities .
- Lack of fencing leading to theft and harm to Agroforest produce and livestock

Agroforestry systems developed by TFRI for Central India

Since the inception of the division to till date various agroforestry systems have been developed as per the requirement of the farmers and agroclimatic conditions of Central India. These are :

- Teak-turmeric silvi-medicnal system
- Sissoo-maize silvi-agri system
- Lac culture Model Silvo-entomo system
- Bamboo based slvi-agri system
- Gmelina based silvi-agri system
- MPTs based Silvi-olericulture system
- Teak-safed musli silvi-medicnal systems
- Paddy-babul model
- Paddy-bach model

Different Tree-Farming systems adopted by the farmers in Maharashtra

- Traditional Forestry - trees(Teak, Khamer, Arjun, Babul, Neem, Albizia odoratissima and Palas) and fruit plants (mango,Ber, Bahera, Jamun,Sitaphal.
- Farm Forestry- Karanj, Babul, Sissoo, Su babool, Eucalyptus, Acacia mangium, Casurina, and siris and bamboo(strictus, arundenasia and vulgaris)
- Block plantations- teak, sissoo(suitable for semi watrelogged condition) Eucalyptus & Su-babul (paper& pulp), *A.mangium* (konkan region), *Casurina* (Konkan and foothills of western ghat) bamboo (industrial and domestic uses)
- Agri- Silvi system (teak with crop) at spacing 2x2m or 3x3m
- Horti –agri system (Oranges with oleri crop), Banana with oleri crop) (Sapota with oleri,) Mango+ oleri)
- Konkan region- Horti-floriculture- Grapes, banana, alphanso, cashew with floriculture, spices and medicinal system under irrigated condition.

Teak-Turmeric Silvi-medicinal model

Edaphic and environmental requirements of Model	This model will perform better in well drained Sandy soil condition with optimum irrigation during its early period (first 1 -2 years). Not suitable under clay, black cotton soil and water logged areas which affect teak growth. Usually comes well in 15-40^{o} C with annual rainfall range of 800-2500 mm and prefers sea level to an altitude of 1200 m.
Significance of the model	This model is beneficial to the farmers, who can plant teak trees in their farm fields along with other annual crops especially with turmeric for higher economic returns.
Existing practice	Teak farmers are not aware of quality planting materials (seedlings and clones) and also for technical inputs on teak farming. Turmeric cultivation - farmers are practicing old systematic cultivation without using high yielding improved varieties.
Improved technique	Research institutions and SFDs are developing quality planting materials (seedlings from CSO, SSO and SPAs and clones from plus trees). Further, turmeric is partial shade loving crop and require moist condition which favours more yield. Introduction of teak with turmeric will give additional income to farmers by using the natural recourses in a optimum way.
Establishment and management of model 	Land should be leveled and ploughed well, weeds/stones should be removed. Planting should be carried out onset of monsoon for better survival and early establishment and good growth. Pit size of 45 cm^3 is essential for teak with a espacement of 4 x 4 m. Irrigation is essential for first three year in a interval of 3 - 4 days, especially during summer. Irrigation will boost the early growth. One year old root-shoot (stump) of teak should be preferred for best survival and easy establishment. Variety Suroma of Turmeric (Average Yield 3.5 t ha^{-1}). Application of Chloropyriphos 20 EC @ 2 ml l^{-1} soon after first monsoon showers kills the adults of termites and white grub and reduces the

	infestation level. Timely pruning (25% intensity) of teak branches is required to get straight stem. Yearly two times weeding is necessary. Intercropping will be possible for 8 - 10 years.
Rotation period & Yield 	Teak trees will be felled/harvested in the age of 10-12 years for pole purpose (average height 11m and 55-60cm girth, @ Rs.1250 per pole) and in 20 years for timber purpose (Av. Ht 16 m and girth 80, @ Rs. 2000 per pole). Turmeric yield - 3.5 t ha^{-1}
Economics of the model 	**Total Expenditure** for whole model (inclusive of all operation from sowing to harvest – **Rs.1.50 lakhs** **Income from turmeric**- Rs. 1.80 lakhs @ Rs 60/kg 3 t ha^{-1} **Income from teak poles** – Rs. 6.50 lakhs @ Rs. 1250 for 200 pole and Rs 2000 per pole for 200 poles. **Net Income** – Rs 6.80 lakhs
Impact and up scaling	Teak-turmeric based agri-silvi model gives risk free farming to farmers, sequester more carbon and enhances overall productivity which ensures higher net farm income to fulfill the Govt. of India slogan of 'Doubling the farm income'. This model can be upscaled through training programmes to farmers, extension materials, farmer to farmer interaction and on-farm field visits.

Bamboo based silvi-agri model

Edaphic and environmental requirements of Model	This model will perform better in well drained Sandy loam soil condition with optimum irrigation during its early period (first 1 -2 years). Bamboo can grow in river and

	gullies to control the soil erosion and conserve moisture. The system is not suitable under clay, black cotton soil and water logged areas which affect teak growth. Usually comes well in 15-40^{o} C with annual rainfall range of 800-2500 mm and prefers sea level to an altitude of 1200 m.
Significance of the model	This model is beneficial to the farmers, who are interested to improve degraded lands by adopting Bamboo along with suitable annual crops especially with *Vigna mungo* and *Triticum aestivum* in a crop rotation to improve the soil fertility and water conservation purpose and simultaneously for additional income from Bamboo.
Existing practice	Generally farmers are not aware about the high yielding bamboo species thorn less bamboo species as well as quality planting materials (seedlings and clones) and also for technical inputs on bamboo farming especially in sustainable harvesting methods. They are adopting desi lathi bamboo (*Dendrocalamus strictus*) in field bunds Not much knowledge about different bamboo species suitability in different soil condition alongwith crop combinations.
Improved technique	Research institutions and SFDs are developing quality planting materials (seedlings from CSO, SSO and SPAs and clones from plus trees). Farmers can grow various intercrops *viz.* urad, wheat, etc. up to 5 years, till the bamboo canopy closes. Bamboo farming will provide income till 40 years of its age at one one planting. Weeding should be done three times during each cropping period to get maximum production from annual crops Further, turmeric is partial shade loving crop and require moist condition which favours more yield. Introduction of teak with turmeric will give additional income to farmers by using the natural recourses in a optimum way.
Establishment and management of model	Land should be leveled and deep ploughed well, weeds / stones / agricultural residues etc should be removed. Planting should be carried out onset of monsoon for better survival and early establishment and good growth of bamboo and crops. Pit size of 45 cm^3 is essential for bamboo with a espacement of 5 x 5 m. Irrigation is essential for first two year in a interval of 3 - 4 days, especially during summer. Irrigation will boost the early growth. healthy seedlings of bamboo developed through cuttings should be

preferred for best survival and easy establishment. High yielding thorn less bamboo species *viz. Bambusa nutans,*

B.balcooa, B.tulda, B.vulgaris, etc. are highly suitable for this model. Vegetative propagated seedlings of bamboos should be preferred for best survival and easy establishment in the main field. Bamboo seedlings (400 seedlings ha^{-1}) should be planted @ spacing of 5 x 5 m after making pits size of 45 cm^3 during the onset of monsoon. Bamboos are managed by timely pruning of the culms from II^{nd} year onwards to avoid the congestion within the culm/clump and to maintain a healthy growth to fetch better growth and returns. Lateral roots of bamboo should be pruned at 2.5 m away from the periphery of the clump to reduce root competition within associate intercrops.

Variety 306 of wheat (average yield 0.16 t ha^{-1}) and Jawahar Urad (average yield 0.10 t ha^{-1}) should be preferred. Further, farmers can grow various intercrops *viz.* urad, wheat, etc. up to 5 years, till the canopy closes. Weeding should be done three times during each cropping period to get maximum production from annual crops.

Application of Chloropyriphos 20 EC @ 2 ml l^{-1} soon after first monsoon showers kills the adults of termites and white grub and reduces the infestation level. Timely pruning of lateral branches of bamboo is required to get straight culm (stem) and to avoid conjunction within the clump. Yearly two times weeding is necessary.

Rotation period & Yield

Bamboo culms can be harvest from 4^{th} year onwards. Generally bamboo is ready to harvest from 5^{th} year onwards under monoculture but in Agroforestry, it is ready to harvest after 4^{th} year due to its fast growth and benefited from the various inputs given to annual crops. Bamboo harvest should be start during March-April month i.e. before onset of monsoon @ 6 -7 culms per clump(average height 11m and 15cm diameter, @ Rs.100 per culm) may be obtained subject to growth and maintenance of the system.

Agriculture crops-wheat (average yield 0.16 t ha^{-1}) and Urad (average yield 0.10 t ha^{-1}) can be obtained from the system.

Economics of the model	**Total Expenditure**- Rs. 96,000 ha^{-1}(inclusive of field operations) **Income from Urad and Wheat**- 1) Rs. 40,000 ha^{-1}, 2) Rs. 70,000 ha^{-1} **Income from bamboo poles**- Rs. 2 lakhs ha^{-1} @ Rs. 100 per culm = 2000 culm (first harvest after 4 years **Net Income** – Rs 2.17 lakhs
Impact and upscaling	Bamboo – Urad /Wheat Agroforestry model has potential to provide additional income in a sustainable manner and this model will fulfill the government goal of 'Doubling the farm income' from its intercrops within short rotation period of 5 years. Further the model generates rural and women employment opportunities throughout the year. In addition, this model improves soil fertility and increase the overall productivity.

Bach-paddy Agri-medicinal model

Edaphic and environmental requirements of Model	The system is suitable under clay, black cotton soil and water logged areas for its best growth. *Acorus calamus (*Bach) can grow in waterlogged area hence it is suitable to intercrop with paddy. The model is suitable under clay, black cotton soil and water logged areas for its better growth. Usually comes well in hot humid condition under 15-40^{o} C with annual rainfall range of 800-2500 mm and prefers sea level to an altitude of 1200 m.
Significance of the model	This model is beneficial for the paddy growers who can utilize their waterlogged land by intercropping of commercially valuable medicinal crops viz. *Acorus calamus* (Bach). Initially the model required big investment for the purchase of planting material. The *A.calamus* (Bach) is a perennial herb, commonly known as sweet flag in India.It is upto 6 feet tall, aromatic and small yellow / green flowers with indefinitely branched rhizomes. It has several medicinal uses to cure cough and cold, improve nervous system and also the respiratory disorders like bronchitis .

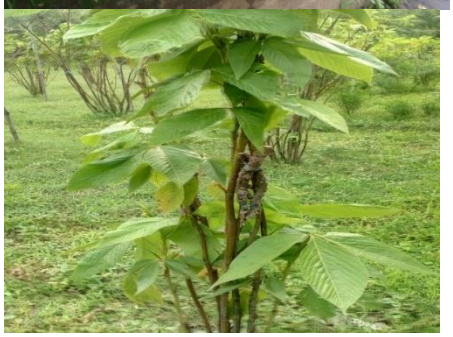
Existing practice	Generally farmers are not aware about the high yielding bamboo species thorn less bamboo species as well as quality planting materials (seedlings and clones) and also for technical inputs on bamboo farming especially in sustainable harvesting methods. They are adopting desi lathi bamboo (*Dendrocalamus strictus*) in field bunds. Not much knowledge about different bamboo species suitability in different soil condition alongwith crop combinations.
Improved technique	Research institutions and SFDs are developing quality planting materials (seedlings from CSO, SSO and SPAs and clones from plus trees). Farmers can grow various intercrops *viz.* urad, wheat, etc. up to 5 years, till the bamboo canopy closes. Bamboo farming will provide income till 40 years of its age at one planting. Weeding should be done three times during each cropping period to get maximum production from annual crops Further, turmeric is partial shade loving crop and require moist condition which favours more yield. Introduction of teak with turmeric will give additional income to farmers by using the natural recourses in a optimum way.
Establishment and management of model 	Land should be leveled and deep ploughed well, weeds / stones / agricultural residues etc should be removed. Planting should be carried out onset of monsoon for better survival and early establishment and good growth of bamboo and crops. **Nursery technique of Bach** **Raising of Bach plants:** Small rhizomes of bach plants should be cut into the small pieces of 4-5cm in length having two internodes is suitable as planting material for better regeneration, growth and yield (1,00,000 plants ha^{-1}). These cuttings should be sown in the soil upto 4-5 cm depth during the month of May. New sprouts may come out after 15 - 20 days. This sprouted material is ready for transplanting

	in the rice field during IInd week of July – August at the spacement of 30 cm X 30 cm . **Farm Yard Manure**: 15 trolley t ha^{-1} of FYM is necessary for the Bach-paddy system It should be applied 1/4th of quantity(3.5) as basal dressing, half of the quantity (7) after two months of planting and remaining 1/4th quantity(3.5)after 6th month of crop. Further, farmers can grow bach alongwith paddy up to 5 years, till its lateral roots will spread. Weeding should be done three times during each cropping period to get maximum production from annual crops. bach is highly sensitive to salinity. The crop is free from grazing. The crop is resistant to insect-pests and fungal attacks. The first year crop provides planting material for next season at least for one hectare area besides marketable produce.
Rotation period & Yield 	**Best time for harvesting**: Approximately 10 months after planting in rice field. **Yield**: 3.5 t. ha^{-1} of dried rhizome (Rs70 - 80kg^{-1}) or planting material (fresh rhizomes 1 lakh propagules @ Rs.1.00) for 1 ha.
Economics of the model 	**Total Expenditure: Rs.1,20,000** (inclusive of field operations cost of planting material, preparation of field, FYM, Wages) **Income from paddy:** Rs. 50,000 **Income from Bach plants**: Rs. 2 lakhs (market rate) **Net Income** : Rs 1.30 lakhs
Impact and upscaling	Bach-paddy Agroforestry model having the potential to provide additional net farm income to farmers' and will one of the best model for Doubling the farm income' in short rotation period of years. In addition, this model can utilize the waterlogged area efficiently and

	effectively and convert into increase in overall productivity and additional income to farmers'. This model can be up scaled through training programmes to farmers, extension materials, farmer to farmer interaction and on-farm field visits.

Flemingia based silvi-agri-lac Model

Edaphic and environmental requirements of Model	This System will perform better under well drained sandy loam soil condition. Since the *Flemingia* plants are fast growing in nature and having narrow crown, hence farmers' can utilize its interspaces by growing traditional agriculture crop like *Cajanus cajan* for their regular income. Usually comes well in 15- 40^{o} C with annual rainfall range of 800-2500 mm and prefers sea level to an altitude of 1200 m.
Significance of the model	This model is beneficial for the Lac growers especially farmers' who are not having traditional Lac host trees like (*B.monosperma*) or Kusum (*S. oleosa*) in their field bunds. *Flemingia semialata* Roxb. is a bushy leguminous plant and proved as a good host to kusumi strain of Lac . This *F.semialata* plants are ready to inoculate Broodlac within a year after its planting and framers' can maintain this model and get lac up to 8 years.
Existing practice	Lac growing farmers are not aware of quality planting materials (seedlings and broodlac) and also technical know how about the species on lac farming on Flemingia. Lac Farming – Usually farmers are practicing lac farming on old trational host existing on their field bunds unscientific manner without using high yielding improved varieties.
Improved technique	Research institutions and SFDs are engaged to develop quality planting materials (seedlings from CSO, SSO and SPAs and clones from plus trees). Further, lac farming require moisture for its maximum yield. Introduction of lac cultivation of Flemingia under Agroforestry system will provide additional income to farmers by using the natural recourses in a optimum way.

Establishment and management of model  	Seeds of *F.semialata* should be sown during April month in the poly bags with 1:1:1 ratio of soil, sand and FYM mixture and the seedlings will be ready for the transplantation during rainy season. Healthy seedlings should be preferred for best survival and easy establishment. Land should be ploughed and FYM may be applied (10 t ha^{-1}) as basal dressing in the month of May. *Flemingia* seedlings (625 plants ha^{-1}) should be planted @ spacing of 4 x 4 m after making pits size of 45 cm^3 during the onset of monsoon. Soil surface along the pit should be treated with chloropyriphos(2g in one lit solution) to control termite attack before rainy season. After one Year of planting, plants are ready to raise good quality of broodlac during rabi season is the best time for its cultivation. **Cajanus cajan cultivation** - Asha variety of *cajan* average yield 0.10 t ha^{-1}) July @ 75cm x 75 cm spacing after transplanting of *Flemingia* plants to manage the field activity. Weeding should be done three times to get maximum production. **Lac farming**- Farmers' are not much aware about the scientific cultivation of Lac. Good quality Broodlac should be selected by the farmer to get maximum yield. Farmers' can select healthy, soft, disease free shoots for the infestation of Broodlac (@ 40 g plant $^{-1}$). Research institutions are developing quality planting materials (seedlings and Broodlac from good quality seeds from plus trees). *F semialata* plants should be pruned from its tip to maintain certain height (up to 1.5) for easy cultural operations like weeding, ploughing, etc. and to protect it against heavy wind during summer season, otherwise plants will be damaged. *This* system performs better in well drained soil condition with optimum irrigation during its early period first 2 years).

Rotation period & Yield 	Flemingia seedlings is ready for lac cultivation after one year of its planting. The plant is a shrub and needs to maintain certain height (2.5m) and more branches for management of lac crop. The lac crop will be ready to harvest within a year.
Economics of the model	**Economics of the model :** **Total Expenditure- Rs. 75,000** ha^{-1} (inclusive of field operations) **Income from Lac and Arhar-** 1) Rs. 1,00,000 ha^{-1} 2) Rs. 1,00,000 ha^{-1} *F. semialata* based silvi-agri-lac model has potential to generate Rs. 1.25 lakhs yr^{-1} ha^{-1} than monoculture of conventional crops like Lac (Rs. 1,00,000 ha^{-1}) or arhar (Rs.1,00,000 ha^{-1}) .
Impact and upscaling	The *Flemingia* plant is so easy to maintain even by the women and within their small piece of land. TFRI has introduced first time of this Lac host species in tropical region of Madhya Pradesh to explore the possibilities of Lac culture on *Fleminga* under Agroforestry model with agriculture crop *Cajanus cajan* and become popular among the Lac growers due to its short period of maturity (i.e. two years). This model is able to generate income as well as employment throughout the year as compared to traditional farming also improves soil fertility and provide additional income. Training and demonstrations are most important component to popularize this model among the farmers' especially for rural women with one time investment. This model can be upscaled through various training programmes including demonstrations, farmer's mela, documentation and domestication of species in farmer's field, and by distributing extension materials, farmer to farmer interaction and on-farm field visits.

DEVELOPING VALUE CHAIN IN AGROFORESTRY: CONSORTIUM OF INDUSTRIAL AGROFORESTRY A NEW INITIATIVE

Dr. K.T. PARTHIBAN

Professor (Forestry) and Head,
Department of Agroforestry, Forest College and Research Institute,
Tamil Nadu Agricultural University, Mettupalayam — 641 301, India
Email: ktparthi2001@gmail.com; Mobile: +91 8870808289

Abstract

India is one among the few tropical countries which has been reporting a progressive Increase in the forest cover over the past two decades. India being a major consumer of wood and wood products, the role of agroforestry as a viable land use system is gaining significant attention owing to its contribution towards meeting domestic and industrial wood requirements. Growing demand coupled with legal issues in wood supply from Government owned forests have resulted in a total mismatch between (TNAU) conceived and implemented "a value chain model" and created sustainability in industrial wood generation and supply in Tamil Nadu by involving in a wide range of stakeholders. In order to strengthen the value chain and to promote agroforestry based on the objectives envisaged in National Agroforestry Policy (2014), the University established a – "Consortium of Industrial Agroforestry" (CIAF) by linking stakeholders and addresses the issues related to production, processing and consumption in agroforestry. Keeping in line with the guidelines provided in the National Agroforestry Policy (2014), the consortium has successfully established decentralized institutions for supply of quality planting materials to the farmers besides facilitating organized plantation developers, harvesting and marketing institutions. Consortium development of activities have paved way for creating the much needed database in tree cultivation, price supportive mechanism for important farm grown industrial wood species and reduced the risks faced by tree growers through innovative approaches like tree insurance and value addition technologies. This consortium mode value chain model in agroforestry holds great potential for adoption and replication across India which would help to create self reliance in raw material security besides augmenting the country's tree cover.

INTRODUCTION

Forests in India have played a significant role in meeting the domestic and industrial wood requirements before the enactment of Forest Conservation Act, 1980 and the National Forest Policy 1988. Owing to policy and legal implications, there has been a paradigm shift in the forest management strategy of the country with more emphasis on conservation oriented management which resulted in restricted supply of wood from

natural forests (Parthiban *et al.*, 2014). India being one of the major consumers in the Asia Pacific region, it is estimated that the country would need 152 million m^3 of wood by 2020. (FAO, 2009). This demand has been estimated for 12 organized wood based industries and does not include the fuel wood demand of the country which is also on the rise.

In 2010, world's agricultural lands occupied 4889 Mha, an increase of 7% (311 Mha) since 1970 (FAOSTAT, 2013) whereas agricultural land area has decreased by 53 Mha since 2000 (Karlheim Knickel, 1990). Increasing wood demand coupled with changes in land use pattern have necessitated significant interest towards agroforestry, a land use system which is being practiced across the country in various forms since time immemorial.

Though agroforestry is an age old practice as an important form of subsistence farming, in the recent past, it is valued as a commercial and profitable land use system across the world. Approximately, 1.2 billion people (20 percent of the world's population) depend directly on agroforestry products and services in rural and urban areas of developing countries (Leakey and Sanchez, 1997). Agroforestry systems are superior to other land uses at the global, regional, watershed and farm scales since they optimize tradeoffs between increased food production, poverty alleviation and environmental conservation (Izac and Sanchez, 2000). The current area under agroforestry is of the order of 400 Mha, of which 300 Mha are "arable lands" and 100 Mha are "forest lands" (Robert Zomer *et al*, 1999; Xu, 1999). It is estimated that an additional 630 Mha of croplands and grasslands could be converted into agroforestry, primarily in the tropics (IPCC, 1996b). FAO has also emphasized that agroforestry must be integrated in the Clean Development Mechanism (CDM) to broaden the scope of agroforestry. In India, several traditional agroforestry systems are successfully established with the tree-crop combination of *Acacia nilotica* with Paddy (Bargali *et al.*, 2009); mango and teak with wheat and rice in Kumaun region (Parihar *et al.*, 2015). Similarly, home garden based agroforestry has evidenced as a successful land use system in Central Himalayas (Vibhuti *et al.*, 2018) which attest the significance of agroforestry in India.

Recognizing the growing importance of agroforestry, the Indian Government directed the wood based industries to generate their own raw material in the National Forest Policy of 1988 (Anon, 1988). However, policy directives were not taken seriously by many wood based industries barring a few exceptions. Growing demand for wood and wood products, increasing interest in agroforestry and legal issues in wood supply from Government owned forests ushered in a total mismatch between demand and supply of wood and wood products (Parthiban and Cinthia, 2017).

Under such circumstances, Tamil Nadu Agricultural University (TNAU) conceived and implemented "a value chain model" to create sustainability in raw material generation and supply in Tamil Nadu by involving a wide range of stakeholders. This model of Industrial Agroforestry was implemented between 2008 and 2014 which

witnessed successful establishment of over 70,000 ha of organized plantations in Tamil Nadu. (Parthiban, 2014). To sustain the positive impacts generated by this value chain model an institutional mechanism, called "Consortium of Industrial Agroforestry" (CIAF), was established by the university which is first of its kind in the country and addresses the issues related to production, processing and consumption in Agroforestry. This manuscript discusses the genesis, organizational structure, activities and achievements of CIAF which could act as a model for the rest of the country for adoption with necessary modifications for promoting and furthering the Government's objectives in agroforestry sector of the country.

AGROFORESTRY —CONSTRAINTS AND INTERVENTIONS

The wood based industries in the state of Tamil Nadu have been interacted for the current supply chain pattern. Based on the interactions and the consultations with the industries, tree growing farmers, non-governmental organization involved in promotion of agroforestry and other stake holders, Forest College and Research Institute of Tamil Nadu Agricultural University has identified several constraints towards promotion and popularization of commercial agroforestry model. These constraints have been grouped into three levels viz., production related constraints, processing associated constraints and the consumption related constraints which are depicted in the fig 1.

a) Production	• Lack of high yielding and short rotation varieties • Non availability of quality planting material • Non availability of Institutions for mass multiplication • Low Productivity front unimproved seedling progenies • Alternate genetic resources unexplored and unexploited • Poor adoption of precision silvicultural packages • Lack of profitable and multifunctional agroforestry model
b) Processing	• Lack of mechanization • Poor understanding on harvest and post harvest Management • Un and underutilization of plantation residues • Inventory on alternate utility of woody biomass
c) Consumption	• Existence of Multi partite supply chain • Lack of price support mechanism • Non existence of contract tree farming • Lack of credit facilities • Non availability of insurance for plantation protection

Fig 1. Constraints and Problems in Industrial Agroforestry

INTERVENTIONS THROUGH VALUE CHAIN APPROACH

The constraints identified and indicated above have been resolved through strong research and development coupled with the associated supply chain process. The entire PCS based industrial agroforestry has been value added through technological support resulting in massive industrial agroforestry development in the state of Tamil Nadu in association with several wood based industries. The interventions have been done through technology development, organizational linkage and facilitating market support system in association with respective wood based industries.

CONCEPTUALIZATION OF CONSORTIUM OF INDUSTRIAL AGROFORESTRY

National Forest Policy of 1988 directed wood based industries to generate their own raw material resources rather than depending on the forest department for their wood requirements. However, the policy guidelines were not taken seriously by most of the wood based industries except a few paper industries. Subsequently, Government of India announced an exclusive Agroforestry policy in 2014, which identified ten strategies to promote agroforestry in the country. To address all the issues envisaged in the National policies, TNAU pioneered by establishing a "CONSORTIUM OF INDUSTRIAL AGROFORESTRY" on 21st March 2015 which has successfully linked various stakeholders in the Industrial Agroforestry value chain and has been Carrying out multifarious activities for the past three years in Tamil Nadu.

OBJECTIVES AND ACTIVITIES OF THE CONSORTIUM

The consortium aims to create sustainable and value added agroforestry initiatives with the following objectives:

- Network and establish linkages with all stakeholders to augment the Production to Consumption System (PCS) in Industrial Agroforestry.
- Promote effective collaboration among public agencies, private industries and organizations engaged in Industrial Agroforestry.
- Develop suitable research and development mechanism for industrial agroforestry in consultation with the consortium partners
- Ensure self reliance in raw material supply and augment associated socio-economic and environmental issues.
- Formulate and recommend policy guidelines for promotion of Industrial Agroforestry.

ACTIVITIES AND ACHIEVEMENTS OF THE CONSORTIUM

CIAF primarily aims to resolve the issues in production to consumption system in agroforestry through systematic Research and Development mechanism. This approach has made several stakeholders across the country enroll as members of the consortium whose present strength is 235. The details of the members are furnished in figure 2:

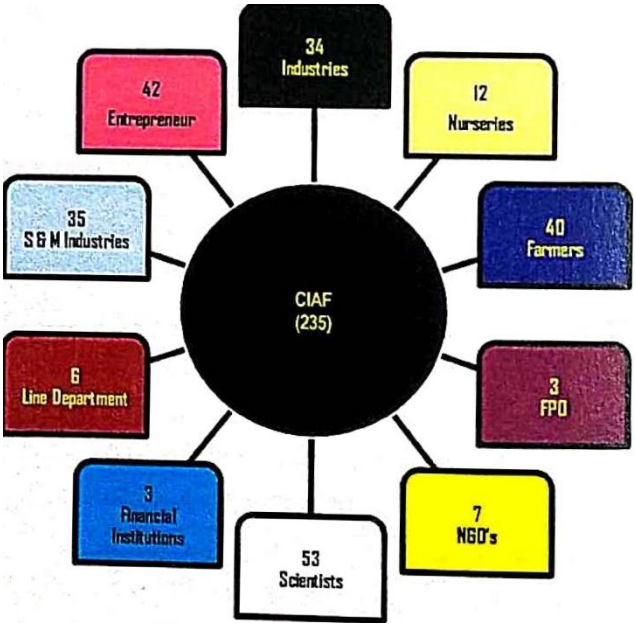


Figure 2. Composition of CIAF

a. INSTITUTIONS FOR PRODUCTION OF QUALITY PLANTING MATERIALS

The CIAF has created 12 decentralized institutions viz, nurseries and clonal production centers who mass multiply over 18 million plants annually which ensures availability of quality planting material in a decentralized manner as envisaged in National Agroforestry policy.

b. ORGANIZED PLANTATION DEVELOPERS

One of the major problems faced by farmers and tree growers is the shortage of labour coupled with timely plantation establishment. This practical constraint was resolved by organizing capacity building programmers to the consortium members on modern plantation development technologies which ultimately helped them evolve as an organized plantation developers across Tamil Nadu. Eleven such plantation developers groomed by CIAF have been responsible for establishing over 5000 acres of agroforestry plantations annually. The list of these institutions along with the annual area of plantations established is furnished in Table 1. Plantation developers of the consortium ensure availability of skilled labour for manual planting as well as machines for mechanized planting which has created significant positive impact among farmers/tree growers of Tamil Nadu.

c. HARVESTING AND MARKETING INSTITUTIONS

The major problem faced by farmers and tree growers include harvesting, transportation and marketing of farm grown trees. In most cases, particularly in Tamil Nadu, harvesting of trees for multifarious uses was restricted to a specific group of

communities who usually practiced manual felling with axe. Manual felling results in considerable quantum of wood wastage leading to respective loss of due economic returns coupled with the absence of decentralization of felling institutions which hindered the expansion of forestry agroforestry plantations. To resolve this issue and to reduce logging related wood loss, the consortium conceived the idea of creating felling institutions from among its members. These felling institutions were provided with necessary capacity building regarding the principles and practices of modern logging techniques including hands on training in the operation of the latest machineries available. Besides improving the harvest efficiency and reduction of human drudgery, these institutions have also enabled decentralized availability of felling groups which harvest over 1 lakh tones of industrial wood per annum in Tamil Nadu. Many of these groups also undertake transportation and marketing of harvested wood thereby providing the farmers with economic returns at the farm itself. The details of felling institutions and their annual capacity are furnished in Table 1.

TABLE 1. LIST OF PLANTATION AND FELLING INSTITUTUIONS

Sl. No.	Plantation developers / Felling institutions	Area planted (acres) and wood harvested/ year (tonnes)
A. List of Plantation developers		
1.	Ever green Plantations, Manaparai, Trichy District	250
2.	P.K.S. Developers, Namakkal District	1000
3.	Green Land Foundation , Thanjavur District	1000
4.	Agroforestry Producer Company, Coimbatore District	500
5.	Agrocorp, Hyderabad	100
6.	Siva Sakthi Farms, Sivagangai District	250
7.	Raja nursery, Cuddalore District	250
8.	Tree project, Theni District	250
9.	Sri Vaari Plantation, Villupuram District	250
10.	Chinnarosa Plantation Developer, Vellore District	100
11.	Priya nursery, Sivagangai District	1000
	Total	**5700 acres**
B. List of felling institutions		
1.	Sathyamoorthy Felling Group, Thanjavore District	10,000
2.	Perumal Timber Mart, Anthiyur Erode District	40,000
3.	Thangavel Woods Traders, Sathyamangalam, Erode District	3000
4.	Agrocorp, Hyderabad	2500

5.	Saravanan Felling Group, Vellore District	500
6.	Forestry and Agroforestry Network, Coimbatore, Karur, Sivagangai Erode District	250
7.	Coimbatore District Agroforestry Producer Company, Coimbatore	50
8.	Bannari Traders, Sathyamangalam, Erode District	5000
9.	Manohar felling group, Erode District	15,000
10.	Evergreen plantations, Trichy District	25,000
	Total	**1,01,300 tones**

d. ORGANIZED WOOD BASED INDUSTRIES FOR MARKETING OF INDUSTRIAL WOOD

Success of agroforestry has been widely questioned for lack of marketing facilities which is cited to be the key reason. To overcome this constraint, the CIAF has identified potential wood based industries and has created market base for a wide range of farm grown trees. The major industries and their wood requirement are furnished in Table 2. These industries are linked in the consortium and facilitate the marketing issues in tree cultivation.

TABLE 1 CIAF LINKED WOOD BASED INDUSTRIES

S.No.	Wood based industry	Species	Price
1.	Suresh Timbers, Elumalai, Madurai Dt.	Teak (30- 45 inches and above)	Rs. 20,000 – 25,000
2.		*Gmelina* (25 inches and above)	Rs. 8,000 – 10,000
3.		*Leucaena leuocephala* (18 inches and above)	Rs. 5,000 – 5,500
4.	Tamil Nadu Newsprints and Papers Limited (TNPL), Kagithapuram, Seshasayee Paper and Boards Ltd., (SPB), Pallipalayam	*Casuarina* spp	Rs. 4,200 (Debarke)
5.		*Eucalyptus* spp	Rs. 5,500 – 6,000
6.		*Leucaene leucocephala*	Rs. 4,500
7.		*Melia dubia*	Rs. 4,200 – 4,400 (Debarke)
8.	Century Plyboards (1) Ltd, Chennai	Eucalyptus (18 inches and above).	Rs. 5,500 – 6,000
9.	Arnbiply Panels and Doors, Mettupalayam	Melia dubia (18 inches and above) Rs. 7500 - 8500	Rs. 7,500 – 8,500

	Maxbond Plywoods, Pollachi		
10.	Vasan Match works, Vellore Ideal Splints and Veneers, Coimbatore	*Ailanthus excelsa* (24 inches and above)	Rs. 5,500
11.	Pavo Energy, Chennai K.G. Denim Limited Coimbatore Senthil Group of Companies, Coimbatore	All Agroforestry tree species	Rs. 3,500 – 4,500
12.	Bharathi Package and Furniture, Coimbatore	*Melia dubia* *Albizia sp.* *Acrocarpus fraxinifolius*	Rs. 8,000

e. DEVELOPMENT OF PRICE SUPPORTIVE MECHANISM

Unlike agriculture and horticulture, there has been a lack of price supportive mechanism for farm grown trees. Till the recent past, wood based industries seldom indicated the price of wood (specieswise) and hence tree growing farmers were never aware of the pricing pattern for wood growing in their farmlands. Surveys conducted by the consortium indicated the absence of a price supportive mechanism which was a major hindrance hampering the expansion of agroforestry in Tamil Nadu. This issue was earnestly addressed by establishing a price support system in the "organized contract farming mode" for farm grown trees. Wood price for various industrial wood species has been fixed based on mutual consultations besides taking a cue from the prevailing local wood market prices. Post adoption of price supportive system in Tamil Nadu, studies conducted by CIAF and wood based industries have indicated quantum increase in area under tree husbandry through agroforestry.

f. VALUE ADDITION TECHNOLOGIES

CIAF is also keen on creating a viable system for enhancing value addition of plantation and industrial wood residues. It is estimated that from 1 ha of organized *Casuarina* plantation, around 5 tonnes of plantation residues are produced. In *Eucalyptus*, for every ton of wood harvested, nearly 200 - 300 kg of wood bark residue is produced. In timber, plywood and matchwood industries, over 30-40% of the wood received by the industries is pronounced as waste in the form of sawdust, chips, wood shavings etc. which has good potential for value addition. These residues are value added in the form of briquettes, pellets, charcoal and activated carbon .

g. MECHANISM FOR TREE INSURANCE

The CIAF has linked with one of the public sector insurance companies viz. United India insurance, the second largest general insurance company in India. Based on mutual consultations and brainstorming, the consortium conceived and developed an "Insurance

mechanism" for seven important farm grown trees viz., *Casuarina, Melia dubia, Eucalyptus, Ailanthus excelsa, Leucaena leucocephala, Gmelina arborea and Dalbergia sissoo*. (Parthiban, 2016). This insurance scheme provides the farmers, tree growers and captive plantation owners with the much needed relief against the risks faced by them against possible losses due to biotic and abiotic factors.

h. FRAMEWORK FOR IMPLEMENTING AGROFORESTRY POLICY IN TAMIL NADU

Consortium of Industrial Agroforestry conducts annual workshops by inviting the enrolled members and special invitees which serves as a platform for brining all the stakeholders in the industrial agroforestry value chain. These annual workshops aid in evaluating the progress made as well as to share the stakeholders' experiences and constraints faced. Based on the outcome of the annual workshop, the CIAF prioritizes researchable issues for the subsequent year. The consortium also organized an exclusive workshop to prioritize the strategies and guidelines provided in the National Agroforestry Policy in order to develop a framework for adopting and implementing an exclusive Agroforestry policy for Tamil Nadu and the recommendations of the workshop were submitted to the Government of Tamil Nadu for adoption and implementation.

i. DEVELOPMENT OF UNIT COST FOR BANKABLE PROJECT

The CIAF has developed unit cost for four major tree species viz. *Melia dubia* (Malabar Neem), *Casuarina,* Kapok and *Ailanthus excelsa* (Indian Tree of Heaven) in consultation with the members of consortium and the details were forwarded to National Bank for Agricultural and Rural Development (NABARD) and insurance agency for approval and implementation to extend institutional credit and insurance for agroforestry.

j. CREATION OF DATABASE

Development of a sound database on the extent and distribution of farm grown tree species (districtwise and specieswise data), intercrops suitable for cultivation, monthly market prices are also being undertaken by the consortium which is being shared among the members of consortium.

k. RESEARCH INITIATIVES

The CIAF also conducts a wide range of research initiatives to resolve the issues in Production to Consumption System. One or the major research initiatives is to inventorize and domesticate new tree species amenable for agroforestry. The consortium has prioritized 30 tree species suitable liar agroforestry and efforts are being taken to develop High Yielding Short Rotation clones/varieties (HYSR), designing Multi Functional Agroforestry Models (MFAM) and ensure adoption or new, emerging technologies by the farmers and stakeholder. The HYSR clones already developed and promoted through agroforestry arc furnished in Table 3,

TABLE 3. AVERAGE PRODUCTIVITY OF HYSR VARIETIES

S.No.	Species	Variety	Productivity (tonnes / ha)
1.	Casuarina sp.	TNAU Casuarina MTP2	150
2.	Eucalyptus sp.	TNAU Eucalyptus MTP1	100
3.	*Melia dubia*	Malaivembu MTP 1 (Plywood)	200
		Malaivembu MTP2 (Pulp and Plywood)	200-250
4.	*Leucaena leucocephala*	FCRILLI5	100
5.	*Dalbergia sissoo*	DS18	150
6.	*Ailanthus excelsa*	MTPAE17	200
7.	*Areolamarckia cadamba*	FCRIAC13	100
8.	*Gmelina arborea*	FCRISS	450 — 500 kg / tree
9.	*Tectona grandis*	Syyaburry - MTPTKO7	15 cft / tree

(Parthiban and Cinthia, 2017)

l. IMPACT OF CIAF ACTIVITIES

The activities of the CIAF have created significant impact in terms of increase in area under agroforestry coupled with improvement in productivity and profitability. It is estimated that these agroforestry initiatives have created 300 mandays/ha of employment and augmented productivity to the tune of over 25m3/ha/annum from the baseline level of less than 10m /ha/annum. It is also estimated that one ton of wood is equivalent to 0.5 tonnes of carbon sequestered and thus expansion of agroforestry in Tamil Nadu through CIAF's initiatives will help to reduce the carbon load in the atmosphere and help address the growing concerns on climate change besides opening up a new vista of carbon trading for the farmers of the state in future.

WAY FORWARD

The consortium activities are spearheaded by TNAU whose present reach has expanded outside Tamil Nadu to Karnataka, Kerala, Maharashtra, Telengana, Andhra Pradesh, Madhya Pradesh, Gujarat and Uttar Pradesh. In near future, the activities of CIAF are expected to extend to other states of the country as well. By 2023, the CIAF proposes to raise a corpus fund of Rs.1,00,00,000 (INR 10 million) for sustaining research and development activities.

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AGROFORESTRY MODELS FOR INCOME GENERATION: A SCENARIO OF PUNJAB

Dr. SANJIV CHAUHAN

Professor & Head
Forestry Department, Punjab Agriculture University, Ludhiana (Punjab)

Agroforestry is a collective name for land use system in which woody perennials (tree, shrub, etc.) are grown in association with herebaceous plants (crops, pastures) or livestock, in spatial arrangement, a rotation or both: there are usually both ecological and economic interactions between the trees and other components of the system. Agroforestry is a land use option that increase livelihood security and reduce vulnerability to climate and environmental change. According to Planning Commission report "Greening India", 33% forest cover can only be achieved through agroforestry,which has many potentials, such as enhance the overall (biomass) productivity, soil fertility, improvement, soil conservation, nutrient cycling, micro-climate improvement, carbon sequestration, bio drainage bio-energy and bio-fuel etc.

The development of agroforestry as a science should be based on five key features: competition, complexity, profitability, sustainability and adoptability. Managing the competition between trees and crops for light, water and nutrients to the farmers benefit is the biophysical determinant of successful agroforestry systems. Socio-economic and ecological complexities are typical of agroforestry systems. Diversity of products and services should be manipulated in a way that puts money in farmer's pockets. Domestication of trees with high value products enhances profitability, particularly those that can be marketed as ingredients of several finished products.

Nowadays, agroforestry has gained popularity among farmers, researchers, policy makers and others for its ability to contribute significantly in meeting deficit of tree products including small and large timber, socio-economics and environmental benefits. Land-use options that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Livelihoods improvement is not just about the positive change towards better quality of life and human well-being but it takes into account the local and global change, which determines livelihoods. The basic objective for me for an overview about successful agroforestry models in Punjab are basically based on social acceptance, environment benefits and economics generation. The tree-based direct needs are exclusively met from farm forestry or agroforestry. At present, poplar (*Populusdeltoides*), eucalyptus (*Eucalyptus tereticornis*), dek (*Meliaazaderach* and *M. composita*), leucaena (*Leucaenaleucocephala*), kadam (*Anthocephalauscadamba*), teak (*Tectonagrandis*), among other trees, are grown by Punjab farmers on a commercial scale. Some of the agroforestry models being practised in state to diversify the traditional crop rotation are highlighted here for reference.

Poplar has become the most preferred tree for farmlands in Punjab and its adjoining states. Almost any crop (cereals, pulses, vegetables, cash crops, forage crops, fruit crops etc.) can be grown with it during the *rabi* season with limitation during *kharif* season. It is one of the world's fastest-growing industrial soft woods (can be harvested within a reasonably short period of 5–6 years). Poplar intercropping is a highly profitable venture as much as poplar growing is a highly lucrative business since market for its products are readily available. Eucalyptus, anotherfast-growing species, has gained ground because wood prices of poplar keeps on fluctuating.Farmers prefer it to other trees because it has self-pruning habit, aside from its light canopy cover, fast growth, multiple uses and straight bole. It is quite hardy in nature, but being evergreen, intercropping is not profitable but preferred as sole plantation. Punjab farmers have recently realized the benefits of growing indigenous, fast-growing dek (*Meliaazaderach and M. composita*) under agroforestry systems. The species can yield high economic returns within a8–10 year rotation and can also partly provide the raw material requirements of the industry, if raised scientifically under agroforestry systems. Dek is mainly used in making furniture and panels; However, under Punjab conditions, dekis less remunerative than poplar/eucalyptus because of its slow growth, and lower price in the market. Leucaena (*leucaenaleucocephala*), a fast-growing, thornless, evergreen, leguminous woody perennial has been found very useful under lower Shiwalik hills. It is specifically raised under silvipastoral models in the state. A number of new leucaena varieties have been introduced for their more fodder quality and quantity. Teak/sagwan (*Tectonagrandis*) and Australian acacia (*Acacia* spp.), though encouraged by the private nursery growers in the agroforestry systems (agri-silvicultural and horti-silvicultural models) in Punjab, will not be suitable or profitable because of their long rotation period. Bamboo is anotherpromising plant for rehabilitating degraded lands, including lower Shivalik hilly areas. It thrives well in semi-arid conditions characterized by low soil fertility and low water-holding capacity. It could be an ideal alternative to other crops. Farmers have been growing bamboo, for various purposes, on their fields, farm boundaries and in other locations, because its roots have a binding effect and it can tolerate drought conditions. Bamboos can supplement to the economy of the farmers, there is huge demand of bamboo in the paper and cottage industry. Farmers of lower-Shiwaliks can grow *Dendrocalamusstrictus, Bambusa vulgaris* (green), etc. on dry sites, whereas, on moist sites *Dendrocalamushamiltoni* is an ideally species.

Horti-silvicultural system

The horti-silvicultural models (integration of fruit trees and short rotation forest trees) remains the most appropriate alternative option for sustainable management of land unit, which will improve the economy of the farmers, besides taking care of the natural resources (soil, water and air). Fruit trees (mango, citrus, litchi, ber, pear, guava, etc.) based agroforestry models are becoming popular, as the forest tree component will be harvested when the fruit trees start bearing fruits, even small wood market is available now therefore we need not to wait for long to harvest timber trees. The adopters would be able to exploit

the national and international fruit and wood markets. It has caught the attention of the farmers not only in Punjab, but also in other adjoining states of Haryana, lower areas of Himachal and terai area of Uttaranchal.

Agroforestry farms as carbon sinks

The practice of agroforestry is an alternative way of addressing poverty, hunger, malnutrition, and deterioration of the environment in areas bypassed by the Green revolution. The emerging carbon market may provide a new agroforestry option for land owners provided that carbon prices are high enough to make growing trees a worthwhile investment than existing land uses. Several studies have shown that integrating trees in agricultural lands often improves productivity of the systems and provides opportunities to create carbon sinks. However, data is insufficient, and an understanding of plant/climate relationships is essential in guiding future policies. Studies are being conducted to explore carbon sequestration potential of agroforestry systems, which may support the farmers in the form of payments for ecological services. The combined contribution of tree and crop is substantially high within the intercropping system. This may be due to the additional carbon pool in the trees and the increased soil carbon pool resulting from litter fall and fine root turnover. The high carbon storage may also be due to the increased growth and assimilation rates of intercropped components as compared to mono-cropping systems. Moreover, timber locks up carbon in its wood products for long periods thereby making it the major carbon assimilator of this type of agroforestry system. The tree-crop based system thus fare better than traditional agricultural systems, providing the best land-use option for increased carbon sequestration.

The Punjab farmers are experimenting with various agroforestry models with the aims of productivity, sustainability and stability. Their concept of agroforestry is aimed at conservation and optimum use of land, water and other climatic resources for production of food, fodder, fuel, timber and wood. It is in agroforestry where the vast solar energy available, nutrients present at different soil depths and water available in the soil are efficiently utilized and environment is ameliorated.

Scientists of the Punjab Agricultural University are working to provide farmers the latest technologies related to the different agroforestry systems. They have been concentrating more on biophysical and socioeconomic aspects of the system. Punjab's present political and administrative environment favours agroforestry. New socioeconomic policies have brought forestry and agriculture closer than ever. Support from different donor agencies to strengthen the research and extension base is encouraging farmers to adopt agroforestry. The Punjab State Forest Department is supporting agroforestry adopters financially under centrally sponsored scheme, Sub-mission on agroforestry to increase area under tree cover.

Diversified agroforestry models in Punjab




SCOPE OF MEDICINAL PLANTS IN AGROFORESTRY AND LIVELIHOOD OPPORTUNITIES THROUGH VALUE ADDITION

NEELU SINGH

Group Coordinator (Research), Scientist-G
Tropical Forest Research Institutes, Jabalpur-482021

About 80% of the population of most developing countries still use traditional medicines derived from plants for treating human diseases. In India, 9,500 species have been reported to be of medicinal value, of which 2,500 species provide raw material to herbal industry. The Ayurveda (900 species), Siddha (800 species) and Unani (700 species) systems are the main users and about 1,000 species are reported to have trade potential.

In recent years, the growing demand for herbal products has led to a quantum jump in volume of plant material traded within and outside the country. Further, growing demand is putting a heavy strain on the existing resources causing a number of species to be either threatened or endangered category. Of late, medicinal and aromatic plants are looked upon as a source of income. The recent study indicated that herbal drug market continues to grow at the rate of 7-30 % annually. Maiti (2013) reported that the export of raw material and finished herbal products is valued at about US $ 100-114 million per year. An ever increasing demand of medicinal plants based medicines warrants their mass propagation. The 54 top most traded medicinal plants are still being collected from the wild. Only few commercially valuable medicinal plants are under cultivation. Many national organizations-Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR), National Medicinal Plant Board (NMPB) ,Indian Council of Forestry Research and Education (ICFRE) and different State Forest Departments are working on different aspects viz., conservation, propagation, varietal development etc. of medicinal and aromatic plants(MAP). Some large private manufacturing units like Dabur, Zhandu, Himalayan Drug, Hamdard, etc. are big traders or manufacturers of medicinal plants based drugs. National Medicinal Plant Board, New Delhi under Ministry of AYUSH, GoI has been working to promote and support cultivation of medicinal plants in a Mission mode approach under Centrally Sponsored Scheme of "National Mission on Medicinal Plants (NMMP)" since 2008-09 in the country through State Government designated agencies to reduce pressure on the collection from wild habitat in forests and to meet the demand of MAPs in National and international market.

The potential returns to the farmer from cultivation of medicinal and aromatic plants are reported to be quite high, cultivated in different parts of the country. The

congenial climate available indifferent plantations offer great scope for cultivation of medicinal and aromatic plants, which in turn would increase resource use efficiency and generate supplemental income.Several medicinal plant require (or tolerate) partial shade, moist soils high in organic matter, high relative humidity, and mild temperatures. Indigenous people living in the different parts in forests or forest margins in India, are known to have conserved and cultivated several medicinal species for centuries.However, several medicinal plants have not been tried so far as intercrops in plantation and require standardization of agro-techniques under different agroforestry systems.

Integration of medicinal plants in different agroforestrysystems as upper story or under story are recognized as the most productive, remunerative, environmentally sound and ecologically sustainable alternative land use systems.

Keeping in view, the high demand of medicinal plants and to increase livelihood opportunities through sustainable farming, Agroforestry can be utilize as a key instrument to provide livelihoods for farmers while protecting and preserving forest reserves and biodiversity as well.

Cultivation of such plants can be taken up in thinned forests and cleared forest patches and as intercrops in new plantations in Silvi-medicinal systems. Two types of intercropping systems with medicinal plants can be adopted-

(1) Medicinal plants (Trees) as upperstory

(2) Medicinal plants as understory

Some important medicinal plants as upper story and under story for different agroforestry systems are summarized below:

IMPORTANT MEDICINAL TREES & BAMBOO AS UPPER STORY UNDER SILVI/MEDI/AGRI AGROFORESTRY SYSTEM

Botanical Name & Common name Family/ Maturity Period	Active ingredients (useful parts)	Varieties available /source	Gross production /income	Major Medicinal properties/Uses	Photographs
Aegle marmelous (Bael) Fam.- Rutaceae Maturity period- After 4-5 year	Carotenoids, Phenolics, alkaloids, Coumarins, flavon**o**ids, terpenoids, and otherantioxidants (Fruit, Bark)	Goma Yashi (Source-ICAR-CIAH, Bikaner) Narendra Bael (NB-5, Narendra Bael -7, Narendra Bael -9, Narendra Bael -16 and Narendra Bael -17 (Source-N.D. University of Agriculture and Technology, Kumarganj, Faizabad, U.P.) Pant Aparna, Pant Sujata, Pant Urvashi and Pant Shivani (Source-G. B. Pant University of Agriculture and Technology, Pant Nagar, Uttarakhand) CISHB-1 and CISHB-2 (Source: Central Institute for Sub- tropical Horticulture, Lucknow, Uttar Pradesh) Thar Divya, Thar Neelkanth, Thar Gaurav	Dhar Divya- Average yield/plant is 85.20 kg in 9th year. Thar Neelkand- Yield: 70-75 kg per plant (8th Year) Yield: 58.58 kg/plant (7th year) and 124.36 kg/plant (12th year) NB-5-28.78 kg par plant (6th year) NB-9-56 kg/plant (6th year) NB-7-(starts fruiting in the 4 th year, 32.10 kg/plant (6th year) Pant Aparna- 40.25 kg/plant (6th year) CISHB-1-42.64 kg/plant (6th year and fruiting starts in the 4 th year)CISHB-2-3845kg/plant (6th	Diarrhea, dysentery, constipation.	

		and Thar Srishi (ICAR-CIAH, Bikaner)	year)Goma Yashi-51kg/plant (6^{th} year)		
Azadirachta indica (Neem) Fam.-Meliaceae Maturity period-After 3-5 years,	Azadirachtin , Nimbolinin, Nimbin, Nimbidin, Nimbidol, Salannin, and Quercetin. (Leaf ,Seed)	6 cultivers -FRI-IFFCO-1,FRI-IFFCO-2,FRI-IFFCO-3, FRI-IFFCO-4, FRI-IFFCO-5 ,FRI-IFFCO-6 Recommended for eastern plateau (Bundelkhand Uphill), Northern plains (Rajasthan) then upland and Gujrat plains) and Deccan plateau hot semi arid region.	Seeds 10-12 kg/tree/yr	Various skin disorders, diabetes, Ulcer, Dandruff/ring worm	
Annona reticulata (custard apple) Fam.- Annonaceae Maturity period-5^{th} year	Tannins, alkaloids, phenols, glycosides, flavonoids and steroids. (Fruit)	Arka Neelanchal Vikram and Arka Sahan (Source: SVRC, Govt. of Odisha) Arka Sahan-IIHR Bangalore	Arka Neelanchal Vikram - 69 fruits/plant); fruit weight (211g) Arka Sahan - 45Kg/tree (5^{th} year and Fruits starts at 3^{rd}year)	As anthelmintic, analgesic, Anti-inflammatory, Antipyretic, wound Healing and cytotoxic effects.	
Buchnania lanzan (Chironji) Fam.-Anacardiaceae Maturity period-After 10 years	Fatty oil,Seed cake contains fibres, carbohydrates, mineral, fats, vitamin B_1, B_2, B_3, C, calcium, chlorine copper, iron, magnesium, phosphorus, potassium, sodium, sulfur, fatty oil, β-amyrin	*Buchnania lanzan* var. Palodensis (Source- Kumar *et al.*, 2020) Thar Priya (Source: ICAR, CIAH, Bikaner, Rajasthan)	Thar Priya - 11.90 kg /plant (Start bearing in 4^{th} year of planting)	Useful in the treatment of diarrhoea, leaves are used in the treatment of skin diseases and fruits are used in treating coughs and asthma.	

Citrus aurantifolia (Kanji nemu or acid lime*)* Fam**.-***Rutaceae* Maturity period- Starts bearing from 3rd year after planting	Flavonoids including apigenin, hesperetin, kaempferol, nobiletin, quercetin, and rutin, (Fruit)	PKM1, Vikram, Pramalini, Chakradhar, seedless lime, Balaji and RasrajBalaji [Tirupati (Andhra Pradesh)]PDKV Lime [Akola (Maharashtra)] Phule- Sharbati [Rahuri (Maharashtra)]	25 kg/ha/yr (6m*3m and 5m*5m spacing approx. 45- 62.5 kg/plant)	Antibacterial, anticancer, Antidiabetic, antifungal, Anti-hypertensive, Anti-inflammation, Anti-lipidemia.	
Citrus limon (Nimbu) **Fam.-***Rutaceae* Maturity period- Starts bearing from 3rd year after planting	Flavonoids, limonoids,phenolic acids,carboxylic acids, coumarins, vitamins and theirsmetabolites (Fruit)	Eureka, Allen, Cascade, Cook, Meek, Thorton, Lisbon, Bradbury, Cavors, Deavor, Hall, Jameson, Ledig, Limoneira,-8A, Monore, Prior, Prospect, Strong, Femminelo, Oval, Genoa, Brena	50-60 fruit/tree (after 3rd yr) 1000-1500 fruit/tree (after 8th yr)	Meniere's disease, Kidney stones, Treating scurvy,The common cold and flu.Decreasing swelling. Increasing urine.	

Commiphora wightii (gugal, guggul) Fam.- Burseraceae Maturity period- after 8-10 years	• Guggulsterone E and guggulsterone Z. • (Oleo-gum resin)	Marusudha (Source: CSIR-CIMAP, Luckhnow,U.P.) NRCCW-1 and NRCCW-2 (Source- NRCMAP, Gujrat)	A yield of 120–130 kg oleo-gum resin is obtained per hectare after about eight years.	Obesity, osteoarthritis, rheumatoid arthritis, gout, facial paralysis, sciatica, constipation, haemorrhoids, liver disorders, inflammation, cyst, cervical lymphadenitis, coronary thrombosis, anaemia, diabetes, urinary calculus, and skin diseases.	
Emblica officinalis (Amla) Fam.- Euphorbiaceae Maturity period- After 4th year	Vitamin – C (Fruit)	Banarasi, Chakaiya, Francis, NA-4 (Krishna), NA-5 (Kanchan), NA-6, NA-7 (Promising variety), NA-10, BSR-1 (Bhavanisagar).(Source) Goma Aishwarya (ICAR-CIAH, CIAH, Bikaner, Rajasthan)	NA-7- 51 kg/tree Chakaiya- 34 Kg/tree NA-628 Kg/tree	Cough, diabetes, cold, laxative, hyper acidity.	
Moringa oleifera (Sahajan) Fam.- Moringaceae. Maturity period- 9 months	Flavonoids. alkaloids, phenols, vitamins, minerals, proteins, glycosides, glucosinolates, Isothiocyanates, terpenes, saponins, and tannins(Fruit , Leaf)	Periyakulam 1 and 2 (PKM1 and PKM2) (Source- Horticulture Research Station of Tamil Nadu Agricultural University (TNAU) Thar Harsha (Source: ICAR-CIAH, Bikaner, Rajasthan)	Average yield 200-220 kg fruits/tree/yr 138 tonn/ha (Spacing 1.2m*1.2m, approx. 19.87 kg/tree) Thar Harsha- 45-48 kg/plant	Arthritis and other joint pain (rheumatism), asthma, cancer, constipation, diabetes, diarrhea, stomach and intestinal ulcers.	

Morus alba (*Sehtut,*white mulberry) Fam.-*M*oraceae Maturity period- after 3rd year	Rutin (293.5 µg/g), chlorogenic acid (226.9 µg/g), caffeic acid (17.2 µg/g), quercetin (15.2 µg/g), gallic acid (8.9 µg/g), kaempferol (5.8 µg/g), and apigenin (3.5 µg/g), Rutin , chlorogenic acid , caffeic acid , quercetin , gallic acid , kaempferol, and apigenin	Kanva-2, S-36, S-54, Victory-1, S-13 , S-34, MR-2 (Source: CSRTI, Mysore) Anantha (Source: Regional Sericulture Research Station in Andhra Pradesh) Vishala (Source: Central Silk Board, Bangalore) Thar Lohit and Thar Harit (Source: ICAR-CIAH, Bikaner, Rajasthan)	Fruit yield Thar Lohit- 12.4 kg to 26.5kg/tree/yr Thar Harit- 32.6 kg /tree/yr plant	The treatment of dizziness, insomnia, premature aging, atherosclerosis, liver and kidney disorders, and inflammation .	
Punica granatum (pomegranate) Fam.- Punicacea e Maturity period-	Flavonoids, Ellagitannin, Punicalagin, Eellagic acid, vitamins and minerals. (Fruit)	Ganesh, Mardula, Bhagwa, PhuleBhagwa Super, Phule Arakta and G 137 (Source:MPKV, Rahuri) CO-1 and Yercaud-1 (TNAU, Coimbatore), Ruby and Amlidana(Source:IIHR,Bengaluru) YCD-1 Pomegranate- (Source:Horticultural Research Station , Yercaud) Goma Khatta (Source: ICAR-CIAH, Bikaner, Rajasthan) CAZRI Vishal (Source:Singh and Meghwal, 2020) Jyoti(UAS, Dharwad)	Goma Khatta - 6.59 kg/tree and anardana yield is 1.18 kg/tree CAZRI Vishal -12-15 t/ha (3.5m*4m, approx. 16.8-21 kg/tree) YCD-1 -60 – 70 fruits/plant/yr	Treatment for Cancer, Osteoarthritis and Other Diseases. The pomegranate has been used in natural and holistic medicine to treat sore throats, coughs, urinary infections, digestive disorders, skin disorders, arthritis, and to expel tapeworms.	

Syzygium cumini (Jamun) Fam.- Myrtaceae Maturity period- Fruit bearing start in 3rd year	Phenolic acids, Flavonoids and Anthocyaninsetc. (Fruits)	Ram Jamun Jamun GJ-2, Jamun GJ-8, CISH J-37, CISH J-42 (Source: Central Institute for Subtropical Horticulture, Lucknow) Konkan Bahadoli (RFRS, Vengurla) Goma Priyanka-(ICAR-CIAH, Bikaner) Narendra Jamun 6-Narendra dev University of Agriculture and Technology, Faizabad , U.P. Rajendra Jamun-1 – Bihar Agriculture Collage Bhagalpur Thar Krantiand Goma Priyanka (Source: ICAR-CIAH, Bikaner, Rajasthan)	Thar Kranti- 65.00 kg/tree/yr Goma Priyanka- 30 kg/tree/yr	Antihyperglycemic , Hypolipemiant, Antiinflammatory, Cardioprotective, and Antioxidant activities.	
Terminalia chebula (Harad) Fam.- Combretaceae Maturity period- After 6 years	Glycosides, Gallic acids, Ellagic acid, Chebulinic acid, Tannic acid (Fruits)	*Vijaya, Rohini, Putana, Amrita, Ab haya, Jivanti* and *Chetaki* (Chattopadhyay and Bhattacharyya, 2007)	Approximatel y 40–50 kg/tree/yr dry fruits	Ingredient of Triphala, Laxative.	
Terminalia bellerica (Bahera) Fam.- Combretaceae Maturity period- After 10 years	*Arjungenin, Bellericacid* and Bellericosides (Fruits)		20-25 kg/tree from mature tree	Ingredient of Triphala	

Tamarindus indica (Tamarind, Tamarindo, Tamarin, Sampalok) Fam.- Fabaceae Maturity period- within three to four years	β-amyrin, compesterol, β-sitosterol and seven hydrocarbons. (Fruits)	Goma Prateek(Source: ICAR-CIAH, Bikaner, Rajasthan) PKM1 (Source: Tamilnadu University (HCRI, Periakulam) Tumkur Parthithan (Source: FRS, Aurangabad, Maharastra) Urigam DTS-1 (Source: UAs, Dharwad) Yogeswari (Source: Forest Deptt. Karnataka)	Average yield – 150-200 kg/tree/yr PKM1 Yield – 250 kg from 9thyear	It is used in wound healing, abdominal pain, diarrhea, dysentery, parasitic infestation, fever, malaria and respiratory problems.	
Zizyphus mauritiana (Ber) Fam.- Rhamnaceae Maturity period-	Proteins & amino acids, flavonoids, alkaloids, glycosides, terpenoides, saponins, fibers, tannins and phenolic compounds. (Seed)	Thar Sevika, Thar Bhubharaj, Goma Kirti and Thar Malti (Source: ICAR-CIAH, Bikaner, Rajasthan) Goma Keerthi(Source: ICAR-IIHR, Bengaluru)	Thar Sevika - 30-32 kg/tree. Thar Bhubharaj- Thar Malti- 30-36 kg/tree Thar Malti - 65-70 kg/ tree Goma Keerthi- 35.6 kg/ tree	Eye diseases, leukorrhea, as an astringent tonic to the heart and brain. The seeds also help to relieve thirst, and have a sedative and hypnotic effect, which is helpful in insomnia, pain, physical weakness, and rheumatic symptomology.	

MEDICINAL HERBS & SHRUBS AS UNDERSTORY COMPONENT(S) UNDER SIVI-MEDI AGROFORESTRY SYSTEMS IN FOREST OR PLANTATION

Botanical Name & Common name, Family/ Maturity Period	Active ingredients/ Parts used	Varieties available /source	Gross production /income	Medicinal Uses	Photographs
Andrographis paniculata (Kalmegh/ Bhuineem) Fam.- Acanthaceae Maturity period- Within one year	Andrographolide (Whole Plant)	CIM-Megha (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	CIM-Megha- 2.5-3.0 t/ha. Of dried herbNet Income- 45,000/ha (from 3rd month) (Bahl *et al*., 2018)	Fever, weakness, gastric problems	
Aloe vera (Grit-kumari) Fam.- Liliaceae Maturity period- 2nd-5th yr	Aloin (Leaves)	CIM-Sheetal (Source : CSIR-CIMAP Lucknow Uttar Pradesh) IC11127 IC111269 IC111280 IC111273 (Source- NBPGR, ICAR, Delhi)	CIM-Sheetal-50 t/ha. Net return- 1,25,000 Rs./ha. Approx (Bahl *et al*., 2018) Cost of cultivation (Rs/ha)- 1,30,000 Leaf yield (ton/ha)- 50-60 Leaf Rate/qt-5000 Gross return (Rs./ha)- 2,50,000 Net return (Rs./ha)- 1,20,000	Laxative, Wound Healing, & Skin burns	

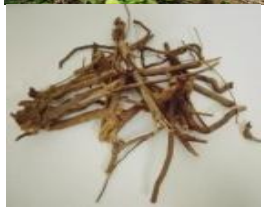
Acorus calamus (Buch) Fam.- Acoraceae Maturity period- Within one year	β-asaron, Flavonoid, monoterpene, quinone, sesquiterpene, and phenylpropanoid (Root)	Jor Lab AC-1 (Source: CSIR- NEIST Jorhat , Assam and lal *et al*., 2019)	Rs -36602.5/ha /yr 50-70 gram/plant	Drepression, Mental ailments, As an insecticide, Paediatric cough and colicky problems.	
Bacopa monnieri (Brahmi) Fam.- Scrophulariaceae Maturity period- One year	Bacoside A & B (Whole plant)	Subodhak, Pragyashakti, and CIM-Jagriti. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	As a pure crop, fresh yield is 22.5 tonnes/ hectare, reduced to approximately 5.5 tonnes/hectare on drying.	Memory enhancer, mental disorders.	
Cassia augustifolia (Senna) Fam.- Liliaceae Maturity period- Within 1 year	Sennosides (Dry tubers)	Sona CSIR-CIMAP's (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	Sona CSIR-Dry leaf yield: 11 q/ha, seed yield: 4-5 q/ha. Net profit- 27,000-30,000 Rs/ha./yr.	Rheumatism, general debility tonic, aphrodisiac.	

Coleus barbatus (Pashan Bheda / Pathar Chur) Fam.- Lamiaceae Maturity period- One year	Bergenin, and Afzelechin (Root)	**Manganiperu** (commercially cultivated in Tamil Nadu). **Garmai** (cultivated in Gujarat state). **Maimul**	Fresh tubers : 15 – 20 t/ha Dry tubers : 2000 – 2200 kg/ha	Kidney stone, Calculus.	
Cymbopogon flexuosus (Cochin grass, East-Indian lemon grass) Fam.- Poaceae Maturity period- after 4 to 6 months	Myrcene, limonene, citral, geraniol, citronellol, geranyl acetate, neral, nerol, terpenes, alcohols, ketones, aldehyde and esters. (leaves)	Cim –Pragti ,Nima , Chirharit, Krishna,CIM-Swarna and CIM – Shikhar, which gives more herb and oil yield. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	Krishna- 230-250kgoil /ha. Nima-25-260 Kg/ha essential oil CIM –Shikhar,- More 280kg/ha.oil yield Net profit of about Rs 60,000 and 1,00,000 /ha./yr depen on irrigation (Bahl *et al*., 2018)	Antispasmodic, Hypotensive, Anticonvulsant, Analgesic, Antiemetic, Antitussive, Antirheumatic, Antiseptic and treatment for Nervous and Gastrointestinal disorders and Fevers.	
Cymbopogon martini (Palmarosa) Fam.-Poaceae Maturity period- after 4 to 6 months	Motia (palmarosa oil), Mentha x piperita (peppermint) and Eugenia caryophyllus (clove) . (Flower)	PRC-I, Trishna,Tripta ,Vaishnavi,CIM-Harsh . (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	PRC-I- 125-150 kg oil/ha. Net Return- 60,000-1,00,000/ha.yr CIM-Harsh- 175-200 kg/ha. (Bahl *et al*., 2018)	Aromatherapy as a skin tonic due to its antimicrobial properties. It has also used in Ayurvedic medicine for skin problems and to relieve nerve pain.	

Cymbopogon winterianus (java citronella) Fam.-Poaceae Maturity period- After 4 month	Citronellol, citronellal, and geraniol . (leaves)	Manjusha, Mandakini, Bio13, Jalpallavi and CIM. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	20 - 30 t/ha/year (spacing of 60 x 45 cm) Citronellal 38.61% (Manjusha)	Anti-Inflammatory, Antinociceptive , and central Nervous system (CNS) disorders .	
Curcuma longa (turmeric) Fam.- Zingiberaceae Maturity period- 7-9 months after planting	Three curcuminoids; curcumin (diferuloylmethane, the primary constituent responsible for yellow color of turmeric)	Suvarna. Suguna, Sudarsana, IISR Prabha , IISR Prathibha., Co-1, BSR-1, Krishna,Sugandham, Roma ,Suroma ,Ranga,Rasmi,Rajendra,Sonia,SRKedaram,Sobha,Sona,Varna, Kanthi.(Source:Department of spices and plantation crops,faculty of horticulture ,Tamilnadu Agriculture university, Coimbatore, Tamilnadu.) CIM-Pitamber (Source-CSIR-CIMAP)	CIM-Pitamber 60–65 tonnes fresh rhizomes/ha Net profit- 1.25–1.50 lakhs/ha (1.25–1.50 lakhs/ha (Bahl *et al*., 2018)	A coughs, diabetes, dermatological conditions, respiratory problems, cardiovascular and hepatobiliary diseases, arthritis, irritable bowel disease (IBS), peptic ulcers, psoriasis, and atherosclerosis.	
Desmodium gangeticum (salparni.) Fam.- Fabaceae Maturity period- six to seven months	Gallic, protocatechuic, salicylic, chlorogenic, caffeic acids, rutin, quercetin and kaempferol in both parts of plant. (root ,whole plant		The total herb yield per hectare is estimated to be 50–55 quintals dry weight, while the dry weight yield of roots is estimated to be 11–15 quintals/hectare..	Febrifuge, aphrodisiac, analgesic, diuretic, antiinflammatory, and haemorrhagic properties. It is used in postnatal complaints, diarrhoea, chronic fever, biliousness, cough, vomiting, and asthma. It is an important ingredient of dasmoolarishta and chyavanprash.	

Embelia ribes (Vidanga) Fam.- Primulaceae Maturity period- After 5-6 months	• Embelin; quercitol, fatty ingredients and alkaloid schristembine, a resinoid, tannins • (Seed)			Relieving Headache, Rhinitis, Haemorrhage, Epilepsy Insomnia.	 
Gloriosa superba (Kalihari) Fam.- Liliaceae Maturity period- Five years	Cholchicin, Alkaloid gloriocine (Seed, tuber)		Seeds 200-250kg/ha.tubers 300 kg /ha.	Skin Diseases, Abortion, General debility.	
Mentha pipertia (Pippermint) Fam.- Lamiaceae Maturity period- Perennial	Menthol, Essential oil (Leaves, Flower, Oil)	Menthone ,menthol rich **:** Kukrail : menthol (34.5%),menthone (27.9%), Tushar : menthol (33.3%),menthone (27.3%) Pranjal menthol(52%),menthone (13.5%) CIM-madhuras:menthol31.2%,menthone 24.3%**.**Menthofuran rich :-V CIM-indus ;menthofuran (27%)and pulegone (15%) CIMAP-patra :menthofuran content:35-46%. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	Tushar- 85-90 kg/ha (Bahl *et al*., 2018) Oil yield (kg/ha)-120 Cost of cultivation (Rs./ha)- 75,000 Value @ Rs.2400/kg-2,88,000 Net Return Rs./ha-2,13,000 CIMMadhuras- High oil yielding (120-125 kg/ha)	Carminativ, Antiseptic and Gastro-stimulant	

Mentha arvensis (Japani mint) Fam.- Lamiaceae Maturity period- after 100-120 days	Menthol , menthone, menthyl acetate, isomenthone, limonene and neomenthol. (leaves)	Menthol mint-CIM-kranti, CIM-saryu, Kosi Peppermint- CIMAP-patra ,CIM-madhuras,kukrai, Pranjal Spearmint-MSSS,arka ,Neera, Neerkalka Bergamot mint-kiran. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	CIM-Suryu- 140-150 kg essential /ha. Containing 78-80% menthol. CIM-Vishisht-60 kg/ha of essential oil (Bahl *et al*., 2018) Menthol mint :Rs.125000/ha Peppermint:Rs.70000-80000/ha Spearmint : 70000-80000/ha	Hypertension and in patients with ischemic heart disease. The infusion of these leaves is used in indigestion, rheumatic pains, arthritis, and as remedy for inflamed joints.	
Ocimum sanctum (Tulsi) Fam: Lamiaceae Maturity period- 3 months	Oleanolic acid, rosmarinic acid, ursolic acid eugenol, , linalool, carvacrol (Leaves/Seed)	CIM-Ayu, CIM-Angna. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	CIM-Ayu- 16 q/ha. dry leaf yield or 110 kg/ha. Oil CIM –Angna 14 q/ha. or 90 kg/ha essential oil (Bahl *et al*., 2018)	Cough, Cold, Bronchitis, used as expectorant.	
Ocimum basilicum (*Indian basil*) Fam.-Lamiaceae Maturity period-	Methyl chavicol-rich, linalool-rich, methyl eugenol-rich, methyl cinnamate-rich, (leaves)	CIM-Saumya, CIM-Snigdha, CIM-Surabhi,CIM-Shishir,CIM-sharda. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	Average herb yield of basil is about 20-25 tonnes and oil yield is about 80-100 kg per hectare .	Headaches, coughs, diarrhea, constipation, warts, worms, and kidney malfunctions.	

Phyllanthus amarus (Bhumi Amla) Fam.- Euphorbiaceae Maturity period- Within one year	Phylanthin (Whole Plant)	CIM- Jivan (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	Yield-15-20 q/ha dry herb	Anemic, jaundice, Dropsy.	
Plumbago zeylanica (Chitrak) Fam.- Plumbaginaceae Maturity period- 10–12 months after transplanting	Plumbagin (Root)		Yield varies from 12-18 quintals/ hectare dry root . The cost of cultivation is approximately Rs 8000/hectare /yr	Stubborn chronic Rheumatoid arthritis, Skin diseases and tumerous growths, chronic menstrual disorders, viral warts and chronic diseases of nervous system.	 
Piper longum (Long peeper / Pipali) Fam.- Piperaceae Maturity period- After first year	Alkaloids (Fruit, Root)	Calicut, Assam and Viswam (Source: Philip *et al*., 2000)	Yield- 100-150 kg/ha dry fruits(in 1st yr and 0.75 - 1.0 t/ha in 3rd to 4 th) The yield of dry spike during first year is around 0.5 t/ha. It increases upto 1.2 t/ha in the third year.	Appetizer, enlarged spleen, Bronchitis, cold, antidote.	

Rauvolfia serpentine (Sarpa Gandha) Fam.- Apocynaceae Maturity period- After 2 year	Alkaloids (Root)	CIM-Sheel (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	CIM- Sheel – Average root from -1200 kg/ha (2nd year) Yield of root- 100-400 gm/plant Net return (Rs/ha)- 150,000/- (Bahl *et al*., 2018)	Hyper tension, insomnia.	
Rosa damascena (Damask rose) Fam.-Rosaceae Maturity period-	Phenylethyl alcohol (78.4%), citronellol (9.9%), nonadecane (4.4%) and geraniol (3.7%) (flower)	Noorjahan, Ranisahiba. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	Noorjahan- 600g rose oil/ha. Valued at 3 lakh/ha. Geraniol- 30% Citronellol- 24%, Nerl- 12 % and Rosa oxide- 1.3% Rani Sahiba- 40q/ha flower biomass Geraniol-35%, Geranyl acetate- 7%, Citronellol-5% and trans –rose oxide -10% (Bahl *et al*., 2018)	Abdominal and chest pains, strengthening the heart, menstrual bleeding, digestive problems and constipation.	
Vetiveria zizanioides (Vetiveria,Vetivergrass) Fam.-Poaceae Maturity period- After 12- 18 months	Sesquiterpenes (3-4 %), sesquiterpenols (18-25 %) and sesquiterpenones (7-8 %). (leaves)	KS 1, Dharini (khus odour), Gulabi (rosr odour), Kesari (saffaron odour), CIM- Vriddhi , CIM- Khus – 15, CIM – Khus - 22 , CIM – Khusnolika and CIM – samraddhi , khus -40 etc.(Source : CSIR-CIMAP Lucknow Uttar Pradesh)	KS 1- 18-20 kg/ha CIM-Vridhi- 20-25 kg/ha (10-12 months) Net profit- 1,50,000/ ha. (Bahl *et al*., 2018)	For relieving stress, It is also used for arthritis, stings, and burns. Vetiver is sometimes inhaled as aromatherapy for nervousness, insomnia, and joint and muscle pain.	

Withania somnifera (Aswagandha) Fam.- Solanaceae Maturity period- One year	Alkaloids (Root, leaf)	NIMITLI-101 ,Poshita, NIMITLI-118 , Pratap, Chetak.(Source : CSIR-CIMAP Lucknow Uttar Pradesh)	NMITLI-118 - 15q/ha (dry root yield) NIMITLI-101-23q/ha (dry root yield) Expenditure per hectare = 30,000/- Gross Return/ hectare= 96,000/ Net income per hectare = 66,000/-	Restorative tonic, stress, nerves disorder, aphrodisiac.	

IMPORTANT MEDICINAL CLIMBER SPECIES

Botanical Name & Family/ Maturity period	Active ingredients/ Parts used	Varieties available /source	Gross production /income	Medicinal Uses	
Asparagus racemosus (Satavari) Fam.- Liliaceae Maturity period- After 2-3 year	Saponin glycosides (Sataverin I-IV) (Tuber, root)	CIM-Shakti, CIM-Sunehari (CSIR-CIMAP, Lucknow , Uttar Pradesh)	CIM-Shakti -5-6 t /ha dried root yield from a 2 year old crop. Net profit- 350,000Rs/ha. CIM-Sunehari- 9 t /ha dried root yield	Enhance lactation, general weakness, fatigue, and cough.	
Dioscorea bulbifera (air potato, air yam, aerial yam, bitter yam) Fam.- Dioscoreaceae Maturity period- After two to three years.	Flavonoids, clerodane diterpenoids, and steroidal saponins and phenolic compounds. (tubers)	Peruvalli (*D.alata*) : Co 1, Sree Roopa, Sree Keerthi, Sree Shilpa Siruvalli (*D.esculenta*) : Sree Latha, Sree Kala	20 – 25 t/ha in 240 days of tubers.	Piles, Dysentery, Syphilis,Ulcers, Cough, Leprosy, Diabetes, Asthma, and Cancer.	
Gymnema sylvestre (Gurmar) Fam.- Asclepiadaceae Maturity period- After Four year	Gymnemic acids(Leaves)		About 1250 kg/ha. dried leaves (every three months). Or 5-6 kg/ha. dried leaves/plant (after 3rd year and about 10,000 – 15,000 kg/ha. of dried leaves.	Diabetes, Hydrocele, Asthma.	

Mucuna pruiens (Kaunch) Fam.- Fabaceae Maturity period- Within 5 months	Levodopa (Seed)		Seed yield is high between 2.5 to 3.0 t/ha on large scale cultivation.	Male infertility, Nervous disorders, and also as an aphrodisiac.	
Tinospora cordifolia (Guduchi / Giloe) Fam.- Menispermaceae Maturity period- Within one year	Alkaloids, Diterpenoid Lactones, Glycosides, Steroids, Sesquiterpenoid, Phenolics, Aliphatic Compounds and Polysaccharides (Stem)		The plant yields about 1500 kg of fresh woody stem, reduced to 300 kg of dry weight per hectare in about two years.	Gout, Pile, general debility, fever, Jaundice.	

MARKET VALUE OF MEDICINAL PLANTS IN 12 MARKETS

IMPORTANT MEDICINAL TREES AS UPPER STORY UNDER SILVI/MEDI/AGRI AGROFORESTRY SYSTEM

Botanical Name/common name	Plant Part	Rates in Different Mandi Rs/Kg										
		Amritsar	Banguluru	Chennai	Dehra Dun	Delhi	Jaipur	Kolkata	Lucknow	Mumbai	Neemuch	Dhanmtari	Shivpuri
Aegle marmelous (Bael)	Fruit	40	40	35	36	32	45	35	30	50	26	55	49
Azadirachta indica (Neem)	Leaf	30	25	25	20	23	30	28	25	40	18	-	33
Azadirachta indica (Neem)	Seed	35	40	38	42	30	35	35	38	50	20	-	50
Embelica officinalis (Aonla/Amla)	Fruit	165	190	180	165	150	175	170	150	175	140	127	200
Moringa oleifera (sahajan)	Leaf	-	-	-	-	-	-	-	-	-	-	-	79
Moringa oleifera (sahajan)	Seed	--	100	90	85	110	125	125	110	110	65	-	79
Terminalia chebula(small) (Harar chhoti)	Fruit	275	300	260	225	240	250	260	250	230	--	27	38
Terminalia chebula (Harar)	Fruit	35	50	42	35	30	45	35	33	45	26	155	30
Terminalia bellirica (Baheda)	Fruit	20	35	22	25	15	28	20	18	27	12	11	24

Source::Market Price of Medicinal Plants, Oct 2018-Dec.2021National Medicinal Plants Board

MEDICINAL HERBS AS UNDERSTORY COMPONENT(S) OF SIVI-MEDI AGROFORESTRY SYSTEMS IN FOREST OR PLANTATION

Botanical Name/common name	Plant Part	Rates in Different Mandi Rs/Kg											
		Amritsar	Banguluru	Chennai	Dehra Dun	Delhi	Jaipur	Kolkata	Lucknow	Mumbai	Neemuch	Dhamtari	Shivpuri
Andrographis paniculata (Kalmegh)	Upper part	43	50	45	35	36	60	40	35	45	21	-	61
Acorus calamus (Buch)	Root	120	110	95	82	100	125	90	90	125	90	95	136
Bacopa monnieri (Brahmi)	Whole Plant	375	450	400	310	350	375	375	350	410	-	-	75
Cassia angustifolia (seena)	Leaf	100	100	100	100	95	70	125	80	115	50		

Source::Market Price of Medicinal Plants, Oct 2018-Dec.2021National Medicinal Plants Board

IMPORTANT MEDICINAL CLIMBER SPECIES

Botanical Name/common name	Plant Part	Rates in Different Mandi Rs/Kg											
		Amritsar	Banguluru	Chennai	Dehra Dun	Delhi	Jaipur	Kolkata	Lucknow	Mumbai	Neemuch	Dhamtari	Shivpuri
Asparagus racemosus (MP) (Satavar)	Root	225	250	225	190	190	240	200	225	260	220	-	235
Asparagus racemosus (Nepali) (Nepali Satavar)	Root	550	600	580	525	510	600	575	525	700	-	-	290
Dioscorea bulbifera (Air potato)	-	-	-	-	-	-	-	-	-	-	-	65	-
Gymnema sylvestre (Gurhmar)	Leaf	120	125	100	70	90	125	100	90	100	55	-	68
Tinospora cordifolia (Giloy)	Stem	40	50	45	32	32	35	42	38	42	28	23	45

IMPORTANT MEDICINAL CLIMBER SPECIES

Botanical Name/common name	Plant Part	Rates in Different Mandi Rs/Kg											
		Amritsar	Banguluru	Chennai	Dehra Dun	Delhi	Jaipur	Kolkata	Lucknow	Mumbai	Neemuch	Dhamtari	Shivpuri
Asparagus racemosus (MP) (Satavar)	Root	225	250	225	190	190	240	200	225	260	220	-	235
Asparagus racemosus (Nepali) (Nepali Satavar)	Root	550	600	580	525	510	600	575	525	700	-	-	290
Dioscorea bulbifera (Air potato)	-	-	-	-	-	-	-	-	-	-	-	65	-
Gymnema sylvestre (Gurhmar)	Leaf	120	125	100	70	90	125	100	90	100	55	-	68
Tinospora cordifolia (Giloy)	Stem	40	50	45	32	32	35	42	38	42	28	23	45

Value addition of medicinal plants have received attention due to:

- The growth of green consumerism
- Side effects of synthetic chemical based products
- Awareness regarding utilization of herbal products
- More open international markets

Value addition at the primary collector level-

- Collection
- Cleaning (removal of unwanted parts like leaves, stems twigs *etc*.)
- Drying
- Storing

➢ **Value addition by market intermediaries and manufacturers.**

Collection

Following factors which can differ from raw materials to raw materials, can influence the yield/ quality of produce

- Stage of harvesting (maturation, flowering stage)
- Time of harvesting (early morning, evening and seasons like winter, summer, pre-monsoon *etc*.)
- Prior to processing, the medicinal plant materials should be protected from rain, moisture and any other conditions that might cause deterioration
- Medicinal plant materials that are to be used in the fresh state should be harvested/collected and delivered as quickly as possible to the processing facility in order to prevent microbial fermentation and thermal degradation

Cleaning (removal of unwanted parts like leaves, stems twigs *etc*.)

Raw medicinal plant materials should be inspected and sorted prior to processing. The inspection may include:

- Visual inspection for contamination by untargeted medicinal plants /plant parts
- Presence of foreign matter
- Organoleptic evaluation, such as appearance, damage, size, colour, odour, and taste (if possible)

Drying

Dryingof medicinal plants play an important role and affect quality of produce severely. The method and temperature used for drying may have a considerable impact on the quality of the resulting medicinal plant materials. Following factors which can differ from raw materials to raw materials, can influence the yield/ quality of produce:

- Rate of drying (avoid decomposition)

- Temperature of drying (avoid decomposition)
- Moisture content after drying (avoid molds growth)

Different drying methods can be utilized for drying of medicinal plants:

- Sun drying
- Shade Drying
- Oven Drying
- Use of solar dryers-Direct Type and Indirect Type
- Lyophilization
- Microwave
- Infrared

Precautions:

- The moisture content of the material should be kept as low as possible in order to reduce damage from moulds and other microbial infestation.
- Temperature and humidity should be controlled to avoid damage to the active chemical constituents.
- Efforts should be made to achieve uniform drying of medicinal plant materials and so avoid mould formation.
- Drying medicinal plant material directly on bare ground should be avoided.
- Natural drying in the open air, medicinal plant materials should be spread out in thin layers on drying frames and stirred or turned frequently.
- In order to secure adequate air circulation, the drying frames should be located at a sufficient height above the ground.
- Insects, rodents, birds and other pests, and livestock and domestic animals should be kept away from drying sites.
- The direct drying (fire) should be avoided, and drying temperatures should be kept between 40-50 °C.
- Shade drying is preferred to maintain or minimize loss of colour of leaves and flowers.
- Lower temperatures should be employed in the case of medicinal plant materials containing volatile substances.
- For indoor drying, the duration of drying, drying temperature, humidity and other conditions should be determined on the basis of the plant part concerned (root, leaf, stem, bark, flower, *etc*..) and any volatile natural constituents, such as essential oils

Storing/packaging

- Storage time before processing also affect quality of medicinal plant materials
- Storage conditions should prevent prevents hydrolysis and oxidation of material.

- Materials used for packaging should be non-polluting, clean, dry and in undamaged condition and should conform to the quality requirements for the medicinal plant materials concerned.

Value addition of Medicinal Plants

The value addition of medicinal plants offers huge opportunities for livelihood generation. Medicinal plants can be processed or value added into consumer-oriented products through different extraction techniques.

Methods of extraction of medicinal plants

1. Aqueous extracts/extraction with solvents:

Maceration

In this process, the whole or coarsely powdered plant materialis placed in a container with the solvent and allowed to stand at room temperature for a period of at least 3 days with frequentagitation until thesoluble matter has dissolved.

Infusion

Fresh infusions are prepared by macerating the plant material for a short period of time with cold or boiling water. These are dilute solutions of the readily soluble constituents of medicinal plant.

Digestion

This is a form of maceration in which gentle heat is used during the process of extraction. It is used when moderately elevated temperature is not objectionable.

Decoction

The plant materialis boiled in a specified volume (1:4 or 1:8) of water for a defined time. It is then cooled and strained or filtered. This procedure is suitable for extracting water-soluble; heat stable constituents.This process is typically used in preparation of Ayurvedic extracts called “quath” or “kawath”. Then the concentrated extract is filtered and used as such or processed further for the preparation of drug extractive.

Percolation

This process is used most frequently to extract active ingredients in the preparation of tinctures and fluid extracts. The solid ingredients are moistened with an appropriate amount of the specified solvent and allow standing for approximately 4 h in a well closed container, after which the mass is packed and the top of the percolator is closed for 24 h. The outlet of the percolator then is opened and the liquid contained therein is allowed to drip slowly.

Hot continuous extraction (Soxhlet)

The finely ground plant material is placed in a porous bag or "thimble" made of strong filter paper, which is placed in Soxhlet apparatus.

For aromatic plants,

Hydro distillation techniques (water distillation/ steam distillation)

Clevenger Apparatus for extraction of essential oil

Distillation unit for extraction of essentialoil

Applications/Scope of essential oils in different industries

Essential oils and aroma chemicals constitute a major groupof industrial products.Themajor consuming industries are

- Soap
- Cosmetics
- Pharmaceuticals
- Confectionery
- Perfumes
- Incense.
- Flavoring food and drink
- Insecticides and pesticides

Essential oil Distillation unit Suppliers in India

Essential Oil Distillation Unit GAK Equipments & Technologies Plot No 54, Sector 82, JLPL, JLPL Industrial Area, Mohali - 160062, Punjab, India Rs 3.75 Lakh/Unit	Andel India Mannaday Mohali,India	United Technologies Narangi Phata, Mumbai	Labotronics Inc. Andheri,Mumbai
Hexamide Agrotech Incorporation Kalamboli,Navi Mumbai			
Traders of Essential Oils in India			
Arsi Traders Shop No. 4, Ground Floor, 218/220 , Kapur Wala Building, Samuel Street , Masid Bunder, Mumbai – 400003Tel No. 22 – 66345180	Sabri Itter 1/6, Jamal Mainsion Nowroji Hill Rd-1, Dongri Mumbai-400009 Tel No.22 – 23713712 Kanha Nature Oils	SK Chemicals No. 102, Suite 41, Pycrofts Road,Mogappair East	Chennai - 600014,Tamil Nadu
Chemizo Enterprise Jodhpur	Essential Oils Dealers A Address : C-153, Ist Floor, Sarvodaya Enclave,New Delhi-110017,	Paras TTrademartPrivate Limited Rai Purwa, Kanpur	

Medicinal Plant Based Value added products:

- Establishment of primary processing based units –Medicinal plants powders
- Medicinal plants based extractives
- Edible products-Juice, Candies, Edible Flavors, Jam Jellies and Chutneys
- Extraction of essential- Aromatic Oils and Compounds, Aroma Therapy
- Herbal cosmetics
- Processing units of medicinally important fruits
- Bio-pesticides and Bio fertilizers

ADDRESS OFTRADERS OF MEDICINAL AND AROMATIC PLANTS

Madhya /Pradesh & Chhattisgarh			
M/S Raj & Company Behind Katju Market, Near parsi Mandir ,Neemach , Madhya Pradesh Ph. No. 07423-221600 Fax – No. 07423-225341 Mob: 9826021601 E-mail: rajspice@sancharnet.in	M/S Reeva Herbals 126/136, Industrial area Chorhata , Reeva Madhya Pradesh Ph. No. 07662-2297250	M/S Jaseko Neutri Foods Opposite C-21 Mall, A.B. Road Indore , Madhya Pradesh Ph.No. 0731-2576009, 92292-333333	A.N. Bhardwaj M/S Perfect Herbals & Oils H.401, Ashoka Hights , Moa Raipur -492007, chhatisgarh Ph. No. 0771-4055495 Mob: 91-9926974509 E-mail: perfectherbals_999@yahoo.com
Bihar:			**Chandigarh :**
M/S Baidhanath Ayurved Bhavan Pvt.Ltd. Baidhanath Bhavan Road, Lodinagar, Patna, BIhar- 800001. Ph. No. 0612-2353143, 6450647 Fax No- 0612- 2368571 Email : baidyanathsales@rediffmail.com	M/S Harbal (S.P.S) Pvt. Ltd. Ashok Rajpath Chauhata, Patna, Bihar – 800004, Ph. No. 0612-2302910, 2302273, Mob: 9431011266.	M/S Shree Krishna Prasad Medicinal and Aromatic plant Manufactured Federation B-83 Ashokpur , Hajpura daily road, Patna, Bihar Mob: 09431421471 Email : mapgab@rediffmail.com	M/S Krishna Herbal company 3604, sector 23-D, Chandigarh- 160023 Ph. No. 0172-3054840 Fax. No. 0172-3054840 Mob: 09876643604
New Delhi			
M/S Dabur India Ltd. 8/3 , Ashaf Ali Road, New Delhi – 110001, Ph-011-23253488	Shri A. K. Jain M/s Arya International D-184, Freedom Fighter Enclave, Nabi saray, new Delhi , Ph. No -011-26659020 Mob: 9811300884 Fax - No – 011-26659022	M/S Gulab singh Jauhary Maal Shri Mukul Gundhi 320, Dariba Kalan , Chandni Chowk ,New Delhi Mob: 9811131890 Ph- No. 011-23263743, 23271345, 23281345 Fax. No. - 23288226	M/S Virat Exports Ajay Kumar Jain 23/3, East Patel Nagar New Delhi- 110008 Ph-No.- 25767182
M/S Rasik Lal Himani Agencies Pvt. Ltd 508, Khari Bavali , Delhi- 110006	M/S Shri Sai Trading Company Shri Gaurav Gupta	M/S Rasik Lal Himani Agencies Private Ltd.	M/S Virat Exports Ajay Kumar Jain

Ph. No- 011-23273875, 23273926 Fax – No.: 011-2930582	1/2249, 3 Flour-2 Street no. 12213,Near Shanti Opticals, Subhash Road,Ramnagar, Shahdara,Delhi Mob: 8447518302, 9891067409 Ph. No. 011-22134539 Fax. No. 011-22134539	First flour, sab house, 3/8 Aasaf Ali Road, New Delhi- 110002 Ph. No. 011-23280016, 9971113564	23/3, East Patel Nagar New Delhi- 110008 Ph-No.- 25767182
Karnataka			
M/S Himalaya Drug Company Makali, Bangalore- 562123 Ph. No. 080-23714444	M/S Sami Labs Limited 19/1,19/2, 1st Main, 2nd Phase Peenya Industries Area, Bangalore- 560058 Ph. +91-8028397973, 75, 78 Fax. +91-8028373035 E-mail: mail@samilabs.com	M/S Sai Baba Sugandh Bhandar 53, Santhupath, Banglore-560053 Ph. no. 080-26714018	
Maharashtra			
M/S Herbs Store 23 Khadak Street Satguru Sadan P.O. 5047, Mumbai Ph.No.022-3739216	M/S B.A.S.F India Ltd. Rohni Palen House, Sudaam Kala, Ahair Marg P.O. 19108, Mumbai -40002 Ph.No. 022-4930703, 7681201 Fax.No. 4952417	M/S A.B.C. Enterprises C-101, Jambodarshan Second koaldangri, Andhari (East) Mumbai-400069 Ph. No. 022-8341364, 8382122	M/S Zhandu Emami Ltd. 3rd Flour Golden Chamber New Link Road , Andheri (West) Mumbai Ph. No. 022-26709000 Fax. No.022-66709085
M/s Albi Agencies 39, Nand Bhawan 59, Babu Jenu Road, Mumbai -400001 Ph.No. 022-2069885 Fax.No. 022-2051593	M/S A.B.C. Enterprises C-101, Jambodarshan Second koaldangri, Andhari (East) Mumbai-400069 Ph. No. 022-8341364, 8382122	M/S M.S. Flower Vaily Agrotec Pvt. Ltd 4/13 manson, Author Bandar Road Kulaba, Mumbai -400005 Mob: 09821453414	M/S Hasim Ali Qamrudeen 820, Bhawani Peeth, G.B. Memorial complex, Near Bhawani Mata Mandir, Pune – 411042 Ph-No- 022-644876, Fax.No.-644776

Shri Shantanu Panja M/S Konark Harbal Mumbai No. 332, Andheru Industrial Estate Sun Mil Compound, Lower Pearl Mumbai -400013, Maharashtra, India Ph. No. 022-40914300 Mob: 08447508019,9323780980 Fax –No.022-24934171 E-mail : exim2konarkgroup.com cmd@konarkgroup.com	M/S Sagar Aromatics Shri Praveen Ghoghri Ho. No.9,Building no. 162 Utthan Darshan , Near Samta Nagar Bus DIpot Kandiwali, East Mumbai – 400101, Maharashtra Mob: 08447501270	M/S K.V.N.Palimars Shri Vinod Kumar Singh S. N.-7111, Shanti Nagar Bhorari Park Fax- No. 0202713080	M/S Shri Shaid Medi Forms Cultivater & Dealer of Medicinal Harbs Gokul-9, Ghati Layout, Near Bhole Petrol Pump, Civil Lines , Nagpur – 440001 Ph. No. 712-65011117, 22220334 E-mail: shri-shhil@hotmail.com
Uttar Pradesh			
Shri Gambhir Chand Jain M/S Gambhir Chand Jain Kirana, Store Annpurna Mandir Ke Bagal me, Sahadatganj, Lucknow Ph. No. 0522-2649114, 2649115, 2649116 Mob:9415023623, 9415087294	Shri Suraj Gupta M/S Panchsheel Traders Sahadatganj, Lucknow Ph. No. 0522-2649619, 2649054	Shri Mahesh Jain M/s Gulab & Company Matadeen Road, Sahadatganj, Lucknow Mob: 94151088206, Ph.No . 0522-2649101, 2649102	M/S Asha Gramodyog Sansthan 647 B/C , 114/1 (P-18), Jankipuram Garde , Near Novel CT Academy Lucknow -226021, Mob:+91-9415753154 E-mail: ashagramodyog@gmail.com
M/S Perfumers & Essential Oil 47/48, New Market P.O Box - 165, kaiserbagh , Lucknow Ph.No. 0522-2612309	Shri Vimal Jain M/s Piyush Trading company Sahadatganj , Lucknow Mob: 09450094031	M/S Kanhaiya Lal , Ashok Kumar 252/6, Rakabganj , Lucknow -3 Mo: 9750200186, 9750299185	M/S Mentha & Alaid Chemicals Block Office, Rampur Barabanki-244901 Ph. No. 05248- 224094, 223508 Fax- No. 25029 Mob:9839174125, 9412718425 E-mail: raj-sri57@rediffmail.com
M/S Perfumers & Essential Oil 47/48, New Market P.O Box - 165, kaiserbagh , Lucknow Ph.No. 0522-2612309	M/S Perfumers & Essential Oil 47/48, New Market P.O Box - 165, kaiserbagh , Lucknow Ph.No. 0522-2612309	M/S Neo Fragrance c/o.Naresh Kumar Kanoyjiya Katra Bahadur , Kannuj Mob: 09453017513, 9695803408 E-mail:neofragrance@yahoo.in	Shri Shailendra Jain M/S Shaivi Industries 42/20, Saket Pali, Narhi, Lucknow -226001 Ph. No. 0522-2288134, 2239152

M/S Gangaram Sitara Kirana Aadhati Annapurna Mandir ke Samne, Sahadatganj , Lucknow -226003 Ph. no. 0522-2649899, 2649816 Mob:9839901518, 9919964209	M/S Bablu Jain Kirana Aadhati Matadeen Road, Chota Chauraha, Sahadatganj, Lucknow-3 Ph. No. 0522-2648226 Mob :09935367206	M/S Rakesh Sandal Industries 25-aazad Nagar, Kanpur-208020 Ph. No. 0512-2563930, 2563931 FAX- No. 0512-2563935 E-mail: info@rakeshin.com	M/S Ashri Flavours, Shri Tekchand B/566, Lakhpedabagh, Barabanki Mob: 9838078627 E-mail: ashriflavours@gmail.com
M/S Neeru Enterprises Vishnu Kapoor 6, Salim Manzil, Civils Lines, Rampur -244901 Ph.No. 0595-2350829, Mob:9837022285	Shri Mahesh Jain M/s Gulab & Company Matadeen Road, Sahadatganj, Lucknow Mob: 94151088206, Ph.No . 0522-2649101, 2649102	M/S Nishant Agrawal Sugandh Aromatic, 536/268, Indira Nagar, Bareilly - 243122 Ph.No. 581-2585005, Mob: 9758876700, 9837087670 E-mail: Hindustan@sancharnet.in	M/S S. K. Traders Company Sahadatganj , Lucknow Mob: 09335242927
M/S Aromed Harbals Ho.No.41 , Sector -25 Indira Nagar, Lucknow -26016 Ph.No. 0522-4022273 Mob:9336814123, 9452861261	M/S Lucknow Kirana Company 88, Shubash Marg, Lucknow Ph. No. 0522-2265961 Mob: 09335282135	M/S Ramesh Kirana Aadhati Gulab & company Ke Samne Sahadatganj , Lucknow-3 Mob:094500093713, 094500937114	M/S Padmavati Harbs 35-B/2 Modal Town Hari Mandir , Behind Baraat Ghar Bareilly , Uttar Pradesh Ph . No. 0581-3959932 Mob:9837003601
M/S Ayuroma Center Mr. anurah Katiyar Rawatpur village, Kanpur Ph. 09415050346 E-mail: ayromacenter@gamil.com	Shri Anil Kumar Barnwal K-64/4, Goladeena Nath, Kabir Lora, Varanasi, Mob: 9415201873	M/S Bhajjamal chanhamal, Purana Deshi Davakhana Neem ke Ped waali Shop, Bajaja, Faizabad Mob: 9415719455	M/S Jagat Aroma Oils Distillation Kannauj, Ph.No.05694-234401
Uttarakhand			

M/S Natuarl Concepts India Ms. Kirti Singh C.P.-12, Awas-Vikas Near O.B.C. Rudrapur-263153 Mob: 981020915, 9219447232 E-mail: naturalconcepts609@gamil.com	Aditya Prakash Agrawal Paith Pairao , Ramnagar Dist. Nainital -224715 Ph.No. 05942-251596	M/S Anand Trading Company Nimbuwala, Dehradoon Cant (Headquater) Uttarakhand -248003	M/S Badri Prasad Jadish Prasad Chandra Shop- 15-C, New Galla Mandi Haldwani, Nainital Ph. no. 274839
M/S Deen Dayal Radhey Shyam C-11, New Galla Mandi , Haldwani, Nainital -247515 Ph.No.253165	M/S Herbal Automation, Hanuman Garhi, Kankhal, Haridwar Mob.9412074986 E-mail: herbalautomation@mail.com	M/S Masers Sharda Brothers Tanakpur – 262309, Dist. Champawat Uttarakhand-262309 Ph. No. 05943-265022, Mob: 9897603288	M/S Prashant trading Company 34, Shivpur , Kerwal, Haridwar-249408 Ph.No. 266401
Punjab			**Rajasthan**
M/S K.S. Aroma & Company Swank Mandi, Amritsar Punjab – 143001	M/S Mehta Pharmaceuticals Chhiharta, G.T.Road, Amritsar-143009	M/S Oriental Traders 615/6, Bagh Jhanda Singh First Flour , Amritsar-143001	M/S Aloe Naturals 20/1,Light Industries Area Jodhpur -342003, Rajasthan Ph.No. 0291-5107777 Mob:09928611999 E-mail :09928611999
Hyderabad	**Kerala**	**Tamilnadu**	
M/S Jena Bio-Herbs Pvt.Ltd . Shri Prem Kumar Ho.No.3-6-294, Haidarguda Hyderabad- 500029	M/S M.M . Abdul Hameed & Sons Essential Oil Exporter P.V. Box -12 Ashokapuram , Aalve-683101 Ph.No. 0434-2624014 Fax No. 084-262517	M/S Shri N. Sundar Geranium Planter Pudumund , Unit Mob:0944302377 Ph.No. 0423-244354	

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SEED COLLECTION, PROCESSING AND STORAGE

Dr. MAITREYEE KUNDU

Head & Scientist - F
Siviculture, Forest Management & Agroforestry Division
Tropical Forest Research Institute, P.O. R.F.R.C. Mandla Road, Jabalpur (M.P.)

The need for planting forest tree species is intensively increased to meet the demand for fodder, fuel, and wood based industrial raw material. For the fulfillment of the program, good amount of seed should be supplied each year. According to one estimate every year 3400 quintals of tree seeds are required in India to afforest an estimated 4,10,000 ha of land. But the fate of any plantation work depends primarily upon the quality of seeds, which can be hardly predicted and mostly depends on the species, time of collection, proper processing, and method of storage.

Seed technology deals with:

- SEED COLLECTION AND PROCESSING
- SEED PRETREATMENT
- SEED STORAGE

Problems in poor quality seeds comprises:

- low germination percentage
- poor emergence
- poor survival
- poor adaptability to site
- susceptible to disease and pests
- poor growth
- low productivity

Characteristics of good seeds:

- well ripened, healthy and true to type,
- pure and free from inert materials and weed seeds,
- viable and have good germination capacity,
- uniform in its texture, structure and look, and
- must not be damaged, broken and affected by pests and diseases.

Seed collection and processing

The collection time and method of collection and processing affect the quality of seeds. Seeds or fruits should be collected just as they have reached ripeness, although there are several other indictors for determination of the collection time.

Collection time may be classified into the following:

(i) Collection of fallen fruits or seeds from the forest floor.
(ii) Collection from the crown of felled trees.
(iii) Collection from standing trees with access from the ground.
(iv) Collection from standing trees with access by climbing.
(v) Collection from standing trees with other means of access.

The object of seed/fruit processing is to achieve clean, pure seeds of high physiological quality, which can be stored & easily handled. Processing includes a number of handling procedures where applicability differs according to fruit & seed type condition of the fruits/seeds at collection & potential storage period. Processing can be grouped into the following 7 procedures:

1) Pre-cleaning, 2) Pre-curing, 3) extraction, 4) Dewinging,
5) Cleaning, 6) Grading, & 7) Adjustment of moisture content.

Planning of seed collection

Before collection of seeds we have to consider the following factors:

1. Which species to collect (species selection)
2. How much seed to collect (quantity)
3. Where to collect (seed sources, seed trees)
4. When to collect (harvest time)
5. How to collect (collection method)

Prediction of correct harvest time is important for collection of seeds:

- The best seeds are produced in mast years
- The best time to collect seeds when they are mature but before they are lost to predators or dispersal
- Forecasting the quantity, quality and timing is difficult
- The earlier the collection, the better will be the work plan

Advantage of premature collection

- To extend the collection season
- To minimize loss of seeds to dispersal and / or predation.
- To avoid development of dormancy
- To reduce pre-processing damage
- To salvage immature seed collected inadvertently.
- The best seed producers are ordinarily dominant trees that have attained middle age and are healthy with reasonable good form.
- It is not advisable to gather seed from short or easily climbed and poor crowned trees.

- It is always advisable to examine the seeds of a tree in the field before effort is expended in gathering more of them. Cutting a cross section to see that how many seeds are hollow, empty and immature.

Procedure for pre-curing

a. Separate fruits in two or three maturity classes
b. Store at ambient temperature at a ventilated place and high humidity: stir regularly to allow ventilation
c. Reduce moisture as the fruits approach mature colour
d. Conclude the process as the fruits attain mature colour

EXTRACTION METHODS

Fruit type	Extraction procedure
Dry dehiscent fruits, e. g. dehiscent pods, follicles and capsules and cones, e.g. pines, eucalypts and most leguminosae	Drying→shaking/tumbling
Dry indehiscent fruits, e.g. indehiscent pods of *Acacia nilotica* and *A. siberiana*	Drying→threshing
Seritinous fruits, e.g. cones, capsules plus some dry compound fruits	Klin heating→tumblingScorching→tumbling
Fleshy fruits w/very thin pulp,e.g. *Ziziphus* spp.	Drying Soaking→maceration→washing
Fleshy fruits w/ soft pulp, e.g. *Prunus* and *Ficus*	Soaking→fermentation→washing Soaking→maceration→washing
Fleshy fruits w/ soft, fibrous pulp, e.g. *Gmelina*	Soaking→maceration→washing→ Abrasion/polishing
Fleshy fruits w/ felty pulp e.g. *Tectona grandis*	Soaking→abrasion/polishing

Maturation indicators for collection of seeds of some important species:

Species	Maturation index	
	Color of pod	Moisture%
Bassia latifolia	Light brown	56-60%
Mimusops elengi	Yellowish orange	30-35%
Holoptelea integrifolia	Brown	4-5%
Hardwickia binnata	Brown	10-11%
Moringa oleifera	Whitish green	60-65%
Abelmoscus moscatus	Reddish brown	16-20%
Terminalia arjuna	Brown	52-58%
Terminalia chebula	Yellowish green	10-11%
Sapindus laurifolia	Yellowish green	8-12%

POST-HARVEST CARE

- The freshly collected seed should not be exposed to sun
- The safest drying method for delicate species is to spread a thin layer of fruits in well ventilated rooms and stirring at regular intervals,
- Seeds should not be left in wet areas otherwise it will rot and die,
- The soft and fleshy seeds should not be kept in heap or large sacks/bags immediately after harvest. They can be kept in small-untied perforated sacks or open basket after cleaning of pulp and drying of seeds. The large and closed sack generate much heat as well as thermophilic fungi that can kill the seeds.
- Seeds should be completely dried and labelled before putting them for storage under species-specific conditions.
- Fruit storage is advantageous in some species for afterripening.
- The freshly collected seed should not be exposed to sun.

SEED STORAGE

The main purpose of traditional seed storage is to secure the supply of good quality seed for a planting programme whenever needed. If sowing time follows immediately after seed collection and processing, seeds can go directly from the processing unit to the nursery, and storage is not needed. This is, however, rarely the case. In seasonal climates with a relatively short planting season, sowing time is normally determined by the wish to have plantable size seedlings at the beginning of the planting season. Hence seeds must often be stored during the period from harvest to sowing.

The objectives of storage of tree seeds are:

- to preserve seeds under conditions that best retain germinative energy during the interval between collection and time of sowing.
- To protect seeds from damage by rodents, birds and insects.

- To preserve quantities of seed collected during years of heavy seed crops to ensure supply in lean year. Length of the storage period depends on the intended use of the seeds. It may be:
- Upto one year: When both seed production and afforestation are regular annual events, but it is necessary to await the best season for sowing.
- 1-5 years of more: Medium term storage maintains seed supplies as a safeguard against subsequent seed crop failure for the next 4-5 years.
- Long-term storage: Maintains special lots for research or for germplasm conservation for more than 5 years. The period of storage will vary according to the seed longevity of the species and the storage conditions, but will be measured in decades in species which are easy to store.

Three factors are important for storage of seeds.

- Seed category
- Temperature
- Moisture content

Seeds are classified on the basis of tolerance of drying:

- Recalcitrant: Cannot tolerate drying.
- Orthodox: Tolerate drying.

Recalcitrant seeds should be stored at 10-20°C with proper aeration facilities at shedding moisture content. Orthodox seeds should be stored at 4-5% moisture content at lowest possible temperature. (upto-20°C) in tightly closed container or polythene bags with minimum change in moisture content. If the facility for temperature is not available, care should be taken in maintaining moisture content. Drying should not be done under direct sunlight. Seeds can best be dried on silica gel in closed container.

STORAGE CONDITIONS FOR SEEDS OF SOME IMPORTANT SPECIES

Species	Seed storage behavior	Critical moisture content	Best storage conditions assessed	
			Seed Moisture Temp. Content (^{0}C)	Storage Temperature
Schleichera trijuga	Orthodox	7-8%	7.1	-10
Bassia latifolia	Recalcitrant	32-34%	32	28
Sapindus laurifolia	Orthodox	4-5%	4	-10
Rauvolfia serpentina	Orthodox	4-5%	3.8	-10

Moringa oleifera	Orthodox	4-5%	4	-10
Terminalia chebula	Orthodox	5-6%	5	-10
Mimusops elengi	Intermediate	8-9%	7.7	15
Holoptelea integrifolia	Orthodox	3-4%	3.8	-10
Emblica officinalis	Orthodox	4%	4.9	-10
Hardwickia binnata	Orthodox	4%	4.4	-10
Terminalia arjuna	Orthodox	4-5%	5%	-10
Abelmoscus moscatus	Orthodox	3-4%	4%	-10

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VALUE CHAIN LINKED AGROFORESTRY MODELS FOR ADDITIONAL INCOME TO FARMERS

Dr. NANITA BERRY

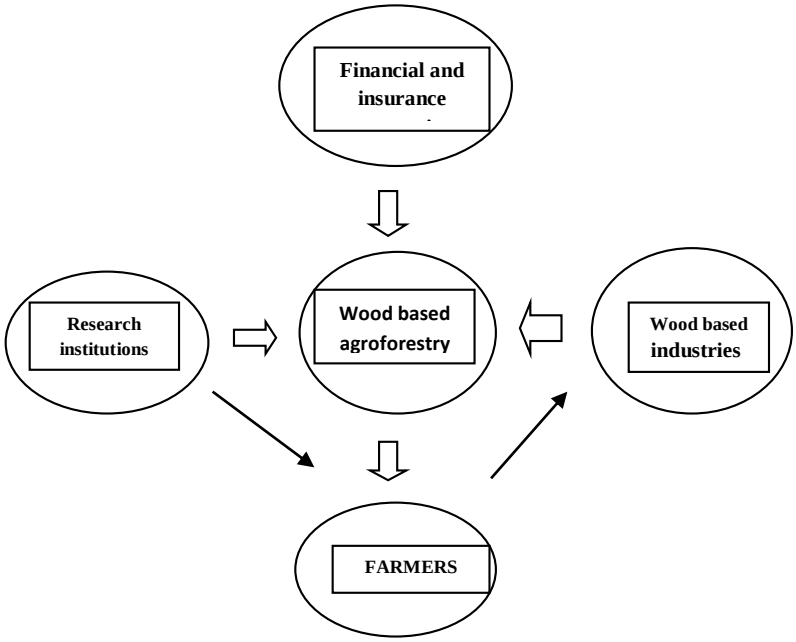
Scientist 'F' & Head
Forest Extension Division
Tropical Forest Research Institute, Jabalpur (M.P.)

Agroforestry is a merger of agriculture crops and/or livestock with tree components on a unit piece of land with special arrangement of time and space. Agroforestry emerges as an effective tool for improvement of rural economy due to low investment, high profitability and high income-generating practices.

In Madhya Pradesh, agroforestry is being practised in throughout the state in the form of traditional agroforestry since time-immemorial. Traditionally, trees like babul, neem, munga, teak, bamboo, palash, mahua, sissoo, jamun, aonla, mango, guava, etc. are deliberately retained by farmers on their farm. However, some new entrants such as Bamboo, teak, subabul (*Leucaena leucocephala*), Eucalyptus and Khamer (*Gmelina arborea*) etc. have also been adopted under agroforestry. Madhya Pradesh is the second largest state of India covering 9.5% of the country's area. Green programmes like farm forestry are found to be effective in many districts in Madhya Pradesh, which supply fast growing, site-specific, improved quality pulpwood planting materials especially clonal material, and provide quick economic support to small and marginal farmers through securing bank loans for plantations.

The involvement of wood based industry for agroforestry is found beneficial for procurement of wood raw material security from agroforestry. Plantation carried out by some paper mills and other corporate houses are the sign of continuum in the wood utilization sector in the state. A famous industrial group has also commenced and promoted tree plantation (specially Eucalyptus) in various parts of Madhya Pradesh. India is one of the leading countries with mushrooming of wood based industries which include pulp and paper, match, saw wood, veneer and plywood, pencil and dendro biomass industries. This growing demand of wood and wood based industries will create a wood deficit of 20-70 million m^3 by 2022. India is one of fast growing forest-based industries in the world. The growing knowledge base coupled with synergistic contribution from the flagship schemes of the government. These private industries adopt buy-back system of marketing in which they provide planting material to farmers at a reasonable cost or free, and purchase after harvesting at prime prices/rates. In this manner, agroforestry practices also bring positive externalities through industrial boost for socio-economic and environmental benefits to local communities.

At present, Bamboo is exempted in tree category and free to transport inter and intra state without any transit permission. This will encourage bamboo cultivation among the farmers. The value chain in agroforestry is emerging initiative and it is very much needed to create sustainable and value added agroforestry initiatives for networking and linkages with all stakeholders (farmers, wood based industries, financial institutions, research institutions, insurance companies, etc.) to expand the production through agroforestry, promote effective collaboration among public agencies, private industries and organizations and develop suitable research and development (R&D) mechanism.



The innovation and uniqueness of the proposed proposal is to establish a value-chain by forming linkage between the research institutions, bankers, wood based industries, nursery people, harvesting & transport groups and the bamboo growing farmers' as a multipartite model.

1. Research Institutions like TFRI (Innovator-technology expert) supply of QPM (quality planting materials) and technical knowhow to farmers.
2. Farmer (Beneficiary) – Farmers' will provide their land
3. Financial institutions like NABARD and insurance companies – will provide financial support.
4. Wood based industries like Orient Paper Mill (OPM- the buyer) will buy agroforestry products with MSP.

For promotion of bamboo based AFS to improve the livelihood of farmers in Madhya Pradesh, TFRI, NABARD and Orient Paper Mill, Shadol entered in tripartiate agreement with farmers and established bamboo based AFS in farmers field in Jabalpur district of MP. TFRI supplied the QPM and advance technique for the establishment and management of bamboo based AFS in farm fields with the espacement of 5x5 m (400 bamboo seedlings/ha). OPM entered MoU with farmers for assured marketing and MSP

of Rs. 3500/t of bamboo. Farmers will start realize the benefits from bamboo farm on 5th year onwards and will continue up to 40 years. Under bamboo based AFS, intercropping will be carried out for first five years with local agricultural crops of farmer's choice and farmer will get additional income of Rs. 60,000 – 70000/ha from sale of bamboo (20 – 25 t/ha) Sometimes, farmers get more income from sale of bamboo in local market also. In future, TFRI is planning to expand the area under farmers field with the support of NABARD and NBM for improvement of livelihood status of farmers in a sustainable manner. The value chain not only increases the overall productivity of the farm but also give more net income to farmers in shorter time. Moreover, it connects farmers with latest tree cultivation techniques and new innovative ideas for adoption. This value chain brings all the stakeholders (farmers, wood based industries, research institutions, financial and insurance companies, etc.) in one platform to share/exchange their ideas in efficient manner to utilize/obtain their requirements in a sustainable manner.

Dr.G.Rajeshwar Rao, Director ,TFRI and Dr. Nanita Berry, PI signed Consortium with wood based industry

Beneficiaries at Orient Paper Mills,Amlai(MP)

Motivational training to the farmers and NABARD officials

A group of the farmers at Vasan Village,Jabalpur(MP)

Discussion with farmer and DDM,NABARD at farmer field

Adoption of Bamboo with Floriculture at farmer's field

Two year old bamboo in filed of beneficiary of NABARD

Bamboo with wheat in farnmer;s field, Konikala village.

Dr.Nanita Berry explaining the benefits of Bamboo

Group of Trainess during the field demonstration programmeunder NABARD project

Management of bamboo for higher culm production

Release of information leaflet on Bamboo based agroforestry system during training programme

BIODIVERSITY CONSERVATION POTENTIAL OF AGROFORESTRY SYSTEMS

M. Rajkumar

Scientist-D
Forest Ecology and Climate Change Division
Tropical Forest Research Institute, P.O. R.F.R.C. Mandla Road, Jabalpur (M.P.)

Crop- and pasture-lands together comprise one of the largest biomes on earth, representing ~40% of global terrestrial area. While agricultural innovations have greatly increased foodproduction, they have also caused extensive environmental degradation; nearly half of globalcroplands are impacted by soil erosion, declines in soil fertility, reduced biodiversity, and ther socio-ecological concerns. In the tropics, deforestation for agricultural expansionaccounts for 8% of anthropogenic carbon dioxide (CO^2) emissions–nearly all global land-usechange emissions–and is the primary cause of species extinctions worldwide. Couplingsustainable agriculture to biodiversity conservation through small, diversified farms, such asthose typified by traditional tropical agroforestry ecosystems, may be a viable complementaryland use strategy in rapidly developing areas of the tropics. Despite the potentialsocio-ecological benefits of agroforestry systems and the possibility for them to support conservationefforts in ecologically fragile areas of high biodiversity, tropical conservation policyremains dominated by efforts to reduce intact forest conversion and promote natural reforestationin lieu of supporting more socio-ecologically integrative practices. Increasingour understanding of the ecosystem service benefits of traditional agroecosystems could helpencourage policy that supports a broader range of conservation objectives.

Biodiversity in agroforestry systems

Agroforestry is a dynamic ecologically based naturalresources management system through integration of treeson farms that diversifies agricultural landscapes and sustainsproduction for increased social, economic, and environmental benefits. Agroforestry systems are known to bringabout changes in edaphic, microclimatic, floral, faunal, andother components of the ecosystem through biorecycling ofmineral elements, environmentalmodifications, and changesin floral and faunal composition. According to Schrothet al. 2004, agroforestry also contributes to biodiversity conservationon a landscape scale in three ways. These are (i) theprovision of supplementary secondary habitat for species thattolerate a certain level of disturbance, (ii) the reduction ratesof conversion of natural habitat in certain cases, and (iii) thecreation of a more benign and permeable "matrix" betweenhabitat remnants compared with less tree-dominated landuses, which may support the integrity of these remnants andthe conservation of their populations.

India has 2.4% of world's area with 8% of global biodiversity and is one of the 12 mega diversity countries of the world (Myers et al. 2000). Among the world's 35 global biodiversity hotspots (GBH), four (Himalayas, Indo-Burma, Sundaland and Western Ghats) fall in the Indian geo-political territory. This richness of phyto-diversity in India is owing to existence of 15 agro-climatic zones with varied ecological habitats. India has ~ 10.45% of global floral diversity. More than 50% of the world's plant species are endemic to 35 GBH, which once covered 15.9% of the earth's land surface and are now reduced to 2.3% (Mittermeier et al. 2011). These hotspots harbor a large number of endemic species, which are facing an increasing threat of extinction (Hazarika et al. 2016).

Agroforestry ecosystems that incorporate perennial trees into agriculture, such as those typifiedby smallholder farmer-dominated areas in the tropics (typically 0.01 to 5 ha), can be a fundamentalcomponent of both biodiversity conservation and socio-ecological resilience. In addition to provisioning natural resources (i.e. food, medicine, and buildingmaterials), agroforestry ecosystems have the potential to maintain higher levels of biodiversityand greater biomass than conventional agriculture. Relative to monoculture or pasture techniques,agroforestry ecosystems may also enhance soil quality, including C content and nutrientstatus, by increasing litter inputs and soil organic matter accumulation. Inmany tropical systems, agricultural productivity is constrained by low nutrient availability dueto highly leached, acidic soils; this problem is amplified because many subsistence farmers inthese areas often cannot access mineral fertilizers.

Positive relationships between plant diversity and ecosystem functions such as C sequestration - which can be driven by either niche complementarity or the greater likelihood of includingfunctionally-important species in more diverse assemblages—have been identified in anumber of model ecosystems, although these relationships are complex and positivespecies/functional diversity relationships are not always observed. Both plant communityfunctional diversity and phylogenetic diversity, rather than simply the number of taxonomicunits (e.g. species or functional group richness), appear to underlie observedbiodiversity–ecosystem-service relationships. However, the nature of these relationshipsremains equivocal in human-managed systems, such as smallholder agroecosystems typicalin developing areas of the tropics.

Plant species diversity in agroforestry systems

Species diversity of the tropical agroforestry systems such as homegardens is generally believed to be very high. Homegardens reached high levels of development in terms of plant diversity, labour input and per cent income derived from garden in regions where population densities are high. Furthermore, they create a forest-like multi-storey canopy structure. Perhaps the forest like structure is derived from either the lackof a discernible planting pattern, or alternatively, the result of deliberate planning to mimic the forest. Moreover, species diversity, size, shape and plant density also vary from place to place depending on cultural, ecological and socioeconomic factors. According to Nair and

Dagar, 1991 although the farmers and land owners integrate a variety of woody perennials in their crop and livestock enterprises, most of these practices are highly location-specific and information on these in India are also mostly anecdotal.

Home gardens	No. of species	Reference
Kerala (17 sub districts), India	127	Mohankumar*et al.* 1994
Barak Valley, Assam, NE India	122	Das and Das 2005
Mayan homegardens of Yucatan, Mexico	301	Rico-Gray*et al*., 1991
Santa Rosa in the Peruvian Amazon	168	Padoch and de Jong, 1991
West Javanhomegardens	179	Soemarwoto, 1987

Case studies

The following case studies which highlights the biodiversity conservation potential of agroforestry systems chosen from representative parts of the world will be taken up for discussion during the lecture:

1. Agroforestry practices promote biodiversity and natural resource diversity in Atlantic Nicaragua (Sistla SA, Roddy AB, Williams NE, Kramer DB, Stevens K, Allison SD (2016) Agroforestry Practices Promote Biodiversity and Natural Resource Diversity in Atlantic Nicaragua. PLoS ONE 11(9): e0162529. doi:10.1371/journal.pone.0162529)
2. Woody species diversity in traditional agroforestry practices of Dellomenna District, Southeastern Ethiopia: Implication for maintaining native woody species (Molla, A. and Kewessa, G. (2015) Woody species diversity in traditional agroforestry practices of Dellomenna District, Southeastern Ethiopia: Implication for maintaining native woody species. International Journal of Biodiversity 643031. doi.org/10.1155/2015/643031)
3. Diversity, structure and standing stock of wood in the homegardens of Kerala in peninsular India (Mohankumar, B., George, S. J. And Chinnamani, S. (1994) Diversity, structure and standing stock of wood in the homegardens of Kerala in peninsular India. Agroforestry Systems 25: 243-262)
4. Dung beetle and terrestrial mammal diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica (Harvey, C. A., Gonzalez, J. and Somarriba, E. (2006) Dung beetle and terrestrial mammal

diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica. Biodiversity and Conservation 15: 555-585)

5. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia (Kehlenbeck, K., and Maass, B. L. (2004) Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. Agroforestry Systems 63: 53-62)

Conservation potential

For the first roughly two decades of agroforestry research, agroforestryscientists were mostly concerned with the sustainable production of agriculturalgoods, especially food, and this line of research has lost none of itsrelevance. However, over the last decade or so, scientists have also becomeinterested in the environmental services that agroforestry practices may provideto local and even global society by maintaining watershed functions,retaining carbon in the plant–soil system, and, most recently, by supporting theconservation of biological diversity.

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Nair P. K. R. and Dagar J. C. (1991) An approach to developing methodologies for evaluatingAgroforestry systems in India. Agroforestry Systems 16:55-81

INSECT PESTS IN FOREST NURSERIES, AGROFORESTRY PLANTATIONS, AND IT'S MANAGEMENT

Dr. MOHAN C

Scientist- B (Forest Entomology)
Division of Forest Protection
Tropical Forest Research Institute, Jabalpur (M.P.)

Introduction:

Large scale afforestation undertaken by the State Forest Department, for which quality seedlings of forest tree species are required to be grown in nurseries, suffer from various insect pests. Combating of these insect pests is a serious problem before the foresters and other tree growers. The mortality or dying off teak, sissoo, khamer, sal etc. in nurseries, plantations and natural forests is causing considerable losses. Soil insects like termites, white grubs feed on roots, cutworms feed on shoots and the lace bug, *Tingis beesoni*, sucks plant sap from shoots and foliage, borers bore root/stem which may ultimately cause death of a plant species. Poor growth makes plants susceptible to adverse environmental changes, which ultimately causes the death of plants.

The users face difficulties in selection of suitable pesticides, making their required formulation and the period of application besides the prevention techniques from these pests in nurseries, plantations and natural forests. In this chapter, efforts have been made to compile all the available information on insects pests in nurseries, plantations and natural forests which is an easy tool for the field workers.

Insect pests associated with various tree species under nurseries, plantations, natural forests and their management

Sl. No.	Tree species and Insect pests	Period of infestation	Sign and Symptoms/ nature of damage	Management
I.	**Teak, *Tectona grandis***			
1	White grubs (*Holotrichia* spp.*)*	June-Sept.	Wilting of the seedlings; Grubs feed roots.	1. Sandy soil should be avoided for raising seedlings. 2. Semi decomposed FYM should not be used. 3. Soil working should be avoided during monsoon i.e. June –July. 4. Soil mixing of Phorate 10 G @ 200 gm/ bed (size 10 x 1 mt) should be used.
2	Grasshoppers	July-Oct.	Leaves are eaten voraciously; green or brown insects jump in beds.	1. Regular weeding of nursery beds before and after monsoon should be done.

				2. Avoid raising like dense or crowded seedlings. 3. Spraying phosphamidon 0.05% i.e. 0.6 ml /Lt. of water.
3	Defoliators: *Hyblaea puera* and leaf skeletonizer, *Eutectona machaeralis*	July-Aug July-Oct.	Larvae feed on leaf and completely defoliated. Larvae feed on parenchymatous tissue and leaf skeletonized.	Foliar spraying of 0.01% alphamethrin or 0.02% cypermethrin (2 ml /5 Lt. water) or 0.005% deltamethrin (9 ml /5 Lt. water) is recommended for control of these defoliators. Introduction of egg parasitoid, *Trichogramma* raoi @ 1.25 lakhs/ ha between June to October in 5 installment should be done.
4	Suckers : Aphids and scale insects	Throughout year	Leaves curl due to sucking of insects	Foliar spraying of 0.05% phosphamidon (5.8 ml in 10 Lt. of water) or dimethoate (17 ml in 10 Lt. water).
II. Sal, *Shorea robusta*				
1	Sal heartwood borer, *Hoplocerambyx spinicornis* Newman	June-Sept.	Beetles gnaw the living bark and the grubs feeding under the bark and sapwood. Full grown grubs make tunnel into the heartwood and completely ruin the timber.	1. Carrying out of 'Trap Tree operation' regularly every year with the onset of first shower of rain in June/July and continuing the operation till the catches become nil from some continuous days in August. After the operation, it should be debarked and burnt. 2. Enumeration of attacked trees should be carried out twice annually in December and March-April. 3. Clear felling and removal of all the dead or dying trees.
III. Khamer, *Gmelina arborea*				
1	*Calopepla leayana*	July-Sept.	Brilliantly blue with pale yellow to orange pronotum bearing oblong beetle and primrose yellow to dark brown with black anal tuft of filaments bearing larvae, defoliate leaves.	Foliar spraying of 0.05% chlorpyriphos i.e. 2.5 ml/Lt. water or 0.04% monocrotophos i.e. 1.1 ml /Lt. water or malathion 0.05% i.e. 1 ml /Lt. water.
2	Sucking bug, Lace bug, *Tingis beesoni*	April-Sept.	Complete defoliation, shoot turning black from tip to downwards due to sooty mould.	Spraying of 0.05% monocrotophos i.e. 1.4 ml/Lt. water + Bavistin 0.2 % (4gm./ lt.) effective against the nymphs and adults.
IV. Bamboo, *Bambusa arundinacea;* *Dendrocalamus strictus*				

1	Whitegrubs (*Holotrichia* spp.*)*	June-Sept.	Wilting of the transplanted culms.	1. Sandy soil should be avoided for raising seedlings. 2. Semi decomposed FYM should not be used. 3. Soil working should be avoided during monsoon i.e. June –July. 4. Soil mixing of Phorate 10 G @ 200 gm/ bed (size 10 x 1 mt) should be used.
2	Termites	Throughout year.	Dying of saplings.	Soil drenching by water emulsion of chlorpyriphos 0.05% (2.5 ml /Lt. water).
3	Bamboo culm borer, *Cyrtotrachelus dux* and *C. longimanus.*	July-Oct.	Leading young shoots up to 1 mt height have an exit hole through which excreta comes out.	1. Damage due to these weevils is less in well thinned areas as compared to the dense culms and hence culms density should not be allowed to increase. 2. Spraying 0.04% monocrotophos i.e. 1.4 ml /Lt. water on young culms during July – August at 15 days interval should be done.
4	Bamboo leaf roller, *Crypsiptya coclesalis*	July-Sept	Larve roll leaf and defoliate plants	1)Use biopesticides i. e. neem extract 2)Use bio control agent i. e predator against aphid 3)Spray Monocrotophos 0.04% or Dimethoate 0.02% against aphids.
V. Tendu, *Diospyros melanoxylon*				
1	*Trioza obsoleta*	April-June	Nymphs/adults suck the sap from the leaves and makes the galls.	Spraying of synthetic pyrethroides like cypermethrin or fenvalerate 0.03% twice in March-April at 15 days interval or Monocrotophos 0.03% proved to be next. Pruning should be done in the first week of March for reducing.
2	Tendu leaf defoliator, *Hypocala rostrata*	April-Oct.	Larvae feed on the leaves of tendu	Spraying of fenvalerate 20 EC i.e. 0.5 ml /lit. of water.
VI. Sissoo/Shisham, *Dalbergia sissoo/D. latifolia*				
1	Whitegrubs (*Holotrichia* spp.*)*	June-Sept.	Wilting of the seedlings; Grubs feed roots.	1. Sandy soil should be avoided for raising seedlings. 2. Semi decomposed FYM should not be used.

				3. Soil working should be avoided during monsoon i.e. June –July. 4. Soil mixing of Phorate 10 G @ 150 gm/ bed (size 10 x 1 mt) should be used.
2	Termites	June-Oct.	Wilting of the seedlings.	1. Soil mixing of phorate 10 G @ 150 gm per bed (size 10x1 mt) during June-July should be done. 2.Soil drenching by water emulsion of chlorpyriphos 0.05% i.e. 2.5 ml /Lt. of water.
3	Shisham defoliator, *Plecoptera reflexa*	July-Oct.	Green coloured looper larvae feed on young fleshy leaves.	Spraying carbaryl 0.1% i.e. 2 gm wettable powder in 1 Lt. water.
4	*Dichomeris eridantis*	July-Oct.	Larvae feed on young leaves.	Spraying carbaryl 0.1% i.e. 2 gm wettable powder in 1 Lt. water.
5	*Heliothis armigera*		Larvae feed on young leaves.	Spraying carbaryl 0.1% i.e. 2 gm wettable powder in 1 Lt. water
VII. Safed Siris, *Albizia procera*				
1	*Eurema blanda*	May-Sept.	Green larvae feed on young leaves of germinating seedlings.	Foliar spraying of endorsulfan 0.05% i.e. 1.4 ml /Lt. of water is highly effective.
2	*Selepa celtis*	July-Oct.	Larvae feeed on leaves from tip of a branch.	Spraying of monocrotophos 0.04% i.e. 1.1 ml /Lt. water is effective.
3	*Spirama retorta*	June-Oct.	Larvae feed on leaves and tender shoots.	Spraying of monocrotophos 0.04% i.e. 1.1 ml /Lt. water is effective.
4	*Rhesala* spp.	June-Oct.	Larvae feed on leaves by binding them silken threads.	Foliar spraying of malathion 0.05% i.e. 1 ml /Lt. water kills the larvae.
5	*Ophiusa (Achaea) janata*	July-Oct.	Larvae feed on leaves of seedlings.	Foliar spraying of carbaryl 0.2% i.e. 4 gm powder/Lt of water or phosphamidon 0.05% i.e. 0.6 ml /Lt. of water kills the larvae.
6	*Catopsilia crocale*	June-Oct.	Larvae voraciously feed on leaves.	Foliar spraying of malathion 0.05% i.e. 1 ml /Lt. of water
7	Aphid, *Aphis gossypii*	Throughout year	Nymphs and adults suck sap from shoots and leaves.	Foliar spraying of phosphamidon (dimecron 85 EC) 0.05% i.e. 5.8 ml /10 Lt. water or dimethoate (rogor 30 EC) 17 ml /10 Lt. water should be used.

	VIII. Karanj, *Pongamia pinnata*			
1	Defoliator, *Hasora alexicalexis*	July-Sept.	Defoliate leaves by rolling them.	Foliar spraying of 0.05% monocrotophos (i.e. 1.4 ml /Lt. water.
2	Leaf miner, *Lithocolletis virgulata*	July-Sept.	Blotches or blisters on leaves.	Foliar spraying of 0.05% monocrotophos (i.e. 1.4 ml /Lt. water or 0.05% of phosphamidon i.e. 0.6 ml /lt. waster is suggested for its control.
	IX. Chironji, *Buchanania lanzan*			
1	Defoliator *Lamida carbonifera*	July-Sept.	Leaves webbed with loose silk in the shelter of which grey coloured larvae feed, skeletonizing & eating irregular patches.	Foliar spray of monocrotophos 0.05% was found to be most effective after 3 and 7 days of treatment.
2	Stem borer, *Plocaederus obesus*	June-Oct.	Grub makes burrows beneath bark/tunnel in to trunks/main stem, moving upward, feeding on internal tissues. Tree shedding leaves & drying up	10 ml solution of dichlorvos (nuvan) 0.5% showed cent per cent tree saved after 30 days of treatment.
	X. Maharukh, *Ailanthus excelsa*			
1	*Atteva fabriciella*	May-Sept.	Larvae form web around the tender leaves and then feed them.	Foliar spraying of 0.05% monocrotophos (1.4 ml /Lt. water), formothion 0.05% (1.6 ml/Lt. water) or malathion 0.05% (1 ml insecticide/Lt. water).
	XI. Neem, *Azadirachta indica*			
1	White grubs (*Holotrichia* spp.)	June-Sept.	Wilting of foliage due to eating of roots and rootlets.	1. Sandy soil should be avoided for raising seedlings. 2Semi decomposed FYM should not be used. 3. Soil working should be avoided during monsoon i.e. June –July. 4. Soil mixing of Phorate 10 G @ 200 gm/ bed (size 10 x 1 mt) should be used.
2	Shoot borer, *Laspeyresia koenigana*	Nov.-Jan.	Young larvae bore from apical end of shoot to downward, plant exhibits forked appearance.	Foliar spraying or monocrotophos 0.04% i.e. 1 ml /Lt. water is effective against this borer.
3	Neem scale, *Pulvinaria maxima*	Throughout year	Thick coating of white patches having nymphs and adults feeding sap from tender shoots and leaves.	Spraying of monocrotophos 0.03% i.e. 8 ml /10 Lt. of water is effective.
	XII. Semul, *Bombax ceiba*			
1	Semul shoot borer, *Tonica niviferana*	May-Oct.	Young larvae bore the shoots from leaf axil under the shelter of silken web	1. Collection and destruction of pupae on bark and leaves in March-May and in July-

				August from seedlings should be done. 2.Soil mixing of sevidol 4G granules or phorate 10 G @ 6 gm/plant is highly effective.
	XIII. Aonla, *Emblica officinalis*			
1	Shoot gall insect, *Betousa stylophora*	June-Oct.	Twigs/shoots swell and form galls.	Foliar spraying of 0.04% monocrotophos i.e. 1.1 ml /Lt. water in June-August at 15 days interval.
2	Defoliators i. Semilooper, *Ophiusa (Achaea) janata*	July-Oct.	Larvae feed on leaves of seedlings.	Foliar spraying of carbaryl 0.2% i.e. 4 gm powder/Lt of water or phosphamidon 0.05% i.e. 0.6 ml /Lt. of water kills the larvae.
	ii. *Selepa celtis*	July-Oct.	Larvae feed on leaves from tip of a branch.	Spraying of monocrotophos 0.04% i.e. 1.1 ml /Lt. water is effective.
	iii. *Spilosoma (Diacrisia) obliqua*	July-Oct.	Larvae feed on leaves of seedlings.	Foliar spraying of carbaryl 0.2% i.e. 4 gm power/Lt. of water or phosphamidon 0.05% i.e. 0.6 ml /Lt. of water or monocrotophos 0.05% i.e. 1.4 ml insecticide/Lt. water kills the larvae.
3	Bark eating caterpillar *Indarbela quadrinotata*	May-July	Larva bores a short tunnel down wards into the wood. This tunnel is used as a shelter tunnel during the day hours. At night the larva comes out through this shelter tunnel to feed upon the outer surface of the bark. A silken roofed path from shelter tunnel to the place of feeding is constructed by each larva.	Removal of excreta web and insert into holes linen swabs of cotton wools cocked in 0.03% Dichlorvos and seal the holes with mud.. Combination of *Cleistanthus collinus* + cow urine + vermiwash 10% was found to be most effective. Varieties – Anand-1, Hatizola, Kanchan, Francis, Chakaiya, NA-7 found to be least preferred by this pest.
	XIV. Neelgiri, *Eucalyptus* spp.			
1	Termites *Odontotermes* spp.	Throughout year, serious in July- Aug., April-May	Wilting and ultimately death of seedlings.	1. Soil mixing 5% chlorpyriphos dust @ 40 to 60 kg/ha during June-July should be done. 2.Soil drenching by water emulsion of chlorpyriphos 0.05% i.e. 2.5 ml /Lt. of water.
2	Cutworms, *Agrotis ipsilon*	June-Oct.	Young seedlings are cut by larvae and sometimes remain thrives in beds.	1. Flooding the nursery beds for at least 2 hrs kills the larvae. 2. Dusting wood-ash on nursery beds should be done whenever the symptoms are seen. 3. Soil mixing of 4% endocel dust 60 Kg/ha or application of

				0.1% water emulsion of chlorpyriphos i.e. 5 ml /Lt. Nearly 50 Lt. water emulsion is required for a 10x1 mt nursery bed.
3	Cricket, *Tarbinskiellus (Brachytrupes) portentosus*	July-Oct.	Seedlings and pieces of foliage are dragged to tunnel through the opening formed in ground.	1. Pouring water in tunnels and then adding some kerosene forces the insects to come out. They can be killed mechanically dipping in insecticidal solution or kerosene. 2. Pieces of pumpkins sprayed with some stomach poison also effective. 3. Poison baits (sulfer 3 parts+flour 100 parts+gur 1 part made up into dry mixture, if spread along edges of nursery is also recommended.
4	Bagworm, *Cryptothelea crameri*	July-April	Hanging of small larval bags made of hairs, leaf epidermis, pieces of twigs, etc.	Foliar spraying of phosphamidon 0.05% i.e. 0.6 ml/Lt. water .
5	Root and shoot borer, *Celosterna scabrator*	Sept.-March	Grub forms tunnel in main shoots and roots.	1. Grub should be removed from the attacked roots by cutting them from side nearly at 40 cm deep in soil. 2. A small quantity of petrol or kerosene or 0.1% dichlorvos (nuvan) should be poured through the exposed hole and later it should be sealed with moils soil.
6	Gall Wasp *Leptocybe invasa*	Throughout the year	Insect forms galls on leaf midrib, petioles & stem of seedlings/saplings/coppice shoots, resulting in stunting of growth.	1) Mix different clones for plantations. Use resistant clones. 2) Use light trap hanging over water trough containing few drops of kerosene for killing adults during emergence & check further egg laying. 3) Phorate 5 gm (2 teaspoon) per polybag. Phorate 10 gm /pit. Spray Imidacloprid or monocrotophos 0.03% +1-2 drop liquid soap monthly interval.
	XV. Anjan, *Hardwickia binata*			
1	*Enarmonia palamedes*	June-Sept.	Larvae feed on leaves	Spraying Carbaryl 0.01% i.e. 2 ml wettable powder in 1 Lt. water is effective to kill this pest.
	XVI. Jamun, *Syzygium cumini*			

1	Defoliators: *Euproctis fraterna, Metanastria hyrtaca, Trabala vishnou*	July-Sept.	Leaves eat voraciously from margins	Foliar spraying of fenitrothion 0.05% i.e. 1 ml insecticide/Lt. water is effective against these defoliators.
	XVII. Babul, *Acacia nilotica*			
1	The cutworms, *Agrotis ipsilon*	July –Sept.	Larvae cut young seedlings.	1. Flooding the nursery beds for at least 2-3 hrs. 2. Dusting wood-ash on nursery beds should be done whenever the symptoms are seen. 3. Soil mixing 5% malathion @ 60 kg/ha should be done.
2	Caster semilooper, *Ophiusa (Achaea) janata*	July-Oct.	Larvae feed on leaves of seedlings.	Foliar spraying of phosphamidon 0.05% i.e. 0.6 ml/Lt. of water kills the larvae.
3	*Rhesala* spp.	July-Oct.	Larvae feed on leaves by binding them with silk.	Foliar spraying of malathion 0.05% i.e. 1 ml/Lt. of water kills the larvae.
4	*Heliothis armigera*	July-Oct.	Larvae feed on leaves	Spraying of carbaryl 0.1% i.e. 2 gm wettable power/Lt. of water is effective.

General recommendations

The control of pest can be defined as check in reproductive rate of an insect by means of one or more factors is known as 'Control'. The numbers of any one species of insect are constantly altering locally with changes in its controlling factors viz., abundance of food, natural enemies including diseases and climatic condition etc. When the numbers of an insect species included to such an extent that an abnormal mortality occurs among its host plants the state of affairs is known as 'epidemic or pest outbreak'. The most important thing in the control of pest is its early detection and prompt report to experts for advice. A control measure may be direct or indirect in its action on the pest or it may be preventive or remedial. It may be noted that it is impossible in practice to exterminate a forest insect pest, the object of artificial control as opposed to natural control is the regulation of the numbers of the pest to the level at which the damage done by it is within financial tolerance.

In other words if the loss is considered as an inevitable accompaniment of the objects of management the pest is said to be under control or economically control. An insect under economic control in this sense is by no means kept at a uniform abundance by the natural control factors, its numbers may fluctuate considerably below the level at which it becomes a pest of economic importance. For purpose of forest protection control measures are: Silivicultural control, Cultural control (Crop rotation), Mechanical control (trap and kill), biological control (by predators, parasites and parasitoids, microbes), tree

resistance to insect attack, Application of insecticides, Chemical control and Integrated Forest Pest Management

Silvicultural control:

Silvicultural control is the regulation of the abundance of a forest insect species by factors of silvicultural practice. Silvicultural practice may be designed and employed so as to obtain the economic control of an insect pest. However,it works independently of any intention on the part of the forest Officer /Manager and is quite unappreciated by him. If a forester converts a previously harmless insect into a pest by an application of silvicultural measures, the pest can only be prevented from doing intolerable damage by measures of a similar order to those that created it.

Mixed Forests-

The value of mixtures in protecting the principle timber species in the crop lies in the following advantages:

- Reduction in the quantity of food supply available to the pest in the area.
- Varied food and suitable shelter are made available for parasites predators that are maintained at a high level doing to the existence of alternate hosts.
- Insectivorous birds get a continued food supply throughout the year.
- Mechanical obstruction is offered to the disposal of crawing defoliator (larvae) that drop to the ground from crowns and reascend the trees.

Thinning:

Abrupt thinning at longer intervals is undesirable gradual thinning at smaller intervals does not interfere with natural balance between the pests, parasites and plants community and ideal procedure is annual. Thinning should as remove (i) recently dead and not yet dry trees in which bark and wood borers normally bread. (ii) Drying trees in which borer attack is partially established will soon commence. (iii) Weak or unhealthy trees since these are more susceptible to attack by defoliators, borers or sap suckers owing to the difference in the time of coming into teak are to weaker physiological resistance. (iv) The removal of trees are dead or dry for 2 or 3 years or more is not of any value as a preventive measure.

Cultural practices:

Cultural practices refer to that broad set of management tactics or options that may be manipulated to achieve the crop production goals or manipulation of the environment to improve crop production. Cultural control on the other hand is the deliberate manipulation of the cropping system or specific crop production practices to reduce the pest populations or to avoid pest injury to crops. These tactics may include: impediments to pest colonization of the crops, creation of adverse biotic conditions that reduce survival of individuals or population of the pests or modifications of the crop in such a way that pest infestation results in reduced injury to the crops.

Mechanical control:

In forestry, the special operations which catch or kill insects by mechanical or physical action are classed in this aspects or artificial control. Some of them are general application against various types of pests.

(a) Role of light trap in surveillance and management of forest insect pests:

The different forest insect pests which have been recorded to cause significant losses in forest trees are teak defoliator *Hyblaea puera*, skeletonizer *Eutectona machaeralis,* White grubs *Holotrichia* spp., Ailanthus web worm *Atteva fabriciella*, Sal heartwood borer *Hoplocerambyx spinicornis*, *Aeolesthes holosericea* etc. Sampling of these insect pests from the forest ecosystem is extremely important for indexing their natural population. Population studies along with their seasonal abundance are important aspects of insect ecology.

Light trap is one of the tool used for such studies. It is equipped with 160 watt mercury vapour lamp, made up of galvanized iron patches and installed in forest areas (nurseries, plantations, Timber depots and seed orchards/ seed production areas/ Germplasm bank etc.). It is operated every night from sunset to sunrise. Insects are collected every morning by hand picking. When insects are trapped in large numbers, spray of Nuvan or kerosene is used for quick knock down of insects. Light trap play an important role to remove a sizable population of adults from the environment. IN a continuous process when employed every night, this helps in reducing the adult population succeeding generations. It has been extensively used as an entomological device for survey, detection and control of the insect pests.

The control of forest insect pests by using the insecticides is almost an impracticable job due to the problem of application of high cost of pesticides and hazards to precious wildlife, birds and other beneficial fauna inhabiting the forest areas. Light trap can play an important role in monitoring of adult insect pests population in forest ecosystem.

(b) **Hand collection and destruction:**

Collection and destroying injurious insects by hand is the simplest and most effective remedy in many cases *e.g.* for caterpillars and large beetles in forest nurseries, white grubs and crickets in seed beds. The use of hand nets or drag nets for small or active insects is an extension of the same *e.g.* for beetles, defoliators, grasshoppers and plant hoppers. Probes of wire or other flexible material are used for poking into the tunnels of wood borers *e.g. Zeuzera, Batocera*.

Biological control:

The use of one organism against another which may a pest from the human point of view is called biological control. Biological control has been extensively in agriculture and

horticulture as well as in forestry where a number of applications have yield excellent results.

(a) **Biological control by predators:**

Biological control operates by either predation or parasitisation of the pests. Both phenomena maintain a state of equilibrium between predator/ predator and parasite/ host populations. However, time comes and in specific regions some pest populations appear to increase unchecked due to either a lack of natural predators or the existence of other condition that prevent effective predation by locally available predator species. In these cases human have sometimes introduced exotic species that prey on the pest or altered the conditions that prevent the effectiveness of these local predators.

However, the processes underlying thisstrategies are not simple Predators- Prey relationship and interactions depend on a number of factors, including (i) density of prey and predator population (ii) behavioral and physiological characteristics of the prey and predators, and (iii) density of alternate food available in the vicinity.

Among the successful predators of forest insect pests are birds and small animals including reptiles and mammals. A common example of bird predator is that of a woodpecker that feeds on cerambycid beetles which damage timber Bird predation of Jackpine bud worm accounts for 40-60% of the mortality of late tar larvae and pupae of this species. *Anthia sexguttata* is the common predator of some lepidopterous larvae and has been tested against some major insect pests *viz*., *H. puera*, *E. machaeralis*, *A. fabriciella*, *P. reflexa* and *C. crocale*.

(b) Biological control by parasites and prasitoids:

Insect parasitoids that prey on insect pests of forest trees belong to the families Tachinidae, Chalcidae (Hymenoptera) Ichneumonidae (Hymenoptera). Specific variants include hyperparasitoids (*i.e.* parasitoids of parasitoids) multiple parasitism (in which two species lay their eggs on or in the same host individual with only one being generally successful and super parasitism (in which many eggs or larvae are placed on or in the same species of which one species survives in solitary hosts but many may survive in gregarious species).

(c) Biological control microbes:

By far the most promising method of insect control is microbial control. A number of microbes belonging to diverse groups have been and are being tested but biological and ecological studies are still required before field test are possible. The potential of microbial control is high as the pathogens are relatively host specific and this mode is complible with other control procedures. Among the pathogens currently being tested against forest insect pests are nuclear polyhedral virus and the bacteria *Bacillus thuringiensis* against tent caterpillars *Malacososma*

*neodiprion (*gypsy moth and tussock moth) which provide foliage protection upto 25% and larval mortality of 100%.

Tree resistance to insect attack:

The most important factors in the environmental resistance is the physiological condition of the host some degree of resistance to insect attack is possessed by practically all forest trees. It may be (a) A general nature, a state of unpalatability to all indigenous insects some at the ultimate regions for this may be geological or hereditary; (b) It may be resistance to all but a few species of insects. This is the normal condition in natural or virgin forest where insect attack on healthy trees in rarely serious or fatal.

A state of equilibrium exists preserving both the flora and fauna. (c) The plant may be totally resistant to the attack of a particular insect species only when in a particular physiological condition. The variations which gives rise to resistance are: (1) Physiochemical such as hardness of the epidermis of the leaf or shoot or seed gums, resins, latex *etc.*, sap reaction and sap density. (2) Physiological, such as seasonal adaption resulting earliness or lateness in fruiting or leaf fall, vigour permitting the outpouring of gums also resins *etc*. The healing of wounds ability to produce a second or more flushes or foliage after defoliation.

CONCLUSIONS

Insect pests often cause serious problem in forest nurseries. The major tree species raised in nurseries in various states in India include both indigenous and exotic species. Teak, *Gmelina arborea, Ailanthes triphysa, Bombax malabaricum* and Albizia are the common indigenous species and Eucalyptus, *Paraserianthes falcataria and Swietenia macrophylla* are the exotic species generally raised in nurseries for plantation programmes. Information on the correct identity of the pest, the nature of damage and the damage intensity are essential for adopting suitable management strategies. Since regular monitoring of forest insects and their damage to specific tree species are not carried out in India, most information pertaining to the forest pests is based on information generated by forest entomologists in specific studies. Of the various forest insects associated with the different forest trees, nearly 20 species of insects are known to cause potential damage (Mohandas *et al*. 1990; Chacko *et al* 2001; Nair *et al.* 1991, 2002; FAO 2003; FAO 2005a; Singh *et al.* 2005; Mathew, 2005). As far as pest management practices are concerned, various strategies involving chemical, biological and silvicultural measures are attempted to protect the forest plantations and nurseries of commercially important tree species such as teak, mahogany and pines.

Photographs of insect pests attacking forest nurseries, plantations and natural forests

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9 a

b

10 a

b

11 a b

1. White grub, *Holotrichia spp.*
2. Termite, *Odontotermes spp.*
3. Bark eating caterpillar, *Indarbela quadrinotata*
4. Sucking bug, *Tingis beesoni*
5. Defoliators, *Hyblea puera*
6. Leaf skeletonizer, *Eutectona machaeralis*
7. Bamboo culm borer, *Cyrtotrachelus dux*
8. Gall forming insect , *Trioza obsoleta*

9(a,& b). Sal heartwood borer, *Hoplocerambyx spinicornis*

10(a & b). Gall Wasp *Leptocybe invasa*

11(a & b) Bamboo leaf roller, *Crypsiptya coclesalis*

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Tropical Forest Research Institute
(Indian Council of Forestry Research & Education) Jabalpur- 482021
In Collaboration with
National Institute of Agricultural Extension and Management (MANAGE)
Rajendra Nagar Hyderabad-500030