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CONTRIBUTING PAPERS

IUFRO Symposium
on
Short Rotation Forestry: Synergies for Wood Production and Environmental Amelioration
(February 10-12, 2011)

Editors

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FOREWORD

India is blessed with almost all types of resources but the nation today faces a near crisis situation, both economic as well as environmental. This is particularly the outcome of overuse and abuse of the various natural resources under the inflating population pressure. The degradation is visible in all the renewable and non-renewable resources yet the forest wealth in particular has met the colossal depletion. Despite framing the national policies and enacting new acts in post independence period, it has not been possible to conserve and enhance the forest cover. Our forest wealth has witnessed colossal depletion and a significant portion of the total land area (approximately 50 %) has been turned into waste. Country on one hand is faced with shortage of forest based products in rural area (timber, fuel, fodder, fibre etc.) and urban/ industrial sector (wood and wood products), and on the other hand drought, floods, soil erosion, air/water pollution, etc. have attained frightening dimensions. Moreover, the forests of the country are neither uniformly stocked nor equitably distributed. The productivity as well as the growing stock position is also not encouraging. To meet the challenges of extending area under plantations, we have to save and improve the existing forest species as well as raise large scale plantations on the depleted forest/ private/ community lands by using preferably indigenous/ exotic multipurpose fast growing species. Tree plantations are the answer to many global problems and plantations can achieve many of the things that people expect of them. They reduce deforestation, restore degraded land, fight climate change, improve livelihood, create employment, etc. Therefore, the plantations are mixture of opportunities.

We are please to collaborate with the Department of Forestry and Natural Resources, Punjab Agricultural University, in organizing an International Symposium on “Short Rotation Forestry (SRF): Synergies for Wood Production and Environmental Amelioration”, during February 10-12, 2011 to celebrate International year of Forests at Punjab Agricultural University, Ludhiana (India). The financial and technical support of the European Commission under BENWOOD project, IUFRO and ICFRE was key to the success of the symposium. I know, the national as well as international delegates addressed diverse issues related to the short rotation forestry to further the cause of plantations in terms of area and productivity. The symposium provided an opportunity for stakeholders to share their experiences and vision on SRF to meet the increasing demand for wood and address the cause of environment.

I am sure that this voluminous special issue of the Indian Journal of Ecology on Short Rotation Forestry with varied related issues will be useful for the readers in persuing the practical cause of SRF. Editors have made appreciable efforts in bringing out the proceedings of the IUFRO Symposium on Short Rotation Forestry: Synergies for Wood Production and Environmental Amelioration in the present format and I am sure this issue will become an important resource for the readers on SRF. The views expressed in the publication are those of the author (s) and Indian Ecological Society acknowledge their support and cooperation.

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Contribution of Trees Outside Forests Toward Wood Production and Environmental Amelioration

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Abstract: Trees outside the forest (TOF) are located, both in rural and urban areas. A large number of TOF consist of trees planted on short rotations and include trees in agroforestry systems, orchards or small woodlots. Globally, nearly half the agricultural land, approximately 1 billion ha, has a tree cover exceeding 10 per cent while 600 million ha has a tree cover of more than 20 per cent. In India, the growing stock of TOF has been estimated as 1599 million m^3 against the forest growing stock of 4499 million m^3. Most trees within TOF have been planted on short rotations and contribute more than half the nation's wood supply. According to another estimate, TOF produce 80 per cent of industrial round wood and 75 per cent of the fuelwood. In recent years, clonal plantations of fast growing species, mainly eucalypts and poplar have been taken up by the farmers and the private sector companies. In 2006, Punjab prepared an inventory of TOF with the assistance of Forest Survey of India. The estimated number of stems was 61.2 million with estimated wood volume of 19.85 million m^3 and most of the TOF were recorded in rural areas (94 per cent). Short rotation forestry has the potential to augment farmers' income substantially. The Green India programme envisages a forest and tree cover of 33 per cent or about 100 million ha. Most of the additional area would have to come from the private sector, mainly agroforestry. We therefore need a national policy to promote TOF. They also help to reduce deforestation and forest degradation while simultaneously enhancing the carbon stock. Our estimates show that eucalyptus and poplar respectively sequester carbon at the rate of 0.45 and 0.47 times their oven dry weights. Unfortunately, TOF are excluded from current climate mitigation discussions. As compared to schemes involving forest-based emissions mitigation (REDD), Reducing Emissions from All Land Uses (REALU), using full accounting scheme for Agriculture, Forestry and Land Use (AFOLU), appears to be more effective, efficient and equitable.

Key Words: Trees outside forests, Agroforestry, Carbon sequestration, REDD

Forests are the planet's largest and most important terrestrial ecosystem. They have a profound influence on the structure and function of the human habitat locally and globally (WCFSD, 1999). The total forest area of the World is just over 4 billion ha, which represents nearly 31 per cent of the Earth's land mass (FAO, 2010). The five most forest-rich countries (The Russian Federation, Brazil, Canada, the United States of America and China) account for more than half of the total forest area.

The net change in forest area in the period 2000–2010 is estimated at -5.2 million ha per year (an area about the size of Costa Rica), down from -8.3 million hectares per year in the period 1990–2000. Forests and trees are planted for many purposes and make up an estimated 7 per cent of the total forest area, or 264 million ha. Between 2000 and 2010, the area of planted forest increased by about 5 million ha per year (FAO, 2010). More than a billion people rely heavily on forests for their livelihoods. More than two billion people, a third of the World's population, use biomass fuels, mainly fire wood, to cook and to heat their homes. Hundreds of people rely on traditional medicines harvested from forests (UN). In 2003, the international trade in sawn wood, pulp, paper and boards amounted to about USD 150 billion, or over just 2 per cent of world trade. In many developing countries forest based enterprises provide at least one-third of all rural non-farm employment and generate income through sale of wood products. The value of trade in non-timber forest products has been estimated at US$ 11 billion. These products include pharmaceutical plants, mushrooms, nuts, syrups and cork (World Bank, 2006). Roughly 275 million poor rural people in India (27 % of the total population) depend on forests for at least part of their subsistence and cash livelihoods, which they earn from fuelwood, fodder, poles, and a range of non-timber forest products such as fruits, flowers, and medicinal plants. Half of India's 89 million tribal people live in forest fringe areas, and have close cultural and economic links with the forest. The increasing human population and rapid economic growth have put immense pressure on forests and other natural resources (World Bank, 2006). About 41 per cent of the forest cover in the country has already been degraded and dense forests are losing their crown density and productivity continuously. At present 70 per cent of forests have no natural regeneration and 55 per cent are prone to fire. It is estimated that 1.7 billion tonnes of carbon are released annually due to land use change, mainly through deforestation. This represents about 20 per cent current global carbon emissions, which is greater than the percentage emitted by the global transport sector with its intensive use of fossil fuels.

Short Rotation Forestry

FAO considers fast-growing species as those capable of a mean annual increment of at least 10 m^3 ha^{-1} under favourable site conditions and providing appropriate techniques are used in ground preparation and for establishment, care and tending of plantations (FAO Staff, 1965). Compared with the above figures, mean annual increments of more than 60 m^3 ha^{-1} per year have been reported for some eucalyptus plantations in South America and Africa over short rotations of 5-8 years. For quicker growing pines grown for timber this figure would be 12-17 m^3 ha^{-1} per year, while broad-leaved timber species, such as teak, would seldom achieve more than 10 m^3 ha^{-1} per year. With such rates of growth, plantations of quick-growing species can produce saw logs of acceptable size in substantial quantities at age 20 onward, and pulpwood in 5-8 years. Thus, exotics have been planted because of their quicker rate of growth and are managed on short rotations to meet the demand for pulpwood, fuelwood and small timber.

Economics and environmental concerns are two powerful forces driving the trend towards tree planting. Promising economic returns on tree planting have been realized especially in tropical and sub tropical areas of South America, Asia and Africa, where biological growth rates are high. Many planted forests are on land that was previously in low-productivity agricultural uses. The economic returns on planted forests, especially high-yielding intensively managed forests are sufficient to continue to induce substantial investments in plantation forestry (Sedjo, 1999).

Trees Outside Forests

'Trees outside forests' (TOF) refers to trees found on lands that are not categorized as 'forest' nor as 'other wooded land' (FAO, 2010a). They include trees (isolated, linear and groups or stands of trees and tree systems) found in rural landscapes (e.g. on farms, in fields, pastures and various forms of horticulture and agroforestry systems, in hedges, along roads and streams) and in urban settings (e.g. on private or public lands and along streets). Trees have been part of local land use systems for millennia. The products derived from them, such as food, medicine, cooking fuel, animal fodder and construction materials, are critical for the subsistence of hundreds of millions of people. Trees in rural landscapes also have protective functions at farm, landscape and global levels. They maintain soil fertility, allow more efficient water and nutrient resource use, control water erosion, and contribute to microclimate moderation. The ecosystem services they provide at a global level in carbon sequestration and biodiversity conservation are also significant. Trees in human settlements are no less important: in addition to their various products, they provide services, such as microclimate moderation and a 'green' environment conducive to good health.

New estimates from analysis of remote sensed images (Zomer *et al.,* 2009) show that globally, in terms of agricultural land area, 46 per cent or 1 billion ha has at least 10 per cent tree cover, about 600 million ha (27 % of agricultural land) have more than 20 per cent tree cover and only 167 million ha have more than 50 per cent tree cover. Agroforestry with more than 10 per cent tree cover is particularly prevalent in SE Asia and Central and South America. The author estimated that 558 million people (31%) live in landscapes with more than 10 per cent tree cover and that there are at least 100 million people living in landscapes with more than 10 per cent trees in each of sub-Saharan Africa, South Asia and South East Asia.

The contribution of trees outside forests to people's livelihoods and national economies is expected to dramatically increase in the current context of climate change, financial crisis and food insecurity.

Wood Production and TOF in India

Forest Survey of India has calculated the total production of wood from estimates of consumption and expert judgement (FSI, 2009). Woodfuel production was estimated to be 261 million m^3 in 2005. Most of the woodfuel is produced outside the forests from trees growing on farm lands, homesteads, common lands and along roads and canal sides (Pandey, 2010). The growing stock of TOF has been estimated as 1590 million m^3 against the forest growing stock of 4499 million m^3 (FSI, 2008). The forest and tree cover in the country has been assessed as 23.4 per cent of the total geographical area. The tree cover was estimated as 9.17 million ha which constitutes about 2.8 per cent of the geographical area. Recent estimates place the woody volume of forest trees at 5129 million m^3 and of TOF at 1620 million m^3 (Pandey, 2010). Countrywide, the most important agroforestry tree was mango, followed by neem and coconut.

TOF contribute about 25 per cent of India's woody growing stock and are estimated to produce about 80 per cent of industrial round wood and 75 per cent of woodfuel (FSI, 2009). While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to atmosphere CO_2 that was absorbed as plants grew. Under sustainable management, this CO_2 is recaptured by the growing forest/trees, and there is no leakage of CO_2. Hooda *et al*. (2007) conducted a study in

Uttarakhand to assess the carbon mitigation potential of eucalyptus in agroforestry systems. Comparisons of six-year rotation eucalyptus for bio-energy with ten-year eucalyptus grown as carbon sink shows that carbon abatement is higher in the former.

The overarching objective of India's new flagship programme, the Green India Mission is to increase forest/tree cover in 5 million ha of forest/non-forest lands and improve quality of forest cover in another 5 million ha (a total of 10 million ha) over a ten-year period. This includes bringing 0.20 million ha of urban/peri-urban lands under forest and tree cover and agroforestry/social forestry over 3.0 million ha. The mission observes that productivity of tree crops on agricultural lands is much lower than that in Brazil and Indonesia (MoEF, 2010a). There is considerable potential in many parts of India to achieve similar levels of productivity in agroforestry systems. As a matter of fact typical yields from plantations of fast growing species like eucalyptus and poplar are in the region of 30-50$m^3ha^{-1}yr^{-1}$ (Lal, 2003,2004). The potential area for agroforestry in the country is as high as 165 million ha but there is absence of a strategic plan for development of agroforestry. The following well known problems relating to this sub-sector are.

- Lack of strategic directions (supply–demand forecasts) for agro-forestry linking potential production with market demand;
- Matching species with the site and access to high-quality planting material of proven suitability, especially at the initial tree-planting phase;
- Over-regulation often restricting the access to markets for farmer-grown timber and tree products, partly because of rules intended to curb illegal logging from natural forests or government plantations; and
- Marketing and price support system to ensure right prices and smoothen market fluctuations.

TOF provide a great opportunity to mitigate climate change and conserve biodiversity through indirect reduction in pressure on forest resources. However, the opportunity can be fully exploited only if we address the above stated problems.

TOF in Punjab

Punjab was the first State to document its tree wealth outside forests in 2006 with the help of Forest Survey of India. The salient findings were:

- The total estimated stems were 61.2 million out of which 57.8 million were in rural areas. This works out to 14.3 stems per ha.
- The total estimated stem volume of wood was 19.86 million m^3 with a volume per ha of 4.3 m^3.
- The dominant species were *Eucalyptus* spp. (23.7 5), *Populus* spp. (21.0 %), *Melia azedarach* (10.8 %), *Dalbergia sissoo* (10.4 %), *Mangifera indica* (4.5 %) and *Acacia arabica* (4.2 %).
- The most preferred species in rural areas are *Eucalyptus* spp. Followed by *Populus* spp. and *Dalbergia sissoo.* For urban areas, the preferred species are *Eucalyptus* spp. followed by *Melia azedarach* and *Populus* spp.
- *Populus* spp. are preferred in block plantations while *Eucalyptus* spp. are preferred in linear plantations.
- The State has vast potential for increasing its tree cover, as 92.7 per cent of its total geographical area is culturable non-forest area.

Being the two most common agroforestry tree species accounting for nearly 45 per cent of tree cover in Punjab, we estimated the carbon content of poplar and eucalyptus trees. The values obtained were 0.47 and 0.45 times their respective oven dry weights. The estimates are in line with the IPCC's default values of 0.43 for twigs/small wood and 0.47 for logs. Using the estimated values, we have developed regression equations to estimate carbon sequestered by a tree according to its diameter and height (Tables 1 and 2).

Table 1. Amount of carbon sequestered (kg) in *Eucalyptus* trees

Diameter at breast height (cm)	Tree height (m)				
	15	17	20	22	24
12	26.6	29.4	33.7	36.3	39.1
15	41.2	45.6	52.2	56.5	60.7
17	52.6	58.4	66.7	72.2	77.6
20	72.4	80.3	91.8	99.4	106.8
25	112.2	124.5	142.4	154.0	165.5
30	160.6	178.1	203.7	220.3	236.8

Note: An additional amount of 20-25 per cent is sequestered and fixed in the soil through root biomass.

Table 2. Amount of carbon sequestered (kg) in Poplar trees

Diameter at breast height (cm)	Tree height (m)				
	16	18	20	22	24
16	28.42	30.34	32.19	*	*
18	32.41	34.66	36.82	38.91	*
20	36.56	39.14	41.63	44.04	46.37
22	40.84	43.78	46.60	49.34	51.98
24	45.26	48.55	51.73	54.79	57.76

* Trees normally not available in these categories. An additional amount approximately 20-25 per cent is sequestered and fixed in the soil through root biomass.

REDD-plus

REDD (Reducing Emissions from Deforestation and Forest Degradation) is the global endeavour to create an incentive for developing countries to protect, better manage and save their forest resources (MoEF, 2010b). REDD+ goes beyond merely deforestation and forest degradation and its scope includes:

- Reducing emissions from deforestation;
- Reducing emissions from forest degradation;
- Conservation of forest carbon stocks; and
- Enhancement of forest carbon stocks.

It is generally thought that enhancement of forest carbon stocks refers to afforestation, reforestation and restoration activities on deforested and degraded lands; though it may also include the sequestration of carbon in healthy standing forests(REDD-NET, 2010). REDD+ was one area where progress was made at Copenhagen. Counties that are already protecting their forests can benefit under REDD+. It is estimated that India could provide capture of more than 1 billion tonnes of additional CO_2 over the next three decades and provide more than USD 3 billion as carbon service incentives under REDD+ (MoEF, 2010b). India also plans to implement REDD+ by utilizing public funds rather than depending on carbon markets (MoEF, 2010c). India's GHG emissions for 2007 was released in May 2010 by INCCA; it indicates that India is now ranked fifth after the United States, China, The European Union and the Russian Federation in global GHG emissions of around 1.7 billion tonnes of CO_2 equivalent and the forests of India sequestered 67.8 million tonnes of CO_2 in 2007 (MoEF, 2010c). The overall objective of REDD+ is to create net emission reductions. REDD+ brings a new logic to what is being paid for, with revenues derived from keeping trees standing rather than cutting them down and that payments for emission reductions will be performance- based. However, there are concerns that REDD+ will be like another CDM with rules that are too complex for many developing countries to benefit from.

Land use is a significant (20-30 %) contributor of global emissions. However, the current policy is focused on the institutionally defined (government) forest and reducing emissions within the institutional forest category. Trees on agricultural landscapes represent a globally important carbon stock. Trees outside forests, woody vegetation outside of institutionally defined 'forest' and peat lands contain large amounts of carbon stocks that are excluded from current mitigation discussions. The ASB Partnership for Tropical Margins has compiled evidence to suggest that promoting high carbon stock uses and reducing emissions from all land uses remains the best way to achieve global climate goals (Van Noordwijk *et al.*, 2009). Their key findings are reproduced below:

- "Compared to schemes currently under discussion for forest based emissions mitigation, Reducing Emissions from All Land Uses (REALU), using full accounting scheme for Agriculture, Forestry and Land Use (AFOLU), will be more:
- Effective, in bringing major 'leakage' concerns into accounting rules and allowing increased land use intensity outside forests as a contributor to net emissions reduction.
- Efficient, by providing many cost-effective options for emission reduction, including tropical peat lands and smallholder agroforestry.
- Equitable, by applying the same accounting rules for Annex-I and non-Annex-I countries, and embracing low-forest-cover countries on a proportionate basis and rewarding the poor.
- The absence of a globally agreed definition of 'Forest' will impede implementation of REDD or REDD+ schemes.
- Trees outside forests, woody vegetation outside of institutionally defined "forest' and peat lands contain large carbon stocks that are excluded from current mitigation discussions".

As stated earlier, there is considerable scope for enhancement of tree cover in India. Even if 10 per cent of the estimated potential area of 165 million ha, is brought under agroforestry/tree cover, India's tree cover would jump from the current area of 9.17 to 16.5 million ha. This in itself would be a substantial increase and this tree wealth could sequester in close to 300 million tonnes of carbon in standing biomass over two decades. Promoting TOF therefore has the potential to improve rural livelihoods, increase food security and contribute to climate change mitigation while at the same time taking pressure off the remaining natural forests.

CONCLUSION

In India, trees outside forests are already making a significant contribution to the supply of industrial round wood and woodfuel. There is considerable scope for expansion of this sub-sector and its inclusion in REDD+ schemes would be a win-win situation. Additionally adopting a whole-landscape approach to reducing emissions by including among others, agroforestry, while proposing full accounting scheme for Agriculture, Forestry and Land Use (AFOLU) will be equally effective.

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Clonal Agroforestry Plantations in India

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Abstract: Our forests cannot meet national needs of timber, industrial round wood and fuel wood because of low growing stock, poor annual increment and degradation of large areas of forest resources. We spend huge amount of foreign exchange on import of timber and wood based products and import bill is growing year after year. Declining supplies from forests and growing market demand for wood combined with development and deployment of genetically improved clones have made agroforestry an attractive alternate land use option for the farmers. Bulk of the requirement of veneer and ply logs and pulpwood demand of paper mills are met through agroforestry plantations that also make very significant contribution to country's green cover, carbon sequestration, amelioration of environment and employment generation. Yet there are very serious constraints hampering development of agro-forestry and limiting exploitation of its full potential. These constraints need to be addressed by Government urgently through innovative policy changes. Specific suggestions for addressing the constraints and strengthening of research and extension services for holistic development of agro-forestry have been given for consideration of the Central and State Governments.

***Key Words*:** Clones, Agroforestry, Poplars, *Eucalyptus*, Productivity, Constraints, Policy support

Trees are reverend in our mythological scriptures and farmers have been maintaining sporadic trees of useful local species in their farm lands and around their farm houses since ages. National needs of timber, industrial round wood for processing and to a large extent fuel-wood have been traditionally met from forest resources. However, with the economic development of our country, demand for timber and wood based products has been growing continuously while sustainable supply of wood from forests has declined because of low growing stock, poor annual increment and degradation of nearly 42 per cent of 69.09 million ha of our country's forest cover. (Anonymous, 2009) As per national forestry action programme timber requirements of India during 2006 were 82 million m^3, whereas, the domestic availability was just 27 million m^3. Timber and wood based products worth US$ 2.75 billion were imported into India during 2006. Estimated domestic wood supply deficit in India will exceed 90 million m^3 by 2020 - a substantial increase from the round wood deficit of 21 million m^3 in 1999 (Midgley *et al.,* 2007). Growing shortages of industrial round wood have hampered modernization and growth of wood based industries.

As our Government owned forests cannot meet growing requirements of industrial round-wood, national forest policy 1988 suggests that wood based industries should source their future wood supplies through persuading farmers to raise agroforestry plantations. Substantial improvement in productivity of forest resources on sustainable basis and promotion of large scale agroforestry plantations are most essential for meeting the national needs for fuel-wood, timber & wood products on sustainable basis and conservation of the forest resources. Productivity and net returns from seed based agroforestry plantations have been generally very low mainly because of extremely poor genetic quality of seed most often used and non availability of adequate quantities of genetically improved planting stock.

Development and large scale deployment of tested genetically superior clones of eucalypts and poplars supplemented with improved scientific package of practices have redefined productivity standards making agro-forestry plantations an attractive land use option with net returns significantly higher than those from traditional crops. Average productivity of commercial poplar and eucalyptus clones is 20-25 m^3 ha^{-1} yr^{-1}. However, many farmers have achieved trend setting high productivity of 50 m^3 ha^{-1} yr^{-1} both for poplars and clonal eucalypt plantations. Sustainable harvest of timber from trees outside forests in Punjab is 1.5 million m^3 per year (93 % of total) compared to 0.12 million m^3 from government owned forests. Likewise in Haryana state, harvest of timber from community and farm lands is 2.8 million m^3 per year (94 % of total) compared to 0.19 million m^3 from forests.

Clonal Poplar Plantations

Trials of various species and cultivars of exotic poplars were initiated by Forest Research Institute, Dehradun and Uttar Pradesh Forest Department during 1960s and *Populus deltoides* clone IC confirmed commercial potential of poplars in Terai areas provided tested, superior and adaptable clones are deployed. Genetically improved, field tested and fast growing *Populus deltoides* clones like G3 and G48 supported with long term bank loans and improved package of practices since 1984 played crucial role in this success story. Assured supply of superior clonal planting stock, supplemented with excellent technical extension services and buy back guarantees provided by Wimco seedling Limited laid very solid foundations of an extremely successful poplars based agro-forestry project (Jones & Lal, 1989). Enterprising farmers adopted scientific improved package of practices for poplar plantations in a big way to take advantage of the growing market demand for high quality logs for manufacture of match splints, plywood and flush doors (Lal, 1991). By the year 1989-90, the planting of poplars on private farmlands covered 4,000 ha with 2 million poplar plants per annum. By the year 1999-2000 planting of poplars under agroforestry system on private farm lands increased to 15 million plants covering nearly 30000 ha annually. Though, it is desirable to retain poplar plantations for 8 years to achieve high mean annual increment and good girth of logs, yet most of the farmers prefer to follow 5-6 years rotation to get early cash inflows. Poplar logs are used by the safety match, veneer and plywood, sports goods and packing cases industries, etc. Centre cores and veneer waste generated during plywood manufacture and small sized wood are used for manufacture of pulp and as fuel-wood.

Poplars require assured irrigation and distinct winter season for good growth. Plantations of poplars under agroforestry system are concentrated in northern districts of Punjab, Haryana, north-western Uttar Pradesh and plains of Uttarakhand. As the availability of farm grown poplar logs improved steadily, plywood industry saw an opportunity to set up poplar based veneer and plywood units. That further spurred demand for poplar logs and in turn more and more farmers adopted poplar planting because of high productivity and attractive economic returns. There are now more than 1100 members of the Northern India Plywood Manufactures Association having veneer and plywood units in aforesaid four states based almost entirely on farm grown poplars and eucalypts. Largest concentration of plywood and veneer industry is in and around Yamunanagar in Haryana state.

Unfortunately, farmers lost heavily to the extent of 18000 million Indian rupees during 2001- 05 because of continuous decline in prices of poplar logs from Rs 4500/- per tonne in 2001 to less than Rs 1000/- per tonne by 2004-05, engineered primarily by the plywood industry. Majority of the small farmers resorted to distress sales and uprooted immature poplar plantations to reconvert their small land holdings to agricultural crops (Lal, 2006). Central and State Governments did not intervene suitably to safeguard the legitimate interests of thousands of farmers. With the stabilization of prices of poplar logs after resolution of issues related to licensing of wood based industries since 2005 and further improvement of prices to current level of Rs. 11000/ tonne, there is increasing trend of planting poplars once again.

Clonal *Eucalyptus* Plantations

Even though large scale seed based *Eucalyptus* plantations have been raised on degraded forest and marginal lands and along railway tracks/road strips, canals and drainage channels in India, yet most of these past plantations have low productivity ranging from 4-10 m^3 ha^{-1} yr^{-1} and large genetic variation because of poor genetic quality of seed used. ITC Bhadrachalam Paperboards Limited launched an ambitious programme in 1989 for development, testing and commercial scale deployment of fast growing, high yielding and disease resistant clones of eucalypts in Andhra Pradesh state (Lal, 2001). Productivity and profitability of eucalypt plantations has been revolutionized with the deployment of genetically improved clonal planting stock of *Eucalypts* since 1992. Average productivity of commercial eucalyptus clones is around 20 to 25 m^3 ha^{-1} yr^{-1} and many farmers have achieved record growth rates of 50 m^3 ha^{-1} yr^{-1} even under rain-fed conditions making clonal *Eucalyptus* plantations an economically attractive land use option both for reforestation projects and agro forestry plantations (Lal, 2003).

Eucalyptus clones have been adopted by many integrated pulp and paper mills in India for promoting agro-forestry plantations around their mills. Current planting level of clonal eucalypt plantations in India during 2010, mostly under agro-forestry system, is estimated to be around 55 to 60 million plants covering 22000–24000 ha area annually. Andhra Pradesh still leads in clonal eucalypt plantations. Wood based pulp and paper mills in Orissa, Karnataka, Tamil Nadu, Madhya Pradesh, Gujarat and Maharashtra are also promoting clonal *Eucalyptus* plantations. Pragati Biotechnologies promotes clonal *Eucalyptus* and poplar plantations on large scale in the states of Punjab, Haryana, Uttar Pradesh and Uttarakhand. Amongst the Government agencies, Andhra Pradesh Forest Development Corporation and Haryana Forest Department are followed by a few other State Forest Departments in raising/ promoting clonal eucalypt plantations.

In north India, clonal eucalyptus plantations are raised under agroforestry system by farmers mostly for production of timber and ply logs with rotation of 8-10 years. However, in south and central India, most farmers grow clonal eucalypts for production of poles and pulpwood under agroforestry system combined with intercrops during first year as most of these plantations are rainfed. Even though peak mean annual increment is not reached, most of these plantations are harvested prematurely at 4-5 years age. Farmers take one or two coppice crops from their eucalyptus plantations.

Significant improvements in quality of produce and reduction in per unit production costs have also been possible with the use of true to type, uniform and genetically improved clonal planting stock. A series of successful clonal demonstration plots, high genetic quality of clonal planting stock, excellent technical extension services and buy back guarantees provided to farmers combined with bumper yields and high economic returns have been the key factors leading to the success story of technology based clonal eucalypt plantations in many states of India. There is ample potential for significant further growth because of growing shortages of industrial round wood and pulpwood.

Other Species

Genetically superior and fast growing clones of *Casuarinas* and *Leucaena* have also been developed and deployed on a small scale. Genetically improved clonal planting stock of *Acacias* has been developed and deployed by Mysore Paper Mills and West Coast paper Mills for the high rainfall areas of Karnataka after selections from naturally occurring hybrids between *Acacia mangium* and *A. auriculiformis* (Lal, 2010) ICFRE institutes and some of the State Forest Departments are in the process of developing and testing clones of many other important commonly planted species including teak (*Tectona grandis*), shisham (*Dalbergia sissoo*), gamhar (*Gmelina arborea*), etc. Very high priority and greater focus are required for speeding up such research so that we can test and deploy superior clones of most of the important tree species amenable to cost effective vegetative propagation.

Research and Development Support

Very strong research and development support is required for success of any large scale clonal plantations programme. As all plants of each clone have same genetic make up, there is utmost need to ensure wide genetic base and diversity of deployed clones to guard against any future epidemic insect pest or disease attack (Lal, 2007). Epidemic attack of hitherto unknown *Leptocybe invasa* wasp causing serious problem of leaf galls on *Eucalyptus* nurseries and plantations since last few years is an example that has necessitated deployment of tolerant clones and biological control measures through parasitoids. Some of the important areas requiring major R & D support on continuous basis are as follows:

- Sound breeding strategies for genetic improvement of seed sources.
- Long term breeding support for development, testing and deployment of new superior clones on continuous basis.
- Improved silvicultural practices including matching of most adapted clones to problematic soils, management of soil fertility and nutrient deficiencies on sustainable basis.
- Integrated management and control of root fungi and leaf spot diseases and insect pests like eucalyptus leaf gall wasp.
- Improving net returns from intercrops including testing and development of shade tolerant crop varieties.
- Processing and utilization of short rotation farm grown timbers including seasoning and preservative treatment, etc.

It will be nice if ICAR, ICFRE, agricultural universities and wood based industries could join hands and pool their resources for coordinated research initiatives to support clonal plantations programmes.

Constraints Hampering Agroforestry Development

Even though very significant progress has been made and agroforestry plantations are already providing bulk of the industrial round wood to processing industries and fuel wood for the rural masses, our country has not been able to harness fully the tremendous potential of agroforestry. If we can restore part of our degraded forest lands to high productivity through technology based plantation and exploit full potential of agro-forestry plantations, we can achieve self sufficiency in timber and wood based products in due course and also realise our declared goal of 33 per cent good tree cover. Government should take innovative policy initiatives to address major constraints listed below that hamper growth and development of agroforestry:

- Market uncertainties in respect of long term demand and market prices of timber and absence of regulated timber markets for transparent trading of farm grown timber.
- Restrictive regime in respect of felling of farm grown trees and cumbersome transit permits in many states.
- No system in place for registration of nurseries and certification of forest seed and clonal planting stock.
- Inadequate focus on tree improvement, R & D support and very poor extension services for agroforestry.
- Small fragmented land holdings and very low ceilings on agricultural land holdings even for waste lands.
- Obsession with subsidized or low cost seedlings of poor genetic quality making scarce land resources under productive.

- Unrestricted import of logs/timber and ban on export of logs including farm grown timber.
- Restrictions on licensing new wood based industries and expansion of existing units.
- Difficulties in getting long term bank loans and insurance of plantations.
- Limited choice of profitable agroforestry models.

Policy Support for Development of Agroforestry

Large scale integrated development of agro-forestry plantations and wood based industries is a win-win situation for all sections of society with following major benefits:

- Diversification of agriculture in many states.
- Domestic value addition through processing of farm grown timber.
- Enhanced revenues from excise duty and tax on processed wood products.
- Savings in foreign exchange otherwise required for import of timber, pulp and other wood products.
- Generation of large scale employment opportunities for the rural poor.
- Amelioration of environment and conservation of biodiversity rich natural forests, etc.

Hence Central and State Governments must address various constraints hampering growth of agroforestry through innovative policy changes. There is urgent need for review of policies and rules that restrict growth of agroforestry plantations Following suggestions are made for the kind consideration of Central and State Governments for holistic development of agroforestry, which will play key role in securing future supplies of timber, industrial round wood and fuel-wood for meeting our national needs and industrial requirements on sustainable basis as well as achieving the desirable goal of 33 per cent effective tree cover in the country:

- Plan for promotion of integrated development of agroforestry plantations and establishment of new wood based industries and modernization/ expansion of existing units.
- State Governments should free farm grown timber species from hassles of securing felling permits and timber transit permits in all states.
- Regulated timber market yards should be established in major timber trading towns to promote transparent trade in timber and prevent exploitation of growers.
- Strengthening of research and extension services related to agroforestry development should be given high priority by ICFRE, ICAR, Agricultural Universities and wood based industries.
- Suitable arrangements should be made for registration of nurseries and certification of planting stock and genetically improved clones to prevent duping of farmers by unscrupulous traders.
- Government should promote investments for agroforestry development through innovative policies, fiscal incentives and tax benefits.
- National Bank for Agriculture and Rural Development and commercial banks should simplify procedures and facilitate flow of long term credit for funding agroforestry plantations.
- Agroforestry plantations enhance country's tree cover and make significant contributions to carbon sequestration. Govt. should facilitate flow of international funding support to farmers for these carbon sinks.
- Government should consider liberalizing of ceilings on agricultural land holdings at least for waste lands to promote their reclamation for agroforestry plantations.
- Import of only specified species of hardwoods should be permitted and export of value added wood products including furniture made from farm grown timber should be allowed.
- State Forest Departments should stop production and supply of cheap subsidized seedlings of poor genetic quality that make scarce land resources under-productive.

Central and State Governments should consider these suggestions positively and initiate suitable action soonest possible.

CONCLUSION

Just as the foundations of green revolution in agriculture were laid by the new improved crop varieties, genetically improved clonal planting stock has revolutionized productivity and improved net returns very significantly leading to growth and development of agroforestry plantations. However, there is tremendous scope for further growth of agroforestry if major constraints still hampering same can be addressed. Implementation of innovative policy changes and positive action on the suggestions given above will go a long way for holistic development of agroforestry plantations in our country with major benefits to all sections of our society.

The only way to achieve our declared objective to have 33 per cent good tree cover is through planned development of agroforestry plantations and restoration of degraded forest lands. Otherwise, this will remain an unfulfilled dream on paper and we will continue to be burdened with huge foreign exchange outflow on import of timber and wood based products year after year. Subtropical to tropical warm climate, ample sunshine, good land and water resources, large labour force and scientific community endow our country with the comparative advantage in timber and biomass production. Therefore, we should speed up all those measures that will facilitate exploitation of our full potential in this area and achieve self sufficiency in timber and wood based products soonest possible. That will also give our country tremendous benefits of ecological and environmental amelioration with excellent tree cover.

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Development of Poplar Based Agroforestry System

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Abstract: Uttar Pradesh Forest Department started research work on poplars in 1950, by importing fast growing clones from Europe and China. As clones imported were from higher latitude, they did not perform well in foot hills and tarai, where, deep, fertile and irrigated sites were available for its cultivation. Success in agroforestry was achieved by introducing Australian clones of American origin. Farmers adopted it as commercial crop due to its fast growth, deciduous nature, clean and straight bole, etc. Removal of restriction on felling and transport by State Governments encouraged farmers to adopt poplar on large scale. Development of local markets and higher demand by industries, helped poplar cultivation in yielding much higher return than field crop. Poplar cultivation activity has generated huge employment in rural sector and has over all improved rural economy. As such, it is going to stay and expand. To maintain better and higher production of poplar wood, selection of new clones is necessary. Key of success of agroforestry programme is source identified planting material at proper time of proper site.

Key Words: Poplar, Agroforestry, Adoption, Productivity, Employment.

In human life wood has significant place and it has special importance from time immemorial. Today, when science has made available iron, cement, plastic, petroleum products and fossil fuels as alternatives of wood, even then, there is no reduction in wood consumption. Rather it is increasing day by day. Many new uses of wood have emerged with development of civilization. Availability of fossil fuels is expected to reduce gradually, but, in case of wood, continuous production and availability is possible. Present days problem is that, land for wood production is getting reduced day by day, mainly due to pressure of population. It is expected, that for a long time wide gap between supply and demand of wood will continue, as such, it is essential that maximum wood is produced out of available sites. It is also necessary that, fast growing tree species are grown even on lands outside forests. So far, farmers have accepted two tree species, mainly eucalyptus and poplars for field planting. But, poor eucalyptus has suffered badly due to unwanted and unscientific propaganda against it. Luckily poplars have escaped such bad propaganda and hence there are enormous possibilities for its cultivation on large scale.

Poplar grows fast and its improved clones become harvestable in less than eight years time. Being a deciduous tree, it suits most for agro-forestry. In addition, it acts as saving bank for farmer in which interest is added every year and can be encashed whenever required. Considering these qualities, Uttar Pradesh Forest Department started conducting research work on poplar cultivation immediately after independence. After 1965, poplar plantations were raised on forest lands of Tarai and after 1980, farmers of Tarai adopted it. During last 33 years, poplar planting activity on private land expanded extensively and apart from Tarai, vast area of plains of Punjab, Haryana and Uttar Pradesh were brought under poplar plantation. In U.P., during 1950, poplar clones were imported from Europe. Another import was done during 1960 again from Europe, But, all of them failed to perform well mainly due to higher temperature and seasonal rainfall in the locality. Success of poplar cultivation was achieved when clones of American poplars which were from warm locations and were adopted in Austraila and South Africa were imported. Subsequently, clones developed by Dr. D.T. Cooper at Stoneville (USA) helped a lot on account of their fast growth and hardy nature. Dr. L.D. Pryor from Australia helped us by supplying planting material of clones developed at Grafton. His rust resistant clones failed in India, but, two clones namely G-3 and G-48 which performed poorer than Italian clones at Tumut (Australia) became back bone of poplar cultivation in India.

Nursery and cultivation practices of poplars were perfected by Sri D. N. Lohani in late seventies of last century when he was working as Conservator of Forests, R&D of Uttar Pradesh Forest Department. Selection of local clones started during 1982, when Sri A. N. Chaturvedi was CF, R & D and later Dr. Pratap Singh, Entomologist, FRI, Dehradun observed flowering of poplars in Gadgadia block of Tarai Central Forest Division, Haldwani. Out of 1982 seedling population, many good clones were developed ; Udai, Kranti,Bahar, L-34 and L-49 are outstanding products of that population, one clone (L-30), which was outstanding for sawn wood is not seen now, trunk of L-30 was more close to a square than a circle, there by producing higher swan wood than other clones. Today, we have clones, which produce twice than what earlier clones were yielding.

Hybrids of G-3 and St-121(D-121) are prominent in them and ranked 1 & 2 for higher productivity.

Planting Material

Planting material of poplar is of great significance in raising plantations. Only source identified planting material should be used. This is because, poplars are raised clonally and there are several thousand clones in cultivation. They are site specific and locality specific. Their wood density is also variable. They are specific to particular day length of light and temperature. It is not easy to identify a clone at nursery stage, unless, one inspects them almost daily and records their characters. Moreover, juvenile growth cannot be taken as an indicator for field performance. In India, we plant entire transplant with some roots. Growth of nursery plants depends much on fertility of nursery and soil working. Very tall plants are undesirable for warmer climate like ours. Because, they take long time to sprout and generally sprout from bottom. The apical bud of nursery plants is highly cutinised, as such, it opens only when, suitable temperature is there to melt wax. Hence, it is advocated to remove apical 30-40 cm length of nursery plant over a healthy bud prior to planting out, by giving clean circular cut. Circular cut has advantage of minimum cut surface and smaller area for healing. A plant between 3 to 4m in height is the best plant to plant out. The height - diameter ratio at collar point be closest to 100, i.e., the diameter should be between 3 to 4 cm corresponding to height. Long distance transport and exposure to sun be avoided. It is better to plant out within 48 hours of uprooting from nursery and prior to planting out, plant may be emersed in fresh, clean and cold water (if possible in running water) for 12 to 24 hours, so that, whole body of plant is fully enriched with moisture. In planting out, care must be taken that plant stands at right angle to field and is well compacted, so that, it does not lean due to heavy irrigation/rainfall/wind. Plant which leans, never reaches to rotation age.

Rejuvenation

Since poplars are planted clonally that too by rootage, influence of stionic effect degenerates planting material considerably. Any clone remains in commercial cultivation till it is replaced by better growing and hardy clone or invaded by pests, as such, to obtain vigorous and upright planting material regularly, it is necessary to rejuvenate planting material after every 3 to 4 years. In fact, for a commercial nursery, this activity is continuous, so that, quality planting material is available regularly. The vigrous planting material is obtained either from roots or water shoots. It is followed by co-leaders. Side branches should never be used for nursery productions, because, they are physiologically older than one year and have poor apical dominance. Because poplar is strong light demander, suppression once set in, lasts forever. Cuttings of same size (length and thickness) be planted in the same bed, so that, during nursery life influence of side shade is avoided. Dipping of cuttings for 24 h in cold and fresh water helps in uniform, early and better sprouting. Moreover, planting density influences plant height, thickness and taper, which are directly responsible for survival and growth.

Intercropping

Agroforestry plays a vital role in improving rural economy by increasing per unit area production and generating rural employment for unskilled and semiskilled persons. Moreover, trees grown, act as saving bank for farmers. For intercropping with poplars, density of plantation is very important. Wider spacing permits enough sunlight for crop production and provide space for proper soil working. It is worthwhile to mention here that poplar responds more to deep and frequent soil working than application of plant nutrients. It is a surface feeder, as such, does not like weeds around it. At the same time, root of poplar need lot of oxygen for better development. Generally poplar is planted at 5m x 4m, 5m x 5m, 7m x 3.5m, 8x2.5m spacing, which permit tractor working.

Sugarcane is the best associate of poplar during first two years of its age, because of deep soil working, fertilizer application and frequent summer irrigation followed by soil working. Moreover, coverage by sugarcane of lower 3 to 4 m plant height avoids branches on lower portion of stem. During third year (2nd ratoon), production of sugarcane drops due to shade caused by poplar. Paddy is most unsuitable crop with poplar as it cuts oxygen movement in the soil, at the same time, due to excessive moisture, root development is poor in poplars resulting into leaning and uprooting of trees. Shade of poplar induces tendency of false grains in paddy, thereby, poor grain yield. Onion and garlic are also bad associates of poplar, because, they are prone to cercospora blight, which spreads on older leaves of poplar quickly. Crops which can be produced along with poplar till the end of rotation are wheat, pipli, cape gooseberry, strawberry, turmeric, ginger, pitchauli, black gram, green gram, rape seed, lentil, coriander, tomato, cabbage, radish, sugar-beat, elephant foot, spinach, celery, brinjal, potato, fenugreek, knoll-khol, turnip, etc. Some crops like sweet pea, chilly, berseem, chickpea and gram can be grown with poplar for 4 years. Maize, mentha, sorgham and soyabean can be grown only during initial two years.

Intercropping does not only hold good for improving income from agricultural crops, but, it is quite beneficial to the poplar plants. Improved aeration from frequent soil working for agricultural crops and inputs, like irrigation, fertilizer application and soil working are beneficial to trees. Thus, poplar plantation with intercrops have better growth than those without intercrop. A study conducted by Gill and Singh (2007) on intercropping of medicinal plants at PAU, Ludhiana during the years 2004-2006 indicated that herb yield of mentha reduced drastically under two years old poplar plantation. In 2 years old poplar, the yield reduction of lemongrass and marigold was minimum i.e. 6.5 and 7.5 per cent, respectively. They further observed that under poplar, turmeric be planted around 20th May, which yields higher than earlier planting. At the same time, ridge planting of it yielded better than flat planting. It also responded to close planting and farmyard manure application. Singh (1998) recorded that bhindi, lobia, palak, methi, dhaniya, cucumbers, muli, gajar, aloo, mirch, baigan, tamatar, sakarkand, matar, foolgobhi, patgobhi, adark and haldi can be cultivated during first two years of plantation age with 8 to 18 per cent reduction in yield. Tiwari (2002) advocated wider spacing of poplars to have better yield from intercrops. He advocated regular pruning of poplar trees and selection of shade loving crops like frenchbean, bhindi, adrak, haldi, jamikand, patgobhi, foolgobhi, aloo and tomato. He further advocated line planting at 10m x 4m spacing on east-west direction and keeping lower half bole of tree clean during two to three years age, after which, two third of lower bole be maintained branch free.

Influence of locality

Latitute influences height growth of poplar trees significantly. In our country, height of trees at Amritsar and Gurdaspur districts of Punjab, which are located above 30^0 N reaches to 36-37m thereby, producing more volume per tree. At Yamunangar and Ambala of Haryana and adjoining locations of Uttar Pradesh, which are located around 29 ^{0}N latitude, the height growth of poplar trees remains around 30-32m. Whereas at Rudrapur, Rampur and Bijnor area of Uttar Pradesh, the tree height declines to 28 to 30m. These places are located at 28 ^{0}N latitude. Places which are at 27 ^{0}N latitude, height of tree restricts to 25 to 27m and out turn is lower. Hence, trees of Lakhimpur-Kheri, Sitapur, Badaun etc fetch much lower price than of Punjab and Haryana. It is not only higher taper which reduce yield but, presence of more branches on the stem makes timber inferior.

Temperature is another important factor. It was noticed that American clones which are originally from warmer locations remain leafless for much shorter duration than European clones. Temperature and light govern phenology of poplar trees. Temperature above 35 0C is infurious to poplars and higher temperature than 40 0C for prolonged period develops cracks on southern and western aspect of bark. This further develops cankar and bacterial infection resulting into decay of stem. Temperature between 15 & 25 0C is most suitable for growth of poplars. Apart from these, the tree is very sensitive to light. This tendency is right from seed germination stage. At warmer and relatively frost free location, period of dormancy of poplar trees reduces drastically. Even artificial light also helps to retain leaves for longer duration.

Employment Generation

Bist and Panse (2008) conducted detailed study on employment potential of agroforestry at Yamunanagar (Haryana), which has emerged as largest market for wood produced by farmers under agroforestry. Apart from Haryana, this market attracts wood from Punjab, Himachal Pradesh, Uttarakhand and Uttar Pradesh. For the year 2003, they recorded average daily arrival of wood 1000 loads (96 % trolleys, 3.5 % trucks and 0.5 % carts) containing 75,00 tonnes of wood with a value of Rs 12.5 million. They recorded 796 agroforestry based units at Yamunanagar, engaging 4,075 persons per day. In addition, 671 industries subsidiary to agroforestry providing employment to 6068 persons per day. It is estimated that around 2000 persons are daily engaged in felling of trees in command area of Yamunanagar market. Overall, it was estimated that wood based industries of Yamunanagar generate about 35 million mandays work yielding Rs 3,000 million every year. Farmers engaged in growing of trees are not covered in this study. Earlier Chandra (2001) estimated that in 8 years, production of one tree on farm land generates half a man days work. Roughly 10m saplings are planted by North India farmers every year, generating 5m mandays work each year.

Price Factor

It is most important factor to encourage poplar as agro-forestry tree. To start with in early eighties the price assured was Rs 150/- per tree of 30 cm DBH. This was promised for saplings planted during 1984-85 i.e. trees to be harvested after 1990. During this period plywood factories of Eastern hills were closed due to ban on felling of natural forests. This forced establishment of plywood units in indo-gangatic plains and development of markets for poplar. Shortage of raw material created price competition and plywood started consuming almost 90 per cent poplars planted under agroforestry system. The average price of poplar wood during last 25 years ranged as under:

Table 1. Prices of poplar

Year of harvesting	Price per m^3 of logs (Rs)
1986	760
1990	2400
1994	3600
1998	4300
2002	1500
2004	5000
2008	6500
2010	7600

There was a dip in cost of poplar wood due to several conditions created by farmers as well as industries, this reduced planting of saplings for 2-3 years resulting poor production and higher price. Now, several medium sector industries for plywood and medium density fiber board are in the market, which has stabilized wood price during last 3-4 years. Present day situation is that, farmers are getting approximately Rs 85,000 to 90,000 per ha per annum from poplar trees. Since no agricultural crop yields this much, hence, poplar is the first choice of farmers of Indo-gangetic plains. As sale of this tree is quite easy i.e. standing trees can be sold, logs can be disposed by volume as well as by weight at the site itself and at any time. Hence, farmers feel comfortable with this tree.

Keep Poplar Vibrant

Considering immense benefits and scope of this species in contributing to eradication of wood shortage, the poplar based agroforestry system should be kept alive and vibrant. Poplar cultivation depends on clonal propagules capable to produce trees of desired form and growth performance. However, clonal cultivation and particularly mono-clonal cultivation invites risks of pests. It is therefore necessary that new clones are continuously selected and tested to replace the old one.

To ensure the productive continuity of poplars, breeding new clones is a must. The superior performing new clones be selected on the basis of growth rate, desirable tree form, rootability of cuttings and disease resistance. Till 1999, following indigenous half sib clones of G-48 were tested for seven years and most of them performed better than commercial clone of the day i.e., G-48.

Table 2. Testing of new clones.

Clone	Ht (m) Mean (SD) CV (%)	DBH (cm) Mean (SD) CV (%)	Total volume (ob) m ^{3}/tree
G-48	27.0(2.9)11	25.7(3.8)15	0.500
WSL-64	27.8(1.5)05	25.6(4.5)18	0.510
WSL-68	27.4(1.3)05	26.1(4.8)19	0.520
WSL-78	28.4(2.2008	25.9(5.2)20	0.530
WSL-24	27.0(2.7)10	26.6(2.4)09	0.534
WSL-54	27.1(1.6)06	27.0(4.5)17	0.550
WSL-37	25.6(1.0)04	27.8(3.8)13	0.552
WSL-1	27.8(1.1)04	27.6(2.1)08	0.589
WSL-28	27.9(1.5)06	28.5(2.9)10	0.598
WSL-26	26.0(1.2)05	29.0(4.1)14	0.600
WSL-39	24.5(2.4)10	31.4(5.4)17	0.667
WSL-49	27.4(1.6)06	30.6(2.9)10	0.700
WSL-22	30.2(2.0)06	29.0(4.0)14	0.700
WSL-27	30.9(3.0)10	29.0(1.5)05	0.716
WSL-32	31.9(1.1)03	31.9(2.8)09	0.887

All the 14 clones performed better than G-48, which was commercial and mother clone. Clones selected on growth and form need testing for rootability of cuttings, pest resistance and locality trails, so that, farmers are able to get better clone in future and continue to grow poplars to enrich their economy and solve problem of shortage of wood in the country.

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Short Rotation Forestry as a Viable Option for GHG Mitigation

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Abstract: Global warming and associated Climate change is an important environmental issue that has captured the world's attention during the recent past. The mitigation of global warming entails reducing the atmospheric concentrations of GHGs, particularly the CO_2. The Land Use, Land Use Change and Forestry (LULUCF), an approach that became popular in the context of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) allows the use of C sequestration through afforestation and reforestation as a form of GHG-offset activities. Tropical fast growing MPTs in this regard assume greater importance on account of their enormous potential to produce biomass and sequester atmospheric C. An investigation was conducted to evaluate biomass production and carbon sequestration potential of four fast growing multipurpose tree species viz, *Albizia procera*, *Casuarina equisetifolia*, *Eucalyptus tereticornis* and *Gmelina arborea* at 20 years stand age. Above ground C sequestration potential, of the four MPTs studied showed wide variation. Among the four species studied, *A. procera* and *Casuarina equisetifolia* recorded higher C sequestration potential, which was 189.93Mg/ha and 185.85 Mg/ha, respectively. Except *Gmelina* all the tree species recorded high C sequestration, which is comparable to the earlier recorded values for tropical forests. Enhanced soil-C storage (0-30 cm) was also found under trees compared to treeless open.

Key Words: SRF, Carbon sequestration, *Casuarina, Gmelina, Albizia, Eucalyptus*

Global warming and associated climate change is an important environmental issue that has captured the world's attention during the recent past. Among the Green House Gases(GHGs) contributing to global warming, CO_2 is believed to be the most prominent one (Lorenz and Lal, 2010) accounting for 60% of the total greenhouse effect. The mitigation of global warming entails reducing the atmospheric concentrations of GHGs, particularly CO_2. One of the approaches for reducing CO_2 concentration in the atmosphere is carbon (C) sequestration, the process of removing C from the atmosphere and depositing it in a reservoir. In response to this reality, many countries have initiated massive AR programmes (afforestation-reforestation programmes) as part of CDM mechanisms to mitigate climate change. In this scenario, tropical fast growing multipurpose trees (MPTs) assume greater importance on account of their enormous potential to produce biomass and sequester atmospheric C (Kumar, 2003). Moreover, forest biomass can be used for energy purposes and thereby reduce the use of fossil fuel or can substitute for other materials such as aluminium or steel constructions whose production consume large quantities of fossil fuels.Finally, increasing the standing stock of forest biomass in many ecosystems may give several environmental benefits other than carbon sequestration.

Despite the growing concerns over the climate change and related issue and the role of trees in mitigating it, limited data is available on biomass and carbon sequestration potential of tropical fast growing multipurpose trees (MPTs) especially in the South Gujarat condition. Many of these tree species play significant role in tropical agroforestry systems. In this context, a field study was taken up with the primary objective of assessing and comparing the aboveground biomass and C-sequestration potential of selected fast growing tree species and to develop allometric equation linking biomass with measurable growth variables. The extent of soil C-sequestration contributed by various MPTs was also evaluated.

MATERIAL AND METHODS

The present investigation was conducted during August 2008 to March 2010 at the Instructional farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, situated at an altitude of about 12 meters above mean sea level, at 20^0– 58' North latitude and 72^0-54' East longitude. The site experience typical tropical climate characterized by hot summer, moderately cold winter and humid warm monsoon with an average annual rainfall of 1,355 mm, the bulk of which is received from second week of June to first week of October. The soil type of the experimental site was placed under Jabalpur series having great group chromuster, sub order upstart and order vertisol as per seventh approximation. The soil is clay in texture (63% clay), high moisture retention capacity (40.50%), and low in organic carbon content (0.26%), medium in available phosphorus (30.39%) and nitrogen content (110.12 kg ha^{-1}). There was no problem of sodicity as pH (7.86) and EC (1.75 dSm^{-1}) were below the critical limit. The study involved the assessment of biomass and carbon sequestration potential in the above ground components of four multipurpose tree species (MPTs) of 20- year-stand age viz., *Casuarina equisetifolia*, *Eucalyptus tereticornis*, *Gmelina arborea* and *Albizia procera.* The trees were established at 2.5x 2.5 m spacing in a randomized block design with four replications.

Estimation of Tree Biomass

For estimating the aboveground biomass and C sequestration, 12 trees were destructively sampled from each tree species such that there were three trees from each replication (3x4=12). After recording the total height and diameter at breast height, the trees were felled at ground level by using power saw. The bole length and total length were recorded and the aboveground portions were separated into stemwood, branchwood, twigs and foliage. Fresh weight of the entire tree component was separately recorded immediately after felling using spring balance. Representative foliage, twigs, branch wood and stemwood samples of each species were collected for moisture estimation. The samples were immediately transferred to the laboratory in double-sealed polythene bags. After recording the fresh weights, they were dried to constant weights at 70^0C. Estimates of dry weight of different biomass were obtained from the fresh weights of various tree components (stem disc, branches, twigs and leaves) and their corresponding moisture contents worked out. The average oven dry biomass of component parts were summed to obtain the total aboveground biomass per tree. It was then multiplied by the number of trees per hectare and converted to aboveground biomass on hectare basis. For assessment of the effective number of trees per ha, the actual number per plot (average of 4 plots) were extrapolated to get number of trees per ha.

Carbon sequestrated per tree is assessed by considering 50 per cent dry weight as reasonable limit of elemental carbon content. This was also computed on hectare basis as mentioned before. For estimating the sequestered soil carbon, the soil organic carbon was analyzed following wet digestion method (Jackson, 1958). Triplicate soil samples were collected from 0-30cm soil depth for carbon estimation.Soil bulk density was estimated separately for the above soil depth after removing the gravels. Soil mass at 0-30 cm soil depth was computed from the corresponding bulk density and soil C-sequestration was calculated for the soil depth by multiplying soil mass with soil organic C-content (%). Saha *et al.* (2010) was followed to calculate C storage on ha basis.

The biomass and volume data obtained from all the sampled trees were pooled and used to develop the allometric equations. Simple linear and quadratic equations were developed for predicting the total aboveground biomass and total mean tree volume using tree height and dbh as predictor variables.

The experimental data were subjected to the statistical analysis by using variance technique. The method of analysis of variance for RBD (Randomized Block Design) was used. The treatment differences were tested by 'F' test of significance based on null hypothesis. The appropriate standard error (S.Em.±) was calculated in each case and critical difference (C.D) at 5 per cent level of probability was worked out to compare the treatment means, where the treatment effects were significant.

RESULTS AND DISCUSSION

Above Ground Biomass

Biomass accumulation is primarily a species dependent factor which may be influenced by factors like growth habit, density, age of tree and environmental condition in which tree is grown (Landsberg *et al*., 1995). The data (Table 1) revealed that the mean tree aboveground biomass and stand biomass per hectare was highest for *Albizia procera* (339.16 kg and 379.86 Mgha^{-1}), which was at par with *Casuarina equisetifolia* (331.81 kg and 371.70 Mgha^{-1}) followed by *Eucalyptus tereticornis* (204.23 kg and 228.73Mgha^{-1}).*Gmelina arborea* invariably recorded the least aboveground biomass both on per tree basis and stand basis (34.37 Kg and 38.49Mgha^{-1}). All the three species produced fairly high above ground biomass at 20 years of stand age compared to reports from elsewhere. For instance, Rai *et al.* (2009) in a similar study at Jhansi reported that out of the eight tree species, highest biomass production was for *Albizia procera* (99.91 Mg ha^{-1}) followed by *Eucalyptus tereticornis* (87.74 Mg ha^{-1}). Reports at younger stand ages also recorded higher biomass accretion rates for *Albizia procera*. Chadurvedi and Das (2002) reported higher aboveground biomass (57.4 kg/tree) for *A. procera* at 5 years of stand age among the 8 MPTs tested at north Bihar.

Table1. Above ground biomass of a 20-year-old MPTs

Species	Mean tree biomass (kg)	Total aboveground biomass (Mg ha^{-1})
Albizia procera	339.16^a	379.86^a
Casuarina equisetifolia	331.81^a	371.70^a
Eucalyptus tereticornis	204.23^b	228.73^b
Gmelina arborea	34.37^c	38.49^c
Mean	227.405	254.69
LSD at 1%	88.72	99.37
CV %	24.39	24.39

Carbon Sequestration Potential of MPTS

The present study also shows the enormous carbon sequestration potential of the MPTs under study. High carbon sequestration potential is an important consideration in all tropical tree planting programmes. This is particularly significant in view of the rising CO_2 levels and the growing need to sequester it. The carbon storage is intricately linked with site quality, nature of land use, choice of species, silvicultural and other crop management practices adopted (Swamy *et al.,* 2003). Present study (Table 2) showed a high carbon sequestration by *Albizia procera, Casuarina equisetifolia and Eucalyptus tereticornis* (189.93Mg ha^{-1}, 185.85 Mg ha^{-1}, 114.36 Mg ha^{-1} respectively). This is in conformity with the earlier recorded values for tropical forests, which varies from 132-174 Mg ha^{-1}(Dixon *et al.,* 1994). Lugo *et al.* (1990) reported carbon storage for 5-16 year *Eucalyptus* plantation to the tune of 4.5-14 Mg C ha^{-1} yr^{-1}. *Gmelina arborea* recorded minimum carbon sequestration both at mean tree (17.184 kg) and per hectare basis (19.25Mg ha^{-1}). Lower carbon concentration of *Gmelina* in the present study can be attributable to poor site-species suitability. Similar results were reported by Puri *et al.* (2002), where lower carbon concentration in *Gmelina arborea* stand is attributed to poor site quality and low soil nutrient status.

Soil C-Sequestration

While reforestation and afforestation are being considered as mechanisms to reduce C emission penalties (UNFCCC 1997), it is important to recognize that, from a soil C sequestration standpoint, tree species differ in their effects. The total amount of soil organic carbon (SOC) within 30 cm soil profile varied significantly among different treatments (Table 3). It was highest under *Casuarina equisetifolia* followed by *Albizia procera, Eucalyptus tereticornis* and *Gmelina arborea*, while lowest under open condition. In the absence of a time-sequence study involving long time intervals, the C stock data were considered as an indicator of the carbon sequestration potential of the systems. Present study revealed greater carbon sequestration potential by N-fixers to non N-fixing trees. Resh *et al.* (2002) had also reported a higher soil carbon sequestration under N- fixing trees compared to *Eucalyptus* species.

It is only natural that soil under multipurpose trees characterized by high amounts of litterfall and root activity contain higher SOC compared to an open land. Incorporation of trees into treeless systems is reported to increase the belowground C stock in a number of situations; for example, a study in Karnal (India) indicated that raising tree on alkali soil increased SOC from 0.12 per cent to a maximum of 0.58% in 20 years (Singh and Singh, 1993).

Allometric Equation

Biomass prediction models are considered to be a non-destructive method for the estimation of biomass of tree stands. Since total estimation of the tree stand is usually impracticable, the biomass estimation from easily measurable tree growth variables is commonly used for prediction. Allometric relationships attempted in the present study linking above ground tree biomass with DBH and/or total height of the trees gave reasonably good predictions (Fig. 1).

The results reveal that dbh alone as independent variable explained a very high proportion of the variation in biomass. Including height as independent variable did not result to a much better explanation of the variation in biomass. Although there was little improvement in the performance of the model by including height data in the model, the improvement was marginal. Considering the huge time invested in obtaining height data in the field, the associated measurement error and the fact that the inclusion of height did not significantly improve the performance of the model, the inclusion of height data in biomass models in the study area is of little significance. Several researchers have concluded that tree biomass is primarily a function of dbh and is relatively insensitive to

Table 2. Carbon sequestration potential of 20-year-old MPTs

Species	Mean tree (kg)	Per ha (Mg ha^{-1})
Albizia procera	169.58^a	189.93^a
Casuarina equisetifolia	165.94^a	185.85^a
Eucalyptus tereticornis	102.10^b	114.36^b
Gmelinaarborea	17.19^c	19.25^c
Mean	113.70	127.35
LSD at 1%	44.36	49.68
CV %	24.39	24.39

Table 3. Soil carbon sequestration contribution by 20-year-old MPTs

Species	Organic carbon (%)	Soil organic carbon (Mg ha^{-1})
Albizia procera	1.35b	54.87b
Casuarina equisetifolia	1.79a	69.54a
Eucalyptus tereticornis	1.12c	41.69c
Gmelina arborea	0.68d	29.85d
Control	0.46e	21.87e
Mean	1.07	43.56
LSD at 1%	0.031	0.844
CV %	1.9	1.26

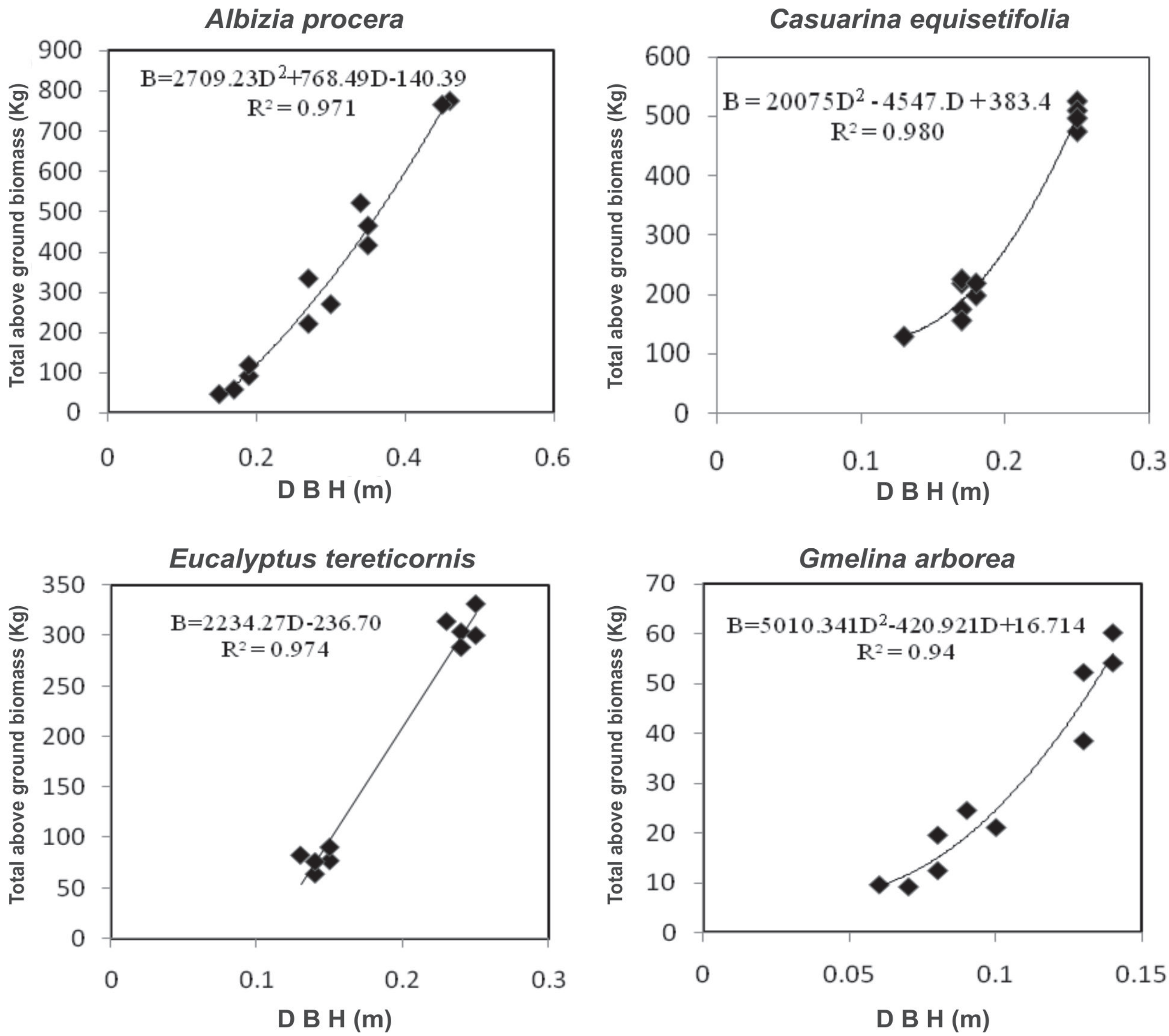

Fig. 1. Prediction models for Total aboveground biomass of *Albizia procera, Casuarina equisetifolia, Eucalyptus tereticornis* and*Gmelina arborea* at 20-year-old stand

tree height and consequently have incorporated only dbh as independent variable in their biomass models (Rapp *et al.,* 1999 and Kadeba, 1991).

The results of the present study enhance our knowledge on species selection for reforestation and afforestation in South Gujarat and in other regions with similar ecological features.Moreover, such information helped to attain more clarity on the functional role of tropical plantations in respect of diverse economic, social and ecological functions that may ultimately help reduce atmospheric CO_2 accumulation. Among the 4 MPTs *Casuarina* and *Albizia* were found to sequester more carbon in the biomass. Present study explicitly revealed that trees can substantially improve soil C sequestration in wooded systems.

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Making Short Rotation Plantation Forestry a Viable Land Use Option

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Abstract: In India, vast areas forested land has turned bare as a result of indiscriminate felling and exploitation. The problem has arisen when demand far exceeded the capacity of forest to supply wood without damage to the natural balance. It is not only the large forests that have been affected, small groves near villages, which helped meet needs of firewood and fodder, too have vanished. A growing rural population with limited income opportunities and the related widespread rural poverty due to shrinking resource base have led to encroachment of forestlands. Diversion of forestland to non-forest uses (of the order of 150,000 ha annually) has also led to large-scale destruction of forests. It is estimated that of the 130 million ha of barren land in the country, 70 - 80 million ha is under private ownership. The success of agroforestry depends to a large extent on opportunities being taken up by large and small investors. There is a great demand of forest products for a diversity of uses and, the forest plantations, mainly established with eucalypts, are managed in rotations of different extent, being shorter for energy and pulp and much longer to obtain sawn wood. And to supplement this demand, forest companies and farmers have been stimulated to cultivate eucalypts. The lands when developed carefully with various site-specific tree species for firewood, pulp and timber for various industries will return the green cover and can help change the picture completely in a few years. It seems reasonable to claim that, by providing the basis for a revolution in plantation economics, research-based clonal propagation has created new horizons for eucalypts in India. It will be most interesting to see if continued progress permits to attain greater levels of self-sufficiency in industrial raw material supplies.

Key Words: Clonal plantation agroforestry, Eucalyptus, Raw material, Adoption

Agroforestry is an age-old practice. Trees and shrubs are important in the traditional farming systems of the tropics, where woody species form a major component of the bush fallow system and are also widely grown in cropped land. Trees and shrubs benefit the farmer in three main areas of direct agricultural benefits (plant stakes, mulching materials, green manure, animal fodder, etc.), environmental benefits (shade, soil erosion control, nutrient recycling, carbon sequestration, etc.) and socioeconomic benefits (saleable commodities, employment, etc).

Agroforestry has not only benefited farmers, it also supplies raw material to wood industry, generate employment of various kinds thus benefiting millions in related economic activities like transportation, wholesale, retailing etc. It help consumers with an affordable supply of wood and contributes to import substitution for timber and timber related products, which India imports worth thousands of crores of rupees a year. Also, agroforestry is as good, if not better, than degraded forests for environmental improvement, pollution control, etc, especially as it can be initiated in farmers' holdings in villages and nearer to urban conglomerations. It is a win-win situation for all.

Agroforestry systems for pulpwood production consist of growing of "commercial trees for wood industry on agricultural fields" with irrigation, fertilizers, plant management technology, etc., in a harvest cycle of 4-7 years. Crops growing underneath form a small part of the gross income. Selective shade-loving or shade-tolerant crops are grown to complement timber production and cash flow.

As the trees have to be grown on a quick rotation, the species selected should not only be fast growing, but also suitable for combing with agriculture to maintain regular returns for farmers till harvest of the trees. Diversification of agriculture should receive very high priority as water resources are depleting and we are unable to arrange proper storage and distribution of huge stocks of food grains. However, tangible results can be achieved only if farmers are offered practical, viable and economically attractive alternative land use options. Technology based farm-forestry plantations with genetically improved, high yielding and fast growing clonal planting stock of species like Eucalypts have tremendous potential for diversification of agriculture and meeting growing shortages of industrial timber on sustainable basis.

Eucalyptus as an Agroforestry Tree Species

The *Eucalyptus* L'Herit, a native of Australia is the second dominant hardwood planted species after *Pines* in an area of 10 to 15 million ha throughout the world (Turnbull, 1999; Neilson, 2000). It is estimated that there will be more than 20 million ha of eucalypt plantations outside Australia by the year 2010 (Doughty and Doughty, 2000). Together with longer-established demand for fuel, demand for eucalypt fibre has promoted establishment of a global plantation estate now likely to exceed 20 million hectares.

Eucalypts immigrated to India soon after European settlement in Australia. One report suggests it may have been as early as 1790, It is claimed seed of 16 species were received from the then infant colony at Sydney Cove. Perhaps as many as 170 species have been introduced since. However, given the seasonal aridity of much of the country, it is not surprising that the "Eucalypts" are now so strongly dominant.

Shifts in public policy and the private sector's insatiable wood demands resulted in a turbulent environment for the forest sector in the past. In particular, in the 1980s, India experienced what was perhaps the most strident of anti-eucalypt campaigns. Analysis of that situation - by Indians and foreigners alike - seems to permit the conclusion that the fault lay not with the eucalypts per se, but rather with the strategic and methodological framework within which their planting was promoted. Certainly, in the current environment, agitation against the eucalypts appears to have subsided.

The National Forest Policy, promulgated in 1988, not only imposes remarkably severe limitations on wood harvests within public forests, but also "enjoins wood-based industrial units to meet their future raw material requirements through developing partnerships with farmers". A strong incentive for farmer – industry collaboration to conform is the fact that India has statutory limitations on the size of agricultural land-holdings.

It is difficult to escape the impression that, without clonal propagation, there would have been no prospects for success in this new approach to expanding the plantation sector in India. Only clones appear able to achieve the growth rates necessary to provide sufficient incentive to farmers to participate in these partnerships. According to Lal and Kulkarni (1992), the "average productivity of commercial clones is about 20-25$m^3ha^{-1}yr^{-1}$ and many farmers have achieved 50$m^3ha^{-1}yr^{-1}$". Unstated here is the probability that higher growth rates require irrigated sites.

Most of the myths associated with *Eucalyptus* like depletion of under ground water resources, deterioration of soils and allelopathic effects on agricultural crops are not based on scientific facts. On the contrary, soil and water resources are better conserved under any trees including *Eucalyptus* compared to keeping large tracts of land barren or even under grass cover. The study showed that *Eucalyptus* consumed 0.48 liters of water to produce a gram of wood, compared to 0.55, 0.77, 0.50 and 0.88 liter per gram for *Siris, Shisham, Jamun* and *Pongamia,* respectively (Prabhakar, 1998). Chaturvedi *et al.* (1988) reported that of ten species tested for water consumption, *E. tereticornis* was found to be the most efficient in biomass production per litre of water consumed.

Demand for nutrients by *Eucalyptus* is less than others, principally because heartwood begins to form at approximately four years. After this point, a significant proportion of nutrients in wood is recycled to other parts of the tree or soil, and the quantities that are immobilized are kept to a minimum. *Eucalyptus* also contributes to the intense deposition of organic matter on the soil - through leaves, bark and roots - estimated at seven tones per hectare per year (Carpanezzi, 1980; Poggiani, 1985; Lima, 1987), thus contributing to the soil fertility improvement.

Eucalyptus is the most popular choice to be planted along the edges, or bunds, of agricultural fields, and appears to be well incorporated and accepted in agro-forestry in India. Silvicultural properties including straightness, narrow crown, self-pruning, high growth rates, adaptability to a wide range of soils and climates, coppicing ability, a tendency not to spread as a weed and wide utility of wood are some of the main features of *Eucalyptus* clones making it popular among the farmers for raising as block plantations. *Eucalyptus* has more than 600 species, among which two species, *Eucalyptus camaldulensis* Dehnh and *E. tereticornis* Smith are cultivated more among the farming community in tropical areas of our country, as being sufficiently drought tolerant while also capable of withstanding, under irrigation and saturation, very hot summer temperatures and suitable for a wide range of sites.

Role of Private Sector in Promotion of Agroforestry and Farm Forestry

In agroforestry or farm forestry programs where intensive cropping of forest species is undertaken, vegetative propagation of desired clones assumes still greater economic importance. Great benefits have accrued from clonal selection and breeding of eucalypts and from more intensive management practices, in which private sector has led the way in India. Fast growing, high yielding and disease resistant clones of *Eucalyptus* popularly called as "Bhadrachalam Clones" have productivity of 3 to 4 times higher compared to the productivity of normal seed based plantations (Lal, 2000). Clonal *Eucalyptus* plantations, promoted, are the first successful example in India of commercial scale clonal plantations of any forestry species traditionally propagated through seedlings.

Eucalyptus plantations promoted by the private companies receive generous incentives such as technical know-how for establishing the trees on the farmer's land and contracts with the farmer to buy some or all of the first harvest for an agreed upon price at the time of harvesting, sales tax exemptions on the pulp wood, procurement though Agricultural Market Committees, no middle man involvement hence farmer can sell his produces directly to the end users and various tax holidays / exemptions for extended periods apart from element of subsidies on the *Eucalyptus* clones are given by the company. These incentives put *Eucalyptus* at an advantage compared to other agricultural crops (including perennials), which receive no such promotion.

Cultivation Practices of *Eucalyptus* Clones

Plantations can be established for afforestation and/or reforestation by using seedling, seed and/or coppicing. *Eucalyptus* is also an important species for bioenergy plantation because of its propagation ability through coppicing, and short rotation age. Establishment starts with planting, and the stand is harvested every 6 years and regenerated by coppicing. The production cycle of *Eucalyptus* comprises establishment (soil preparation, planting and fertilization), management operations, harvesting and transportation to the end.

Apart from superior genetic quality of the planting stock, site quality of the land, adaptability of the clones to specific sites, implementation of improved package of practices and effective protection of plantations from damage by pests, diseases and cattle are important factors, which determine the overall productivity of the plantations. Therefore, the Company developed improved package of practices for raising and maintenance of clonal *Eucalyptus* plantations and demonstrated benefits of the same to the farmers. These plantations are harvested in 4 - 5 years cycle, one among the shortest maturity cycle in the world. Because the E*ucalyptus* tree coppices after felling, it is possible to obtain more than one harvest from a single tree. Study of soil profiles and analysis of soil samples is carried out to match adaptable clones to the planting sites.

Deep ploughing of the soil with disc plough or mould-bold plough in both directions is recommended for preparing the fields for transplanting of clonal saplings. Spacing of 3 x 1.5 m is recommended for production of poles and pulpwood, and larger spacing is desirable for production of timber from clonal *Eucalyptus* plantations. Transplanting in 30 x 30 x 30 cms. pits is carried out after the onset of the monsoon rains so that plants establish and grow well benefiting from the good moisture availability throughout the monsoon rains. Soil in and around the planting pit is treated with 2 ml of chloropyriphos in 1 litre of water to prevent damage to the young clonal saplings by termites during the critical establishment stage. Cultural practices recommended include timely weeding and soil working, protection against damage by insect pests and cattle and raising of leguminous or any shallow rooted crops in between the 3 meter wide planting rows. As *Eucalyptus* is heavy feeder of nutrients like N, P, K and Ca and most of the soils in India are deficient in nitrogen and phosphorus, application of fertilizers to supplement availability of these deficient plant nutrients is recommended. Based on the soil test reports application of P and Ca has to be given as per requirement. Soil and water conservation measures like raised field boundaries and staggered trenches are recommended in well-drained planting sites for holding the rainwater. For block plantation the distance between the trees 3 meters and with in rows 1.5 m which hold 2222 plants per ha and allows raising of intercrops in first two years in the cycle of 4 year rotation period. Intercrops such as chilies, cotton, tobacco, black gram, green gram are widely grown with *Eucalyptus* during the initial years.

Biomass Production of Clones

Eucalyptus plants have a lot of variation that results into lower biomass productivity. It has been found that in seedling plantations, 67 per cent inferior trees produce 33 per cent of the total volume, while 33 per cent superior trees contribute 67 per cent of the volume. The clonal plants have higher productivity due to better genetic quality and uniformity. In Congo, Brazil and Papua New Guinea, clonal plantations of *Eucalyptus* have produced 70-90m^3 ha^{-1} yr^{-1}. The productivity of clonal plantations raised under rain fed conditions has given yields varying from 20 to 44m^3 ha^{-1} yr^{-1} compared to 6-10m^3 ha^{-1} yr^{-1} of seed route plantations. Comparative growth data of various clones, in one of the clonal testing area, is given in Table 1.

Major gains in productivity of *Eucalyptus* plantations have been achieved in a short time span of 15 years through applications of vegetative propagation and cloning techniques for gainful exploitation of existing useful variation. Development and commercial scale deployment of locality specific, high yielding, fast growing and disease resistant clones of *Eucalyptus*, traditionally propagated through seed, has been successfully achieved by the Company. The productivity of clonal plantations raised under rain fed conditions has given yields varying from 20 to 44 m^3 ha^{-1} yr^{-1} compared to 6-10m^3 ha^{-1} yr^{-1} of seed route plantations (Lal and Kulkarni, 1992). However, many farmers have redefined productivity standards by achieving unprecedented record yield of 50 m^3 ha^{-1} yr^{-1} (Table 2).

Table 1. Growth data of eight years clones at Bhadrachalam

S.No.	Clone	GBH (cm)	Height (m)	Vol/ha UB m^3	CAI Vol/ha (UB,m^3)	MAI Vol/ha (UB,m^3)
1	288	58	21	334.1	55.9	41.8
2	6	60	20	321.0	40.3	40.1
3	286	57	20	313.2	40.9	39.1
4	284	54	20	278.3	35.2	34.8
5	285	54	19	262.2	28.8	32.8
6	277	53	17	234.2	25.2	29.3
7	275	51	19	235.1	28.0	29.4
8	3	50	19	227.9	26.0	28.5
9	274	47	19	204.0	23.3	25.5
10	269	49	17	193.0	21.8	24.1
11	276	49	18	188.9	15.5	23.6
12	271	47	18	185.3	22.8	23.2
13	283	46	17	164.1	31.9	20.5
14	268	47	17	165.3	19.0	20.7
15	270	41	16	130.1	8.3	16.3
16	SC	36	14	53.1	0.0	6.6

1. Volume in cubic meters (without bark) calculated based Regression Equation $V = 0.00258 + 0.0281\ G^2H$; 2. Spacing 3M x 2M ; 3. No. of saplings planted per treatment 9 with 3 replications; 9. GBH = Girth at Breast Height; CAI = Current Annual Increment; MAI = Mean Annual Increment; Vol. = Volume;

Economics of *Eucalyptus* Based Agroforestry Systems

The combination of agricultural crops with *Eucalyptus* trees for pulpwood production can bring a higher profit than pure plantings of either. The profitability of *Eucalyptus* planting by individual farmers varies with the farm gate prices and yields of the trees, which in turn depend on the quality of the soil, the spacing, and the technology of production. The opportunity cost of the land is an important factor affecting the net return to the planters. Under the base case, we have used the net return of inter- crops like chilies, cotton, Green gram, black gram, upland rice on land with fairly poor soil. Cost of cultivation of 1 ha of *Eucalyptus* clonal plantation is presented in Table 3,4,5 & 6**.** For calculating the estimated returns of the *Eucalyptus* based agroforestry systems the average yields of the crops (chilies, cotton, black/green gram and paddy) of the Bhadrachalam area of Khammam district of Andhra Pradesh were taken. Similarly the average *Eucalyptus* yields of the region were taken for calculation of gross and net returns. The prevailing labour and material costs as of June, 2009 were taken for calculations.

High yields combined with better quality of produce and lower per unit production costs have improved profitability of clonal *Eucalyptus* plantations substantially. Because of better soils, adequate irrigation facilities and more progressive farmers, productivity of clonal *Eucalyptus* plantations is likely to establish new records. Farmers can expect on an average net returns upto Rs.3, 00,000/ ha^{-1} at 4 years rotation from irrigated clonal *Eucalyptus* plantations assuming yield of 150 tonnes and current farm gate price of Rs.2000 per tonne for *Eucalyptus* logs. No wonder that clonal farm forestry plantations of *Eucalyptus* are emerging as an attractive alternative land use option offering tremendous opportunities for diversification of agriculture.

Based on cost structure, yields, and farm gate prices, it was found that larger-scale planters are likely to receive a higher profit than the smaller-scale planters. While large-scale planters make a healthy profit of Rs 0.2 million per year ha^{-1}, small-scale planters with low-cost credit from the agricultural banks, just break even. Our findings support the general belief that tree planting is usually a business for relatively wealthy farmers, who have large enough land holdings and the capital to diversify their farming activity and experiment with new crops. Small farmers find it difficult to adopt tree growing because of the tree's lengthy production period and the high initial establishment cost. The lack of capital and small land holdings make it difficult for small farmers to diversify their cropping patterns. Larger holdings, more farm assets, higher off-farm income, and access to low-cost credit allow larger planters a better chance to accept the risk of adopting new crops with a relatively long gestation. To over come the financial burden of small farmers, they can adopt agroforestry models which allow growing of intercrops along with the trees crops which can fetch some immediate returns in the first two years.

Table 2. Productivity of *Eucalyptus* clonal plantations in agroforestry

S.No	Name of the farmers	*Village*	District	Age (Months)	Soil type	IRR/RF	Clone no.	Survival %	Spacing (M)	Vol ha^{-1} (UB,CUM)	CAI	MAI
1.	Seshaiah	Lingamguntla	PKM	63	Sandy	IRR	10	96	3.0 x 1.5	217.76	38.96	41.48
2.	Sitaramaiah A	Gullapally	PKM	51	Black	RF	128	98	3.0 x 1.5	170.53	42.93	40.12
3.	Reddy D.CH	Nelaturu	PKM	50	Red	IRR	3	99	3.0 x 2.0	150.00	35.50	36.00
4.	Reddy D.CH	Varagani	GNT	53	B. Cotton	IRR	10,52,71	92	3.0 x 2.0	125.79	58.22	28.48
5.	Ranga Rao V	Yanamadala	GNT	41	Red	RF	3	67	3.0 x 2.0	145.51	60.11	42.59
6.	Sambasiva Rao P	Unnava	GNT	42	B. Cotton	IRR	3,6,7,128,130	96	3.0 x 1.5	134.47	77.81	38.42
7.	Venkata Reddy D	Nimmalagudem	WG	42	Sandy Loam	IRR	3	95	3.0 x 1.5	120.74	44.84	34.50
8.	Laxman Rao	Jangareddygudem	WG	48	Sandy	RF	3,7,10,27	98	3.0 x 1.5	129.21	54.56	32.30
9.	Koteswara Rao S	Pothuru	GNT	40	B.Cotton	RF	130,	83	3.0 x 2.0	133.23	98.23	39.79
10.	Koteswara Rao Ch	Palapadu	GNT	41	Red	IRR	130	52	3.0 x 2.0	161.04	107.44	47.13
11.	Balakrishna M	Veerabhadravaram	WG	24	Red	IRR	3,10	98	3.0 x 1.5	83.79	31.84	41.86
12.	Ramakrishna T	Bitragunta	NLR	27	Red	RF	3,	52	3.0 x 1.5	71.41	21.31	31.74
13.	Raghava Reddy G	Lingampalli	NLR	27	Red	IRR	10	98	3.0 x 1.5	64.83	30.63	28.81
14.	Mohan Reddy	Leguntapadu	NLR	22	Black	RF	3,7,130	100	3.0 x 1.5	54.16	36.20	29.54
15.	Srilakshmi Ch	Tenamadala	GNT	15	Red	IRR	105,130	99	3.0 x 2.0	32.53	32.53	26.02
16.	Krishnaveni K	Santavelluru	NLR	12	Red	IRR	3,10,130	99	3.0 x 1.5	30.83	30.83	30.83
17.	Madhusudhan Rao Ch	Nellipaka	KMM	27	B.Cotton	IRR	3,10,130	94	3.0 x 2.5	52.33	30.53	23.26
18.	Ramaraju G	Pochavaram	KMM	40	B.Cotton	RF	128,3,7,15,8	99	3.0 x 2.0	100.47	44.72	30.14
19	Butchiramaiah MV	Nandigama	KMM	64	B.Cotton	RF	6,10,3,8	87	3.0 x 2.0	168.83	70.68	31.66
20.	Chandrasekhara Rao TV	Venkatareddypeta	KMM	40	Alluvial	RF	128,116,3,6,7,130	98	3.0 x 2.5	103.18	63.72	30.96
21.	Bhaskar Rao T	Pochavaram	KMM	52	B.Cotton	IRR	3,10	99	3.0 x 2.0	146.01	73.76	33.69
22.	Bhaskar Rao T	Pochavaram	KMM	40	B.Cotton	IRR	3,7,130	97	3.0 x 2.0	132.52	78.52	39.76
23.	Subba Raju G	Pochavaram	KMM	29	B.Cotton	IRR	3,7	99	3.0 x 2.0	67.31	43.31	

PKM – *PRAKASHAM*; KMM – *KHAMMAM*; NLR – *NELLORE*; GNT – *GUNTUR*; WG – *WEST GODAVARI*

Table 3. Economics of *Eucalyptus* based agro forestry systems with chillies as intercrop (ha^{-1})

Crop	First year (chillies)	Second year (black gram/ green gram)	Third year	Fourth year	Total
Chillies (irrigated)					
Cost of cultivation	70625	70978	71333	71690	284626
Gross returns	90000	90450	90902	91357	362709
Net returns	19375	19472	19569	19667	78083
Chillies with *Eucalyptus* (irrigated)					
Cost of cultivation	83779	17117	12697	12933	126526
Gross returns	75000	11306	—	300000	386306
Net returns	-8779	-5811	-12697	287067	259780
Eucalyptus (irrigated)					
Cost of cultivation	32154	12469	12697	12933	70253
Gross returns	—	—	—	300000	300000
Net returns	-32154	-12469	-12697	287067	229747

Table 4. Economics of *Eucalyptus* based agro forestry systems with black gram/green gram as intercrop (ha^{-1})

Crop	First year (black gram/green gram)	Second year (black gram/ green gram)	Third year	Fourth year	Total
Blackgram /green gram (rainfed)					
Cost of cultivation	9625	9673	9721	9770	38790
Gross returns	11250	11306	11363	11420	45339
Net returns	1625	1633	1641	1649	6549
Black gram/Green gram with *Eucalyptus* (rainfed)					
Cost of cultivation	33029	10836	6384	6589	56838
Gross returns	11250	11250	—	200000	222500
Net returns	-21779	414	-6384	193411	165662
Eucalyptus (rainfed)					
Cost of cultivation	25904	6188	6384	6589	45065
Gross returns	—-	—	—	200000	200000
Net returns	-25904	-6188	-6384	193411	154935

Table 5. Economics of *Eucalyptus* based agroforestry systems with cotton as intercrop (ha^{-1})

Crop	First year	Second year	Third year	Fourth year	Total
Cotton (rainfed)					
Cost of cultivation	26250	26381	26513	26646	105790
Gross returns	30000	30150	30301	30452	120903
Net returns	3750	3769	3788	3807	15113
Cotton with *Eucalyptus* (rainfed)					
Cost of cultivation	46654	9203	6384	6589	68830
Gross returns	30000	11250	—	200000	241250
Net returns	-16654	2048	-6384	193411	172420
Eucalyptus (rainfed)					
Cost of cultivation	25904	6188	6384	6589	45065
Gross returns	-	-	-	200000	200000
Net returns	-25904	-6188	-6384	193411	154935

Table 6. Economics of *Eucalyptus* based agroforestry systems with paddy as intercrop (ha^{-1})

Crop	First year	Second year	Third year	Fourth year	Total
Upland paddy (rainfed)					
Cost of cultivation	8100	8141	8181	8222	32644
Gross returns	18000	18090	18180	18271	72542
Net returns	9900	9950	9999	10049	39898
Upland paddy with *Eucalyptus* (rainfed)					
Cost of cultivation	28404	8680	4869	5066	47019
Gross returns	9900	9950	—	200000	219850
Net returns	-18504	1270	-4869	194934	172831
Eucalyptus (rainfed)					
Cost of cultivation	25904	6188	6384	6589	45065
Gross returns	—	—	—	200000	200000
Net returns	-25904	-6188	-6384	193411	154935

As the Government of India has already launched a massive program of watershed development, linkage of agroforestry as an integral part of this program will not only provide an opportunity to enhance biomass production, but also improve the profitability. Through soil and water conservation, green manuring, agroforestry and integrated crop protection, the yields of inter- crops can be substantially high, till the inter crops are affected by the shade. Such tree based farming systems have been highly effective in preventing migration of rural families and supporting livestock husbandry to enhance their income by 35-40 per cent. Each hectare of clonal plantation with productivity of 20 m^3 ha^{-1} yr^{-1}. can produce enough fuel wood and small timber to conserve 20 ha natural forests. Reforestation of degraded forest lands, devoid of tree cover, with high yielding clonal plantations can restore this timber of local communities. This will help minimizing biotic pressure on the natural forest and conserve the rich biodiversity.

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Private Sector in Short Rotation Forestry: Opportunities and Challenges

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Abstarct: Forestry, unlike agriculture sector in India, has traditionally been associated with the government sector. Forest resources including approximately 22% geographic area & vegetation associated therewith; professional & technical workforce- one of the largest in the world, and the forest operations for conservation & controlled harvest of forest produce are strictly regulated by numerous central and state laws enacted from time to time. Of late, the private sector (PS) has emerged as a leading player in promoting short rotation forestry (SRF) outside government controlled forests in different parts of the country. The efforts of WBI (wood based industry), in facilitating growing of high yielding plantations of fast growing trees (FGTs) with the help of farming community leading to significant increase in tree culture outside government forests & the increased wood availability produced therefrom, are largely recognized and appreciated. Increased engagement of wood based industry in this new endeavor is a dire need to sustain their business by securing raw material on drying the traditional raw material sources and a couple of them have been successful in their endeavors. A few of them look it as an opportunity of corporate social responsibility (CSR), whereas, in a limited cases, it has developed as an independent business. Promotion of plantation schemes through public money during 1980's and 90's, purely a business opportunity, vanished the same pace of expansion, on tightening the regulations. The presence of private sector in SRF is limited to the production and supply of planting stock of genetically improved clones for their growing by the farming community, R&D on developing new clones of FGTs & their integration with the planting stock production & supply systems, and in public private partnerships (PPP) for procuring the wood produced therefrom. Inability of private sector to hold land for raising plantations, under the land ceiling limits which are not even at par with horticulture sector, has been the most limiting factor for its direct engagement in plantation activity. Tense competition in wood based industry to secure raw material from other's promoted plantations calls for wood based industry to develop their catchments on the pattern of sugarcane industry and resolve this issue. Tree culture on farm land is purely an adhoc opportunity and arrangement,farmers continue to grow trees so long they get remunerative wood prices better than other land use production options. Government laws and regulations on land, labour, tree harvest & transit, and imports & exports of farm grown wood need a fresh look for creating a favorable environment for long term stability in this surging sector. The government sector also needs to create a healthy environment for FSC (Forest Stewardship Council) certification of farm grown forests- a unique opportunity for both the industry & the farming community, and also the need for finalization of the procedures for registration of tree clones under the Protection of Plant Varieties and Farmers Right Act 2005. The role of this sector in indirect carbon emission reduction through production and substitution of firewood for fossil fuel, locking of carbon in wood products need national and international recognitions.

Key Words: Poplar, Agroforestry, Adoption, Private sector, Planting stock, Employment

Wood based industry (WBI) has traditionally been developed with the subsidized and committed supplies of wood from government forests. Timber harvest and its supply to the industry were almost curtailed during the last two decades when many states stopped green felling from government forests. Some units facing acute shortage of wood for their manufacturing facilities towards the end 21st century, started promoting plantation activities including R&D on SRF species as a long term strategy for sustained availability of raw material. Wimco in the north and ITC in the south started their forestry programs four and two decades back, respectively, whereas, many others especially paper and pulp industry emulating the success stories of these two companies started their own forestry programs later on. In a short span of less than two decades many of the private sector(PS) players, having wood as the main raw material, have created reasonable plantation resources in and around their catchments to augment much needed wood raw material for their manufacturing units. Public Sector now supplies major share of the planting stock of some of the fast growing species like poplar, eucalypts, su-babul, casuarina and a few others. This is despite the fact that the government is by far the most dominant player in the forestry sector and directly own and manage about 97 per cent of all forests, whereas, more than 90 per cent of India's wood based products are manufactured in private sector.

Demand and Supply of Wood and Wood Articles

Till recently, the government forests were the main source of wood raw material for meeting the requirement of wood based industries (WBI) and also that for domestic and governmental projects like railways, construction, etc. The government sector now discourages use of timber even in the construction industry and is substituting it with other alternatives like steel, aluminum etc. WBI cannot survive without wood which is the basic raw material for their operations. The gap between its demand and supply is widening and the scenario is fast changing with increased wood requirement and reduced supply from the existing sources. FAO's reports (The state of World's Forests) on consumption of wood and wood related products, indicates that in a decade period from 1999 to 2009, its consumption has constantly increased. Maximum increase is seen in wood based panels, and pulp and paper during this period.

National Forestry Action Program indicates a negative wood balance of 599.6 Mm^3 by 2015. Other estimates and documentations also reveal a similar trend. Rai and Chakrabarti (1996) reported timber production of 43 Mm^3 (12 Mm^3 from forests and 31 Mm^3 from farm land) and 199 Mt firewood(101 Mt from forests and 98 Mt from farm land). Total wood production from the governmental forests of 23 states and UTs is reported as 1.873 Mm^3 roundwood and 2.094 Mm^3 firewood (ICFRE, 2003). The annual official timber/log trade through forest corporations is estimated to be 0.6 to 1.0 Mm^3 by Behera (2005). This is against a fuelwood consumption of 306.352 Mm^3, industrial wood as 27.231 Mm^3, sawn wood as 14.943 Mm^3, wood based panels as 2.758 Mm^3, pulp and paper as 4.550 Mt and paper and paper board as 5.301 Mt (FAO, 2009).

Imports have now become one of the essential source for meeting the raw material needs of the WBI. Timber (in log or sawn form) and pulp have been placed under Open General License (OGL). Imports are in the form of logs, chips, wood pulp, waste paper and other wood related products. Import of unfinished timber is encouraged and there are higher tariff rates on finished and semi-finished value added wood products. Imported timber is mostly used by the building and construction industry, plywood industry and by a few other sectors. The imported timber has also benefited a large number of saw mills, particularly in urban centers and in the vicinity of sea ports. Presently, the imported wood is comparatively cheaper than locally grown timber and is being imported from numerous countries around the world. Imports of wood and wood products are increasing with increase in the domestic consumption of wood and its inadequate availability in the country.

Import of wood and wood related articles in quantity and value terms is available in the official website of Ministry of Commerce, GoI. (MoC n.s.) which shows that the imports of all the wood and wood articles except firewood are increasing at a fast rate. Maximum increase is seen in import of industrial wood and paper products. The author while visiting Kandla port in Gujarat, one of the main port for the import of wood, observed that this port alone is receiving around 0.1 Mm^3 wood each month, which is further being dispatched throughout the country for industrial and domestic consumption. The import of radiata pine in Kandla port alone constitutes around 75 per cent (of the imported wood) mainly from New Zealand and Australia.

Private Sector in Short Rotation Forestry

Private sector is now delicately engaged in promoting SRF on farm land. Private sector (PS) is unable to raise its own plantations for raw material production since the land laws do not permit holding of land over certain limits, which are different in different states and extremely low not even at par with other horticultural trees and other plantation species like tea, coffee, etc. In Uttar Pradesh and Uttrakhand, a farmer can hold 12.5 acre land for the practice of agroforestry under the ceiling laws, whereas, this limit is 40 acres for horticultural orchards. Agroforestry, therefore, needed to be treated at par with atleast horticultural orchards under land ceiling laws. PS is therefore engaging in indirect activity of promoting SRF by (1) producing quality planting stock, (2) conduct R&D on tree improvement, nursery production, and (3) provide technical know how to grow field plantations and also in developing agriculture crops in association with tree species.

A major share of the planting stock of poplar, eucalypts and a few other species planted by farmers and even a little by the government institutes is now made available by the private sector. More than 50 M seedlings were being planted by just 12 PS companies (Saigal *et al.,* 2002). Pande and Pandey (2004) further reported planting of around 75 M saplings by 13 PS companies. This figure appears to have increased now since Wimco now grow 5 M poplar saplings and 2 M plants of other tree species in comparison to just 2.7 M poplar saplings shown in their report of 2002 and 2004. Further, some other companies not included in their list have also started supplying planting stock in and around their command areas. Unorganized sector that includes individuals on separation from plantation companies, farmers and even small private companies have now started significant contribution in planting stock production and their supply to the tree growers. Many of them started this activity as a business opportunity for them in remote villages where employment opportunities are very limited. For example, Ex- Wimcoites (including many workers) on separation from the company took up the business of growing and selling poplar saplings and their contribution is more than that of the organized sector including Wimco. Government sector including State Forest Departments, State Agriculture Department, State Agricultural Universities and Forest Rsearch Institutes hardly grow poplar nurseries for supply to the farmers and these collectively have insignificant contribution in the total production and supply of poplar saplings to the tree growers.

The share of planting stock supplied by the private sector and the plantations promoted thereof are increasing since tree growers have now started better appreciating the quality of the planting stock supplied by the private sector from which they are able to realize better returns on harvest and sale. Wimco has become a brand name for poplar clones and their planting stock and ITC for eucalypts clonal planting stock. Numerous growers recognize Wimco as poplar company since the company has been associated with the farming community for the last four decades and established poplar on these new territories. In India, eucalypts is one of the main species planted on the farm lands and its planting especially that of clonal stock is increasing in many states especially after the heavy infection of gall insect throughout its growing locations. *Eucalyptus tereticornis* and *E. cameldulensis* are largely planted eucalypts with seed origin planting stock in India which get heavily infested with gall insect. Plantations of some eucalypts clones have shown fairly good tolerance to this pest and their plantations are increasing post-gall infestation. In Andhra Pradesh alone, approximately 40 M clonal eucalypts is planted each year. In Anand, Mehsana and some other districts of Gujarat where planting of trees on boundaries of fields is the main form of agroforestry, the density of trees per unit area is increasing as a result of creation of more boundaries on division of land.

India with 3.92 million ha eucalypts plantations (Dhiman *et al.,* 2010) and 50 per cent of the global poplar based agroforestry (Ball *et al.,* 2005) leads the world atleast in the culture of these two trees mainly on farm land. Private sector has played a significant role in this achievement. Wimco and ITC have individually created 0.1 Mha poplar and eucalypts plantations, respectively, through supply of quality planting stock from their nurseries till date. The major clonal planting stock of eucalypts now grown in the country is from ITC's clones and poplar from Wimco's clones. These two companies are undisputed leaders in R&D, clone development and in the production and supply of quality planting stock of eucalypts and poplar. Many private sector companies especially that of paper and pulp, state forest departments, other government institutions like universities and research institutes also contributes in R&D on eucalypts and a few other species, whereas, Wimco is the only private sector player baking the poplar program through its R&D and extension units.

SRF, in India, is now redefining the production forestry, some tree species like *Leucaena leucocephala* being harvested at a very short rotation of two years for pulp wood, whereas, some others like *Populus deltoides* at less than 4 years for timber production in some locations. Some tree species like poplar, kadam (*Anthocephalus cadamba*), drek (*Melia azedarach*), etc are being better produced on agricultural holdings than that on forest land. Cultural operations in agricultural crops help these trees grow very fast. It is possible to harvest very high wood yields on good soil sites with better drainage and frequent earth working. The maximum wood production that has ever been recorded in India has been reported from the farm grown poplar, eucalypts, *Leucaena, Casuarina*, etc. The production forestry is therefore now shifting from the government forests to non- forest areas especially commercial agroforests. Eucalypts in the Tarai Region of Uttranchal has been reported to yield true volume upto 66.75 m^3/ha/year at 10 years rotation when grown on farm land (Dhiman, 2007), whereas, poplar under similar conditions in Punjab has been reported to yield timber upto 58.39 m^3/ha/year at 5 years rotation (291.98 m^3 or 248.324 t/ha in five years) (Dhanda and Verma, 2005). Poplar and eucalypts planted in agroforestry are producing around 20-30 m^3 timber/ha/year on farm lands, which is very high productivity in comparison to 0.5 m^3/ha/yr from the government forests. A very high productivity of agroforestry plantations is a motivating factor for making it economical remunerative to its growers.

Plantations of FGTs on farm fields now constitute an important wood resource and has significantly increased the wood availability for the industry and local people. Paper and pulp industry which was largely dependent for its raw material procurement on government forests till recently was procuring around 76 per cent (approximately 35.85 Mt in 2004-05) from farm forestry sector as against a procurement of 11.32 Mt pulp wood from government forests during 2005-6. This balance has now further tilted towards wood supplies from farm land. ITC has procured 99.41 per cent of its wood requirement from farm forestry during 2009-10 (ITC, 2011). Wicmo and other poplar based industry in the North India are already based on farm grown poplar. Veneer, plywood, match and many other wood based industries which once dependent on the government supplies are also fully supported with raw material from farm grown trees. In Kerala, almost all the wood supply comes from non- forest sources. While in 1965, 75 per cent of all wood supply came from forests, by 1993-94, the picture has completely changed and as much as 94.1 per cent of the wood came from the non forest sources. Home gardens contributed 83.1 per cent of wood, estates 8.2 per cent and imports 2.8 per cent. In case of the industrial wood, home garden provided 47 per cent, estates 29.7 per cent, imports 13.7 per cent and government forests only 8.7 per cent (Saxena, 1998). FSI (2009) documented 5508.456 M number of trees outside forests (ToFs) holding 1599.57 Mm^3 wood volume as against 11909.8379 M number of trees with 4498.66 Mm^3 wood volume in forest land. It is evident from these figures that the ToFs hold around one third of the total wood volume held in trees inside forests. Further, TOFs are in the fast mode of production and harvest than that of trees inside forests, which are mostly under conservation plans. Based on the calculations of TOFs being harvested on short rotation, it is inferred that these are meeting over 93% of requirement of the industrial wood and almost major part of domestic wood requirement.

The impact of private sector in promoting SRF is visible all around. The industry procures wood from the plantation grown in the respective command areas of the factories. Their extension staff is located near the farming sites to provide technical knowhow to the growers. R&D in many cases is well integrated and synchronized with farm operation on farmer's fields. The results of such testing are realistic since they are grown with the actual agronomical inputs given by the farmers to their normal crops and these enhance the acceptability of the field research. Dedicated and responsible human resources engaged by the private sector plays a key role in the success. This makes the main difference in the extension approach in PS when compared with that of government departments in which case tree growers still show inhibition for free and fare dialogue with the government staff. Wimco was the first private sector company that created an extension wing in 1977 to promote poplar plantations in North India, the company still maintains fairly large extension human resource through out the poplar growing region and elsewhere for the promotion of tree culture on farm land. Many other PS companies have now created similar wings for developing similar interface with the farming community. Some low volume units in North India have started taking land on lease and growing trees mainly poplar for their own consumption since their wood requirement is small and they can meet it this way. In some other locations like Mehsana and Anand districts of Gujarat the saw mill owners are believed to contribute money for growing planting stock procured from the forest department which is than supplied to the farming community at subsidized or low prices.

CHALLENGES

The role of some private sectors in developing SRF for wood procurement is widely recognized and appreciated. PS has ably demonstrated that public private partnership (PPP) is also possible for long gestation crops like trees. Deshpande (2005) while reviewing the Wimco-NABARD poplar scheme on PPP mentioned that the satisfaction level of the farmers participating in the scheme was better than the expectations. Despite, there remains many challenges for the long term sustainability of wood from this highly sensitive venture of growing trees on farmers fields. These are briefly discussed below.

Sustenance of wood availability. The majority of wood based industries in different states had undergone difficult times 2002 onward when many units were suddenly made to shut down pending development of procedure for their regularization. The industry was allowed to establish and operate without registration as the existing laws were interpreted during their establishment that way. Central Empowered Committee (CEC) under the supervision of the Hon'ble Supreme Court of India is closely monitoring the industry and has now finalized the procedure for confirming the fresh registration of new units and that of the unregistered old units based on the documented additional wood availability. An undertaking is also taken from the new units that they will make their own arrangement of wood of selected tree species for their product manufacturing and will not demand any wood from the state governments.

This mode of wood production through farmers has been reasonably successful for both the wood based industries and growers with some exceptions. WBI is now completely relying on the farming community for providing wood from their farm land. Import of industrial wood, though constantly rising, this mean is meeting a small portion of total requirement. Both these means appear to be adhoc arrangements. Farmers grow trees on their farm land, if market conditions favour remunerative returns- atleast better than that from the traditional agricultural crops. The present level of farm land use favors tree culture because of very good market prices of wood produced thereon. Better appreciation in returns associated with agricultural crops on developing scarcity of food or on introduction of high value crops or decline on wood prices lead to decline in tree culture. This affects wood availability and could have a direct impact on functioning of wood based industry. The present low costs of imported wood in comparison to locally grown wood, and also that of finished and semi-finished wood products could also affect the present activity of wood production leading to long term negative impact on wood based industries.

Import and export barriers. Poplar- a major raw material for panel industry, is considered as agricultural produce in India. Poplar wood import and exports therefore are viewed as agriculture produce and is not readily allowed. The prices of poplar wood have already recorded all time high rates in all the local wood markets. Recently, some industrial units closed down their operations, high costs of locally available wood were making their business uncompetitive and unsustainable. The free trade in poplar wood similar to other tree species could have allowed the industry to get import of this low value wood available in many other countries to sustain wood based industry business in India. Similarly, when the prices of poplar wood were very low during 2002-2005, the farmers were not getting its prices even at par with that from agricultural crops. Export of its wood during that period could have made farmers to realize value for their tree produce and to keep them tempted to remain in its culture. The present crisis of non-availability of its wood as a result of very low planting during 2003-2006 could have been avoided. The policy on import and export on farm grown timbers thus needs to be revisited periodically to balance and readjust the gap between demand and supply of wood.

The import of fresh wood also carries insects and pathogens and therefore is a carrier for such invasive species. Wood reaching Indian ports needs to be free from insects and pathogens and thus requires its fumigation and a quarantine certificate attached therewith. The facility of fumigating wood is not available in many wood exporting destinations around the world and there have been some instances when the wood without quarantine certificate was not accepted in Indian ports. Fumigation of wood in ships and containers before unloading at ports is very costly on account of treatments and halting charges of ships. The present fumigation measures appear to provide superficial treatments and the wood born pathogens and insects especially in fresh wood are difficult to eradicate with these treatments. These barriers have started affecting the easy wood imports that existed a couple of years back.

Shifting of wood based industries towards wood sources. Abundant poplar wood availability in northwestern Indian states encouraged panel industry to shift and expand their manufacturing base in this region (Dhiman, 2004) after their businesses were adversely affected as a result of Supreme Court ruling in Goda Varman v/s. Union of India matter. This shift has though provided good opportunity for these new locations to develop plantations and panel industry base, it uprooted most of the wood based industries from northeastern states. Northeastern region has good rainfall and deep soil conditions with excellent tree growing conditions. The wood based industries could have made to develop raw material for their industrial units in those locations rather than getting uprooted and shifted their manufacturing facility elsewhere. Poor wood raw material availability and its ever escalating costs in North India are now making this industry unviable in domestic and international trade. Imported wood, semi- finished and finished wood products are already reaching in the panel manufacturing base in northwestern India. The low cost imports of timber in Indian ports also facilitating expansion of wood based industry near those destinations. This approach of wood imports could be a serious threat for the established industry in the long run. Availability of wood for such industry even at port locations could be affected in the future on environmental regulations for cutting trees getting upper hand in countries exporting the wood. It is in the interest of wood based industry to draw a long term strategy for their operations and businesses.

Regional imbalances in wood production and usage. Wood being the main and costly raw material, its availability in the surrounding locations has been one of the deciding factor in the establishment and expansion of wood based industries. Traditionally, this industry developed near the wood availability around the government forests. With depletion of the committed wood supplies from the government forests and its increased availability on the farm land, WBI developed and expanded in clusters in many locations. For example, Yamunanagar in Haryana and Udham Singh Nagar in Uttrakhand have now developed large clusters for panel industry. These clusters not only receive wood from other locations within the states but are surviving on the wood receipts from the adjoining states. Escalating wood prices across the country and the state initiatives to develop their own WBI, are encouraging states to create barriers for movement of the wood to other states. There is increased demand from the local WBI for low cost wood. Presently, Haryana and Uttrakhand WBI cannot survive on the wood resources available within these states and their survival will be seriously affected if the inter-state movement of the wood is restricted. Uttar Pradesh, a major contributor to the wood supplies to both Haryana and Uttrakhand, has started raising voices for such barriers. CEC under the supervision of the Hon'ble Supreme Court has been reviewing each case of establishing new WBI based on the documented additional wood in that state.

Research and development limitations. R&D initiatives in PS on tree species are now four decades old. Wimco was the first company to initiate organized research on forest tree species outside government sector to develop poplar, euclaypts and other tree species of industrial and social importance. Later on, ITC-PSPD initiated eucalypts R&D

program which is also widely acknowledged as a successful initiative in developing new clones and their domestication. Further, some other WBI's especially paper companies started encompassing R&D in their forestry programs. Research on trees and plantations demand heavily on time, land and human resources. R&D in corporate houses is seriously affected for the want of land resources. New clones developed by the PS with limited resources have now entrenched in the farming systems. Some of the R&D inputs especially that on ecological, silvicultural and biotechnological aspects need large areas for experimentation. PS needs to provide special initiatives to hold increased land area for such experimentation. Premature release of tissue cultured poplar during 1990's, without proper field testing, performed much below the traditionally propagated poplar (Dhiman and Gandhi, 2010; Pande and Dhiman, 2010) and its culture has already caused loss of around Rs. 3000 crores to the growers.

Organizational support. There is no dedicated organization to provide developmental and research support to the tree culture on farm land. The activity is presently sand-witched and overlaps between agriculture and forestry sector with no clear cut mandate for either of them. Tree culture on farm land is not the same as is on forest land. It has been amply demonstrated that the productivity of poplar and eucalypts is much higher on farm land in association with agriculture crops than their sole growing on forest land. Tree harvest, marketing and trade for farm grown trees is now day to day activity. Many wood based industries purchase their wood requirement on daily basis. Even planting of some trees like eucalypts by the growers is staggered during the greater period of the year. The inventory of trees on the farmland and wood availability thereon is changing on day-to-day basis. Some unusual happening sometimes significantly disturb this continuum of wood production and harvest. For example, one misunderstanding on scope of the wood trade that was created on the closure of the WBI during 2002-2005 resulted in sharp decline in tree culture. The impact of low planting during that period on wood availability is continued to persist till date.

There is no organization to maintain and document tree inventory and capture the change. The only authentic database on tree inventory on forest and non forest land is monitored and developed by the Forest Survey of India. The latest FSI Status of Foress Report 2009 is based on 2006 imagery data (FSI, 2009). This database is inadequate to address the actual status after half a decade ago based inventory. Further, there is a lot of overlapping of inventory of farm grown trees with that of forest lands. For example, the FSI picks up all the areas (over 0.5ha) having inventory of trees (more than 10 per cent crown cover and 5m in height) as forest cover irrespective of the location in forest or non - forest land. Some of the planted trees on farm land quickly attains the crown cover of 10 per cent required to be picked up as forest. Poplar block plantations with around 500 trees per hectare attains 10 per cent crown cover in the first year itself (Dhiman, 2009) and qualifies for being picked up as forest. Thus, there appears to be a lot of overlapping causing variation in the actual tree cover on farm land than presented in the FSI report. It has also been realized that growers are not aware of many aspects of growing and trading trees including technical know how. The information barriers remain major issues in adoption of tree culture. An organization fully dedicated to ToFs could only handle these aspects effectively.

Felling and transit regulations. Felling and transit regulations on trees grown by the farmers have been one of extremely important constraints in the sale of farm grown tree produce. The issue has been widely discussed and debated numerous times. Ministry of Environment and Forests, GoI has understood to have issued the directions during 2004 to states for relaxing such regulations on certain tree species grown by the farming communities. This is a state matter and some state governments have relaxed felling and transit regulations on selected tree species grown by the farmers. However, situation has not improved in some states. The felling and transit regulations are still imposed on timber of such species, which are grown by the farmers but these do not exist in government forests and are not even grown on forest land. Felling permission is more complicated if the species is not listed in those notified either transit free or those requiring transit permission. For example, kadam which is grown by numerous farmers in North India is not listed in the state lists. Permission for felling and transit of this category of the tree is provided after these are verified by the Revenue, Forest and sometimes also from the marketing boards in Uttar Pradesh and Uttrakhand. Transit regulations are little more complicated in Uttar Pradesh. Similarly, felling of kadam in West Bengal requires approval from the District Magistrate based on a recommendation from a committee constituted for this purpose in the forest department. The committee comprising of forest official, pradhan of the area and a few other members recommend harvesting of the plantation raised on the farm land based on which District Magistrate provides the approval thereof. Government of Assam has notified rules for controlling, felling and removal of trees from non-forest areas in 2002 wherein tree growers are required to register their plantations of some species with the State Forest Department (GoA, 2002). The process of obtaining felling permission in West Bengal takes approximately 3 to 4 months under normal conditions. The entire process of procuring this permission is tiring, frustrating, time consuming and also financially taxes the permission seekers.

Emerging international and national trade barriers. Business in wood related products is getting influenced by the international and national trade barriers. Many european and western countries are now demanding Forest Stewardship Council (FSC) certificate for import of forest based products to ensure that the timber used for manufacturing such products was not obtained by harvesting wood from the natural forests. This is being followed to ensure that the sustainability of the forests is maintained by using the wood from only the plantations meant for this purpose. Wood based industry in India has already started actively involvement in this venture. There are already 132 FSC (mostly CoC-chain of custody and a few on CW-Controlled Wood) certificates for 162 sites available till now and many more are in the pipeline. FSC certificates are available in different categories varying from CoC to CW to Management certificates. Most of the certificates available till date are those in CoC and CW categories. The procedure for getting FSC certification are complicated and are based on numerous conditions prevailed in other countries than that exist in India. Our Government needs to develop Indian system and procedures required for such FSC certification to provide some relief on this emerging aspect.

Forest plantations are considered as a potential mean for carbon sequestration. India has already shown its presence in A&R projects under CDM mechanism by registering three projects, first of which was initiated by the PS-ITC. A&R projects need land resources to grow forest plantations and conserve the carbon in wood and soil. Unfortunately these procedures developed for land surplus countries have limited scope in India since land for this purpose is hardly available. Principals and procedures developed for A&R projects in surplus land countries are inadequately addressing the significant contribution of SRF plantations raised in India. The role of SRF atleast in generating huge quantity of firewood and as a mean of offsetting use of fossil fuel that will help in carbon emission reduction needs recognition by developing synergies with energy projects. India would be in disadvantage to keep its carbon emission reductions under check as per the international commitments once the rural population, a major user of firewood, start using energy efficient fossil fuels on their getting better rising standards with improved economical conditions. The present annual consumption of firewood is 302 m tones/annum in India. Firewood accounts from 20-30% of all the energy used in India and 90% of its is in the domestic sector. Therefore, firewood is more than just a commodity being consumed, supplied and processed and traded.

Inadequate efforts. Wood based industries is working on cut throat competition because of very high costs of wood that being the main raw material. Inadequate availability of it in many units compels them to explore its procurement from locations wherever it is available. Many units are encroaching the wood resources promoted by others in far away locations. In the recent past, wood has moved from north to south and east states since there was acute shortage in selected locations. In many locations, there is hardly any effort by numerous wood users and they merely encourage procurement of wood to their units from sources promoted and developed by others. For example, None of the major poplar based units in North India has direct contribution in developing poplar plantations and they use its wood promoted by mainly Wimco. The share of poplar wood use in Wimco is between 0.5-1 % of its availability in the entire poplar growing region and around 80% of it is used by the plywood industry without making any contribution in its plantations. Some of the new units have been given conditional registration that they will use only poplar and eucalypts wood in their units. Monitoring agencies need to prevail upon such units for having their direct involvement in plantation programs and also to recognize and appreciate those who are developing plantations for themselves and others.

The past experience of PS engaging in promoting tree plantation through public money has not been good. During 1980's and 90's, around 1000 companies mobilized between Rs. 100 billion to Rs. 250 billion from 2.7 to 15 million investors with an understanding of multiplying returns through growing trees (Saigal *et al.,* 2002). Most of these companies lacked in forestry base, wrongly convinced the investors regarding the better returns on their investment. There was no organization to guide the individual investors and growers against such unscrupulous activities and many unsuitable tree species were planted which ultimately resulted in their failure. There was also no regulatory mechanism for such companies and except for a couple of genuine corporate houses which kept their promise to the investors all others collected the investor's money and disappeared over night. Planting stock of numerous unsuitable tree species is still being supplied by some of the greedy nursery growers for making quick money out of this business and farmers only realize the mistake in venturing such activity after many years when they do not get the expected growth/returns from their planted trees.

The demand for registration of cultivars of forest trees has been rising for some time (Dhiman, 2006) under the provisions of The Plant Variety and Farmer's Right (2002) Act which is in place for nine years now. Varieties of agricultural crops are now being registered under this act, whereas, procedures are yet to be developed for forest tree species. ICFRE has started registration of the cultivars, which though does not have legal backing but is an documented acknowledgement of the efforts of the breeders. Registration of cultivars in ICFRE may help in their registration with the Plant Variety Authority. Yet, the PS and also the breeders in the government institutions needs to push up this issue to protect their rights as well.

CONCLUSION

There is a huge gap between demand and availability of wood in the country. The extremely high wood prices of local timber, increasing imports of timber, semi finished and finished products thereof and long term non-commitment on sustained availability of wood from any defined sources make this sector highly sensitive to these international and national trade barriers. PS endeavors in creating forest plantations with the help of farming community is a favorable development to bridge this widening gap. Further, opportunities to remain it engaged in this new adventure are enormous and based on the realistic need to secure raw material for their manufacturing facilities, corporate social responsibility, and business requirement. Private Sector pleads for creating an enabling environment by removing the barriers, engage with those Wood based Industries which still enjoys the fruits of wood availability created by others, establish an organization for making inventory and support system for tree culture on farm land, develop information base on tree culture for the benefit of the growers and industry and develop new Wood based Industries clusters to meet the increased demand of products. Such efforts will certainly help in further development of SRF for the benefit of the farming community, private sector and the country.

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Effect of Pre- extraction on the Pulping and Paper Making Properties of Short Rotation *Trema orientalis*

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Abstract: The depletion of the world fossil fuels, fluctuating prices and the increasing problem of greenhouse gas effects have strengthened interest for an alternate renewable raw material to replace petroleum products. Biomass provides a potential source of added-value chemicals. *Trema orientalis* is one of the fastest growing trees in the world, grows everywhere in Bangladesh, which may provide potential green products. At the 4 year age, the average height and DBH of *T. orientalis* are 12m 24cm, respectively. Chemical compositions of *T. orientalis* are 20-24% klason lignin, 22-23 % pentosan, 48-50% á-cellulose along with extractive, ash etc. *T. orientalis chips* were pre-extracted with water at 150 and 170 °C for various time. The pre-extracted liquor (PHL) was analyzed for sugars, lignin and acetic acid. The sugars, lignin and acetic acid in PHL were increased with temperature and time. Pulping of pre-extracted mass was carried out in kraft process. Inferior pulp yield and paper making properties were obtained when pre-extraction was done at higher temperature and time. Pre-extraction at 150°C for 1hours followed by kraft pulping showed comparable pulp yield, bleachability and papermaking properties with non-extracted *T. orientalis*, while pre-extracted liquor yielded 3.1% acetic acid, 1.9% lignin and 3.5% hemicelluloses on wood.

Key Words: *Trema*, Pulp & paper making, Pre-extraction

Considering climate change, the need for biofuels and bioproducts and the desire to obtain more value from the existing pulp industry has generated considerable interest for promoting the development of forest product biorefineries. A promising approach to configuring the forest product biorefinery is to fractionate and convert woody biomass into products including pulp, extractives such as tall oil, as well as a number of minor products, while the unused biomass fractions, including lignin and hemicellulose solubilized during pulping, which will add value through bioconversion to liquid transportation fuels and extract components. In the forest product biorefinery concept, pre-pulping extraction has been shown to make available hemicellulose components of the wood while preserving both the yield and quality of the pulp production. Recently pulp mills are considering pre-extraction of hemicelluloses prior to traditional pulping processes in an integrated forest biorefineries (Jahan *et al.*, 2009). In the commercial chemical pulping process, hemicelluloses are partly degraded and subsequently combusted in the recovery furnace of the pulp mill. But these hemicelluloses provide low heating value than lignin. Preextraction of the hemicelluloses prior to pulping would make these polysaccharides available for other applications, such as fermentation to ethanol or butanol (feedstock for bioenergy) or for conversion to other bioproducts (Wang *et al.*, 2010). Many studies have been carried out to extract hemicellulose prior to pulping (Yoon *et al.*, 2008 and Al-Dajani and Tschirner, 2008) in alkaline to a acidic range of pH. These pretreatments all share common features with chemical pulping that include chemically modifying and solubilizing a portion of the hemicellulose and lignin. Hot water pretreatment is a self-catalytic process with the mechanism of hydrolysis based on the cleavage of acetyl and uronic acid ether substitutions that result in the formation of acetic and other organic acids which further hydrolyze of polysaccharides to oligomers and monomers (Niemel and Aln, 1999), such that a hot water pretreatment will results in hemicellulose solubilised as a mixture of oligomers and monomers. Alkali treatment at moderate temperature is an approach for hemiccellulose extraction from wood chips prior to pulping (Al-Dajani and Tschirner, 2008).

Trema orientalis is one of the fastest growing trees in the tropical and temperate regions and produce wood that may be widely used by the forest industry (Jahan *et al.*, 2008 and Jahan *et al.*, 2010). This tree becomes mature as pulpwood within 3-4 years. At the 4 year of age, the average height and DBH of *T. orientalis* are 12m and 24cm, respectively. Pulp qualities do not vary within the entire region of Bangladesh (Jahan *et al.*, 2010). Wood production of *T. orientalis* per year per hectare is 2.5 times higher than Gamelina *arborea*, which is being presently used as pulpwood in Bangladesh. *Gamelina arborea* could be replaced by this species. This paper describes the water pre-extraction of *T. orientalis* prior to kraft pulping. The resulting prehydrolysate liquor (PHL) is characterized in order to find suitability of value added products and the effect of pre-extraction on the pulping and papermaking potential have been evaluated.

MATERIAL AND METHODS

Three 4 years old trees of *T. orientalis* were selected for this experiment. Two feet from top and bottom from the stem and 1 ft from terminal part of branch of these trees was discarded, remaining portion was debarked and chipped to 0.5 x 0.5 x 2 cm size for pre-hydrolysed pulping.

Prehydrolysis. The prehydrolysis was carried out in an electrically heated 20 litre capacity digester. Water prehydrolysis was done at 150 °C and 170 °C for different time. The wood to liquor ratio was 1: 4. The time required to raise maximum temperature was 50 min. After completing pre-extraction, digester was cooled by circulating in cold water and the liquor was drained for sugar analysis, lignin and acetic acid. The percentage of dissolved wood components were measured gravimetrically.

Lignin analysis. The dissolved lignin in the prehydrolysate was measured based on the UV/Vis spectrometric method at wavelength 205 nm (TAPPI UM 250) or 280 nm. At 280 nm furfural and HMF adsorption strongly interfere with the lignin absorption because their specific adsorption coefficients are more than tenfold higher than for lignin. At 205 nm wavelength furfural and HMF adsorption play only a minor role, therefore, the lignin concentration was measured at this wavelength.

Acetic acid. Acetic acid in the PHL was dehydrated by anhydrous sodium sulphate. 1 μL was injected into GC. Pure glacial acetic acid (GAA) was used as reference standard. Analysis of GAA was carried out on Gas Chromatograph model 14B, Shimadzu, Japan loaded with software Class GC-10 (version-20). The GC was equipped with Flame Ionization Detector (FID) and Capillary Column, FAMEWAX, dimension 15mX 0.25mm RESTEC. Before injection the column was conditioned at 180°C for about 2h for attaining thermal stability before use. The temperature of the column oven, injection port and detector were 180°C, 240°C and 250°C, respectively.

Solid and ash contents. The total solid content in the PHL was determined by drying at 105°C till to constant weight.

Sugar Analysis. The sugars in the pre-hydrolysate (PHL) and the acid hydrolysis liquor were determined by Ion Chromatography unit equipped with CarboPac ™ PA1 column (Dionex-300, Dionex cooperation, Canada and pulsed amperometric detector (PAD). Acid hydrolysis of PHL with 4% sulphuric acid was carried out at 121°C in an oil bath (Neslab Instruments, Inc., Portsmouth, N.H., USA) to convert oligosaccharide to monosaccharide. The PAD settings were E1 = 0.1 V, E2 = 0.6 V and E3 = -0.8 V. De-ionized distilled water was used as eluant with a flow rate of 1ml/min where as 0.2 N and 0.5 N NaOH were the column regenerant and post column detector's supporting electrolyte respectively with 1 ml/min flow rate. The addition of 0.5 N NaOH is necessary to maintain optimum detector sensitivity and minimize baseline drift for an isocratic separation.

Pulping. Pulping was carried out in same digester of pre-hydrolysis and pre-hydrolysed *T. orientalis* mass and non-extracted chips of 1500 g of oven dried (o.d.) was cooked. Pulping conditions of kraft were as follows:

- Active alkali was 18 per cent on oven-dry (o.d) raw material as Na_2O
- Sulphidity was 25 per cent
- Cooking time was 120 min at maximum temperature (170 °C). 90 min was required to raise maximum temperature (170 °C) from room temperature.
- Liquor to material ratio was 4.

After digestion, pulp was washed till free from residual chemicals, and screened by flat vibratory screener (Yasuda, Japan). The screened pulp yield, total pulp yield and screened reject were determined gravimetrically as percentage of o.d. raw material. The kappa number (T 236 om-99) of the resulting pulp was determined in accordance with Tappi Test Methods.

Evaluation of pulps. Pulps were beaten in a PFI mill at different revolutions and handsheets of about 60g/m^2 were made in a Rapid Kothen Sheet Making Machine. The sheets were tested for tensile (T 494 om-96), burst (T 403 om-97) and tear strength (T 414 om-98) according to TAPPI Standard Test Methods.

DEpD bleaching. Pulps were bleached by *DEpD* bleaching sequences (where D represents chlorine dioxide and Ep represents peroxide reinforced alkaline extraction). In the first stage (D) of *DEpD* bleaching sequences was 3 per cent. The temperature was 70 °C in Do stage for 60 min. Pulp consistency was 5 per cent. The pH was adjusted to 2.5 by adding dilute H_2SO_4. In the first alkaline extraction stage, temperature was 70°C for 60 min in a water solution of 2 per cent NaOH and 0.2% H_2O_{2}. (on od pulp) Pulp consistency was 10 %. In the D_1, pH was adjusted to 4. The ClO_2 charge in the D_1 was 1.5 per cent. The brightness (T525 om 92) of the bleached pulp were determined in accordance with Tappi Test Methods.

RESULTS AND DISCUSSION

Prehydrolysis

Forest products companies may increase revenue by producing biofuels and chemicals in addition to pulp products in an Integrated Forest Biorefinery (IFBR). In such biorefinery, hemicelluloses are extracted prior to pulping and used for the production of hemicellulose based biomaterial, fuel, acetic acid, etc. *Trema orientalis* was water-prehydrolysed prior to pulping in order to remove partial hemicelluloses from wood. Fig. 1 represents the yields of wood residue after pre-extraction at 150 and 170°C for different time interval. It is clearly shown from the figure that both time and temperature had strong impact on the dissolution of wood components. The dissolution rate of wood components is high at the first stage followed by slow stage associated with the dissolution of branched hemicelluloses. Similar observation was found in the auto-hydrolysis birch wood (Testova *et al*., 2009). Subsequently detail pre-hydrolysis was carried out 150°C for 1 h and 170°C for 1.5h. The pre-hydrolysis at 150°C dissolved 9.9 per cent wood component, of which 2.1 per cent acetic acid and 1.9 per cent lignin and remaining part is hemicelluloses. The mechanism of hot water extraction depended in part on the cleavage of *O*-acetyl and uronic acid substitutions that resulted in formation of acetic and other organic acids. These acids catalyze the hydrolysis of the hemicelluloses to soluble oligomer and monomers (Liu, 2008). Increased amounts of hemicelluloses were removed from the wood with the increase of prehydrolysis intensity (Table 1). For paper pulp, complete removal of hemicelluloses is unnecessary because they play an important role in formation of sheets. It is better to remove the hemicelluloses that dissolved during pulping processes. Acetic acid in the PHL was also increased with the increase of prehydrolysis intensity. Garrote *et al*. (2001) reported that the amount of free acetic acid in the hydrolyzate depends on the amount of residual xylan in the wood and xylan converted into high and low molecular weight oligosaccharide or xylose. The acetic acid was generated from the direct deacetylation of the xylan in the wood (Garrote *et al*., 2001).

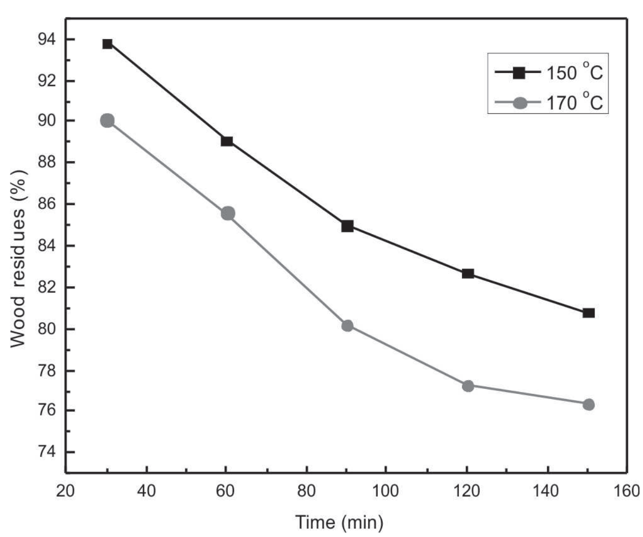

Fig. 1. Effect of time and temperature on the loss of wood components

Mass Balance

The wood residue after pre-hydrolysis and solid content in the PHL was close to 99% in both prehydrolysis conditions. This 1% loss in the mass balance is due to the degradation in unknown products. This concurs with the finding of Leschinnsky *et al*. (2009). The lignin, acetic acid and total sugars in PHL was 92.7 per cent and 91.7 per cent of solid content at 150 for 1h and 170°C for 1.5h, respectively. This less than 100% balance can be explained by the formation of furfural, and other xylose degradation products, which was not quantified in this study. The xylose and oligoxylose content in the PHL was increased from 4.6 per cent to 7.9 per cent with the increase of pre-hydrolysis intensity (150°C for 1h vs 170°C for 1.5h). Testova *et al*. (2009) also found that xylose and oligoxylan content in the PHL increased with the increase of temperature at same p-factor. Total sugars in the PHL was 49 per cent on solid content at 150°C for 1h, which decreased to 43 per cent at 170°C for 1.5h. This implies that the drastic pre-hydrolysis conditions is not suitable for the isolation of hemicelluloses. It increased xylan degradation products, lignin dissolution etc in the PHL (Testova *et al.,* 2009). Xylose/xylan can be converted into xylitol, yeast, furfural and others by chemical or enzymatic processes.

The lignin content in the PHL was 18-21 per cent of the solid content. Lignin content in the PHL was also increased from 1.9 per cent to 3.3 per cent with pre-hydrolysis increased. Yoon *et al*. (2008) extracted loblolly pine in hot water prior to pulping and obtained 5.11 per cent lignin in the prehydrolysate. The lignin content in hot-water extract of sugar maple was 3.27 per cent (Amidon and Liu, 2009). Lignin can be the starting material for high value-added applications in renewable polymeric materials development (Satheesh *et al*., 2009). The value added applications of lignin not only helps to boost the economic viability of the biorefinery but also serves as a source of renewable materials.

Pulping

Pulping of residues after pre-hydrolysis were carried out in kraft process under identical cooking conditions and compared with non-extracted pulp. Pulp with similar degree of delignification was obtained without significant loss of pulp yield when pre-hydrolysis was done at 150°C for 1 h. With the increase of pre-hydrolysis severity, pulp yield decreased by 2.6 per cent, kappa number also reduced to 16.7 from 18.2. During pre-extraction with water, some hemicelluloses and lignin were removed, thus wood chips become open resulted improved reaction activity lignin with cooking chemical. Therefore, the delignification was faster for the pulping of extracted *T. orientalis*. This result complies with earlier findings of pre-extracted wood and nonwood (Lei *et al.,* 2010). From this result, it can be concluded that mild pre-hydrolysis is suitable for *T. orientalis* pulping to get a good pulp yield.

Paper Making Properties

The effect of PFI refining on the drainage resistance (°SR) of pulps obtained from water pre-hydrolysed kraft cook and conventional kraft cook is shown in Fig. 2. As expected drainage resistance increased as PFI revolution increased in all types of pulps. Refining resistance increased with the increase of severity of pre-hydrolysis condition. Pre-extracted pulp at 150°C for 1h needed 4250 revolution to reach SR number 40, which was 2500 revolution lower as compared with the control pulp. This is attributed to the lower amount of hemicelluloses in pulp. Pulps with lower hemicelluloses are very resistance to refining and have poor strength properties, while pulps with high hemicelluloses content are easier to refine and produce stronger sheets (Casey, 1980). Similar results were observed in water pre-extracted kraft pulps from loblolly pine. Drainage resistance of pulp obtained from pre-extracted at 170°C for 1.5h did not reach 40. It has been reported that pulp with 99% á-cellulose could not refine at all and would not make satisfactory paper as fibers do not swell.

Fig. 3 shows the effect of pre-extraction on the tensile strength of kraft pulp obtained from *T. orientalis*. Tensile strength decreased with the increase of severity of pre-hydrolysis conditions. At SR number 30, tensile index was 43 N.m/g and 30.5N.m/g for pulp obtained with pre-hydrolysis at 150°C for 1 h and at 170°C for 1.5 h, respectively, which were 31 per cent and 51 per cent lower than the pulp obtained without pre-hydrolysis. Similar results were obtained for burst index as shown in Fig. 4. The negative effects of pre-extraction on the tensile and burst strength could be explained by low interfiber bonding ability of hemicelluloses deficient pulp.We observed no significant difference in tear resistance at SR number 30 between pulps obtained without pre-hydrolysis and pre-hydrolysis at 150°C

Table 1. Chemical composition of pre-hydrolysis liquor of *T. orientalis.*

Prehydrolysis condition	Yield (%)	Solid content (%)	Sugars (% on wood)										
			Lignin	Acetic acid	Xylose		glucose		arabinose		Rhamnose		Total sugars
					mono	oligo	mono	oligo	mono	oligo	mono	oligo	
1h at 150°C	89.1	9.3	1.93	2.1	1.1	2.3	0.10	0.45	0.26	0.21	0.09	0.08	4.59
1.5h at 170°C	80.2	18.5	3.26	5.8	2.9	3.2	0.27	0.56	0.31	0.36	0.13	0.17	7.90

for 1h (Fig. 5). But pulp obtained with pre-hydrolysis at 170°C for 1.5 h severely lost tear resistance. Tearing resistance depends on total number of fibers participating in the sheet rupture, fiber length and strength of fiber to fiber bonds (Casey, 1980). Thus an acceptable tear strength of handsheets is obtained if pre-hydrolysis is properly control.

Bleaching

Pre-extraction of hemicelluloses may change bleaching potential of the produced pulp. So unbleached pulps obtained with and without pre-hydrolysis were subjected to a conventional ECF bleaching ($D_oE_pD_1$) in order to assess the bleachability. The brightness and opacity were almost same in all pulps using same bleaching chemicals. This indicated that pre-extraction had no impact on pulp bleaching. For evaluating papermaking properties, bleached pulps were beaten in a PFI mill in different revolution and handsheets were prepared. The physical properties at °SR 35 were obtained from the extrapolation. The number of PFI revolution required to reach target °SR 35 was 2150 revolution for pulp without pre-hydrolysis, while pulp pre-hydrolysed at 150°C for 1h and at 170°C for 1.5h required 3500 and 5860 revolution, respectively. (Table 2). After bleaching, the papermaking properties of pulp obtained from pre-hydrolysis at 150°C for 1h were almost similar to control pulp. From the bleaching results, it may be concluded that the pre-extraction of *T. orientalis* at 150°C for 1h produced pulp of almost similar optical and physical

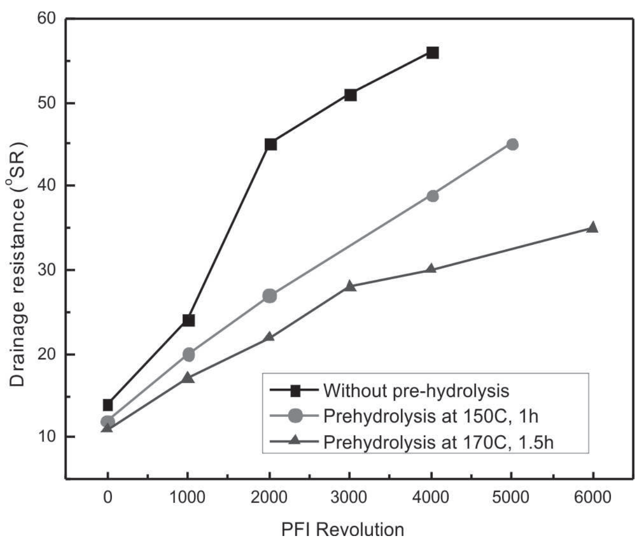

Fig. 2. Effect of pre-hydrolysis on the drainage resistance of produced pulp from *T. orientalis.*

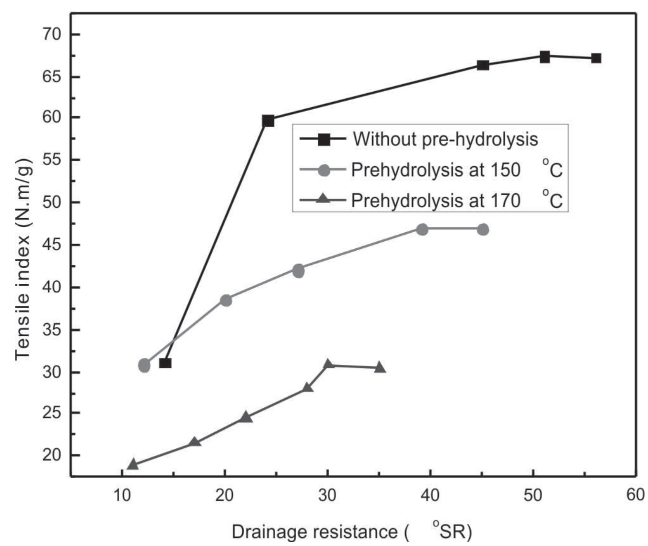

Fig. 3. Effect of pre-hydrolysis on the tensile index of produced pulp from *T. orientalis.*

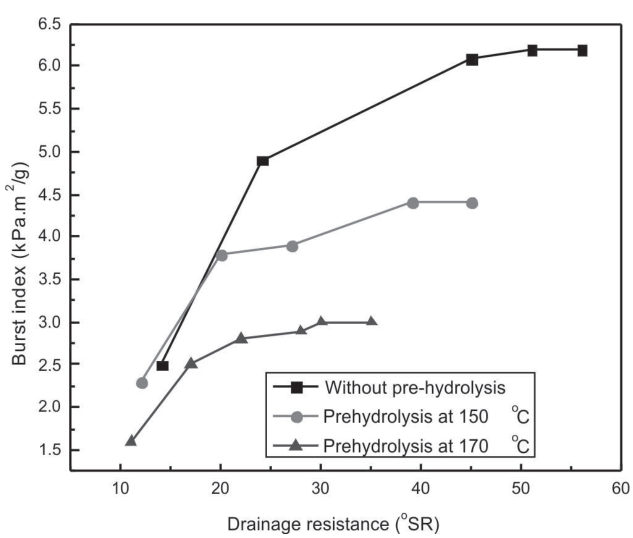

Fig. 4. Effect of pre-hydrolysis on the burst index of produced pulp from *T. orientalis.*

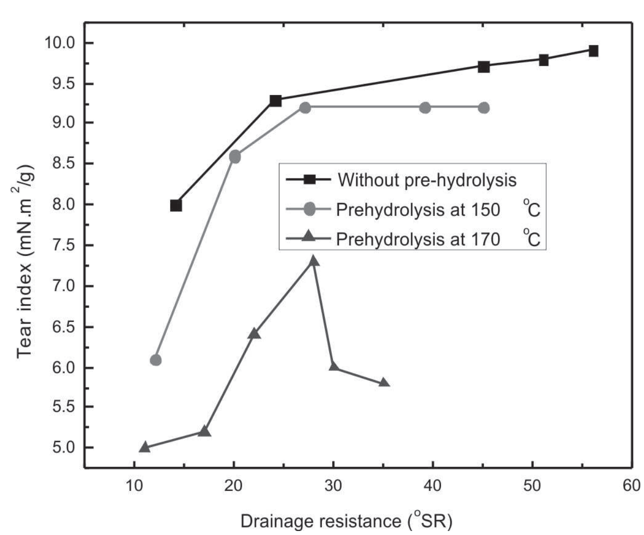

Fig. 5. Effect of pre-hydrolysis on the tear index of produced pulp from *T. orientalis.*

Table 2. Effects of pre-hydrolysis on the pulp bleaching

Properties	Without pre-hydrolysis	Prehydrolysis 150°C 1h	Prehydrolysis 170°C 1.5h
Brightness (%)	86.4	86.0	85.6
Opacity (%)	91.1	91.1	91.1
PFI Rev to reach 35 °SR	2150	3500	5860
Tensile index (N.m/g)	56.3	54.9	30.4
Burst index (kPa.m²/g)	5.0	5.1	3.0
Tear index (mN.m²/g)	10.9	9.5	7.3

properties to control pulp.

CONCLUSIONS

The pre-hydrolysis intensity increased wood components dissolution in the PHL. The acetic acid, lignin and sugars content in PHL were increased with the increase of pre-hydrolysis intensity. Mild pre-hydrolysis conditions (150°C for 1h) produced almost similar pulp yield and kappa number to non-hydrolysed *T. orientalis*. Drastic pre-hydrolysed conditions (170°C for 1.5h) produced pulp with lower yield and inferior strength properties. The prehydrolysed pulp was very difficult to beat due to the loss of hemicelluloses. After bleaching, the optical and papermaking properties of pulp obtained from pre-hydrolysis at 150°C for 1h were almost similar to control pulp. The pre-hydrolysis at 170°C for 1.5h is suitable for producing dissolving grade pulp.

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Designing and Augmenting Pulpwood Supply Chain through Contract Tree Farming

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Abstract: The success of industrial wood plantation schemes and the related plantation establishment is widely questioned. The reasons for the failure are numerous; but the key reasons are non-involvement of local people, lack of assured buy back and minimal support price. Besides, the middlemen and local contractors in the existing marketing system play a major role and in most cases they decide the harvesting time and also price fixation. Absence of efficient production to consumption system coupled with price incentives and assured buy back is a major constraint faced by the tree growing farmers. This constraint on industrial agroforestry can be overcome through augmenting the existing supply chain system by linking the farmers directly with industries. This augmented supply chain system will assure strong buy back system with a minimum support price. The precise information on marketability of industrial raw materials grown in farmlands is also equally important to assure profitable income to the grower. Against this backdrop, a value chain on industrial agroforestry in Tamil Nadu has been introduced and implemented through National Agricultural Innovation Project of ICAR. Through this project tri-and quad-partite models have been designed and successfully adapted across the state. This contract tree farming model involved four partners viz., research institutes for supply of potential genetic resources of pulp wood species and industries for mass multiplication of the potential genotypes through clonal technology and supply them at subsidized rate to the farmers. The other two partners in this model are farmers for growing pulpwood trees in their farm and financial institutions to provide credit facilities to the tree growing farmers. This quad partite model has been successfully implemented and demonstrated in 200 ha covering 207 farmers distributed in 5 districts of the state. This model gained significant momentum both within and outside the project site resulting in horizontal expansion of industrial agroforestry model in more than 11,284 ha benefitting 4389 farmers located in 24 districts of the Tamil Nadu state. This model provided and augmented the multipartite supply chain into a tri partite and quad partite model and given enough scope for adaption by any wood based industry.

Key Words: Pulpwood supply chain, Contract farming, Tri and Quad-partite model

The biological diversity of forests and their ecological functions are the heritage of mankind. These forests are most important and remarkable natural resources, which play a significant role in the economic prosperity and ecological stability of the country. The forests of India are shrinking under acute socio-economic pressure and the foresters are at the cross roads. India's forests till recently are being denuded at an alarming rate of 1.5 million ha per year and fortunately deforestation has come down rapidly with the enactment of the Forest Conservation Act (1980). Currently, the forest area in the country is around 23.84 per cent and in the state of Tamil Nadu, it is around 17.5 per cent, which is much low against the mandated requirement of 33 per cent. Not only is the forest wealth of the country is poor but also its productivity in terms of mean annual increment (MAI) is also one of the lowest (0.5 – 0.7 cu.m per ha per year compared to the global average of 2.1 cu.m per ha per year). The less forest area coupled with the low productivity of Indian forest has ushered in a total mismatch between the demand and supply of both domestic and industrial wood requirement (Parthiban and Govinda Rao, 2008).

India, due to burgeoning population is under tremendous pressure to meet the ever growing multifarious demands for wood and wood products. The demand for pulp and paper is one such thing. Today, there are about 600 paper mills in India with 34 in the large scale sector. During 1990's, the per capita consumption of paper was 3.3 kg, which has now escalated to 5 kg, but still lower compared to the global average 47.7 kg. The current production of raw material for pulp and paper production is 2.7 million tones as against the demand of 5.04 million tones. The shortfall is as high as 45 per cent. The projected demand in 2015 is 7.98 million tones, which are still more staggering (Srivastava, 2005).

Under such circumstances, the National Forest Policy 1988 directed the wood based industries not to depend on forest department supply for meeting the raw material demand. In fact, the policy has given clear guidelines to the industries that they should meet their raw material demand by establishing direct linkages with farmers by providing quality planting material, lending credit facilities and also with assured minimum support price (Anon, 1988). However, these activities are gaining slow momentum for want of suitable institutional mechanism to augment the traditional multi-partite supply chain system. Against this back drop a value chain model has been designed for industrial agroforestry involving paper industries, farmers, research institutes and financial institutions where in the existing multi-partite supply chain has been transformed into a value chain model as per the concept developed and popularized by Porter (1985) and also as evidenced in other value chain models of Feller *et al.* (2006). This paper elaborates the missing links in the traditional supply chain system and the interventions made for value additions to augment the profitability of the production to consumption system.

Constraints and Interventions of Industrial Wood Value Chain

The industrial wood raw material requirement is traditionally met from the plantations of forest department till the recent past by the wood based industries. But due to expansion of industrial paper production, diminishing supply from the unimproved plantation and uncertain availability are the major bottle neck in the current supply chain. The major constraints and the interventions through the current value chain are depicted in Fig. 1.

Non-Availability of Adequate and Quality Raw Material

The biggest challenge faced by the wood based industries is the spectare of raw material unavailability. The available raw materials are not only certain but also with varying degree of quality which resulted in erratic pulp recovery. Hence, promotion of farmer's linked clone based agroforestry activities in marginal agricultural lands will help to augment the quality raw material availability in a shorter period of 3 years compared to existing 5 years of rotation (Karmarker and Haque, 2008 and Parthiban *et al*., 2009). Against this back drop, the current study has been designed to develop institute-industry-farmers linked nursery and plantation planning process through demonstration in a decentralized approach.

Lack of Quality Planting Material and Productive Plantations

Traditionally plantations are raised by the farmers through unimproved and unknown seed sources, which recorded the yields of 5 and 7 cum per ha per year. Such poor yields with small and scattered plantations coupled with all logistics problem and escalated cost in felling and transportation are the stumbling blocks for the wood based industry particularly the pulp and paper industries to be economically viable and internationally competitive. Intensively managed plantations based on genetically improved planting stocks can achieve the productivity levels of 15 – 30 cum per ha per year even on marginal lands. Hence, the current project intervened strongly by introducing improved genetic resources of pulp wood species and their popularization across the farm lands of the state. This process acted as a basis for productivity improvements coupled with profitability, income and employment generation through various decentralized forest based nursery and plantation activities.

Poor Understanding on Value Addition Process

The productivity and profitability of the plantations are directly linked to the time and type of harvesting system coupled with suitable post harvest management system in order to reduce the logging impact and to augment the productivity. Traditionally, plantation operations in the country are done manually and the plantation residues are not properly utilized. Rather the plantation residues are left in the field without any utilization. The current study intervened through introduction of mechanization in harvesting operation and established value addition process of plantation residues through Briquetting technology. The plantation and industrial wood processing activities accounts for 20 – 30 per cent of residues which are either unutilized or underutilized for want of suitable recycling technology and the associated supply chain system. The current study resolved this issue by introducing value addition process and designing new supply chain.

Unorganized Supply Chain and Trade

The success of Industrial wood plantation schemes and the related plantation established is widely questioned. The reasons for the failures are numerous; but the key reasons are non involvement of local people, lack of assured buy back and minimal support price. Above all, the supply chain was multipartite as indicated in Fig. 2. To augment (Eaton, 1988 and Gahukar, 2007) chain system and to transform them as value chain system, the research group has designed a Quad-Partite Model Contract farming system through efficiently linking the growers, industries, research institutes and financial institutions. Currently the price information pattern of pulp wood species is not known to growers due to lack of price information system and its dissemination. This project strongly resolved this issue by establishing a separate website to periodically disseminate the pricing pattern of industrial wood species through regular updating system.

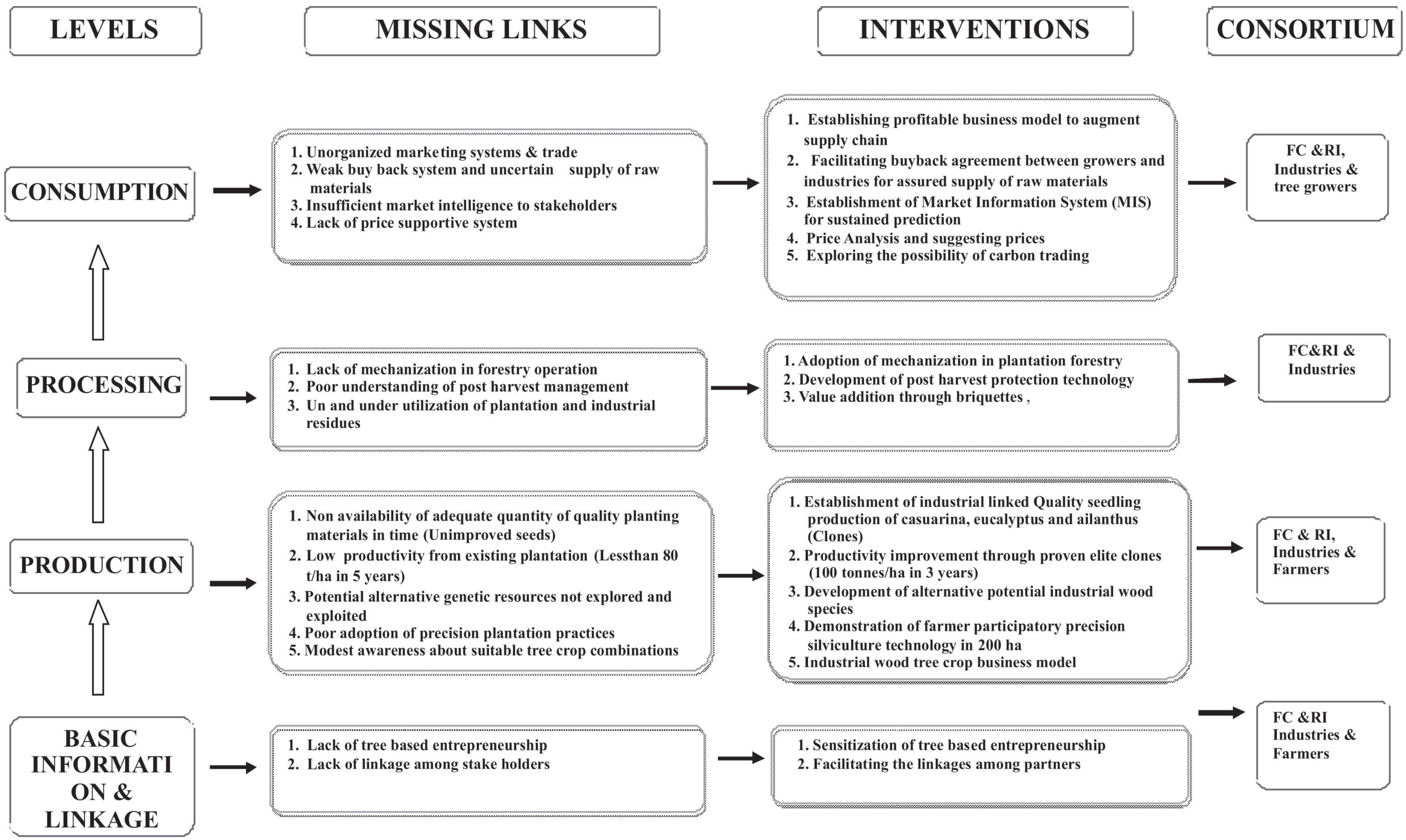

Fig. 1. A value chain on industrial agroforestry in Tamil Nadu

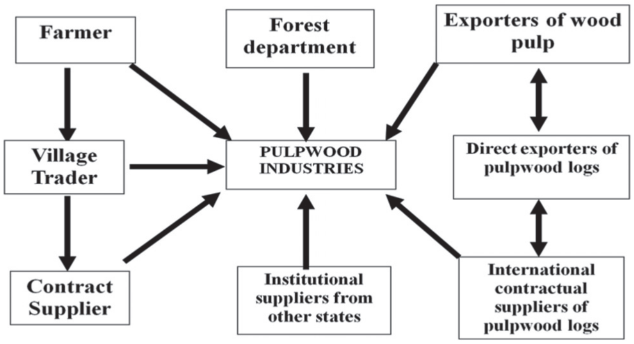

Fig.2. Status of Supply Chain – Multi – Partite

Existing Supply Chain

Currently there exist two supply chain systems, viz., Forest department supply and farmer's supply. The major raw material supply comes from the Tamil Nadu Forest Plantation Corporation (TAFCORN), which accounts for nearly 1.5 lakh tonnes of wood pulp supply. The remaining raw material comes from the farm lands through the traders. The supply chain of farm forestry is depicted in Fig. 3.

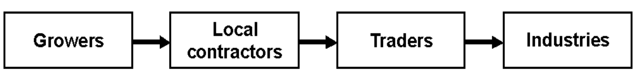

Fig. 3. Existing supply chain of pulp wood.

In the existing supply chain, growers sell the whole plantation on the acreage basis not taking into consideration the actual volume of the growing stock, which resulted in minimal returns to the growers. The local contractor's buy the plantations, fell them and classify them into poles, pulpwood and firewood. Only the wood size of 1 to 2 inches alone is supplied to the industries and other sizes are sold for pole purpose by the traders, which resulted in uncertain and erratic pulp recovery and quality. This necessitated development of strong supply chain with a successful contract farming model.

Contract Farming Model

To meet the above needs and increase the area under pulp wood plantation through farm forestry, the two paper industries in association with Tamil Nadu Agricultural University has developed a tri-partite and quad-partite model for promotion of pulp wood based contract farming system. Through the system, it is intended to produce quality and sustained raw material through a strong supply chain.

Tri-partite Model

This model incorporates industry, growers and financial institutions. Under this system, the industry supplies quality planting material at subsidized rate and assures minimum support price of Rs. 2000 per tonnes or the prevailing market price which ever is higher. The financial institutions viz., Indian Bank, State Bank of India and Syndicate Bank provide credit facilities to the growers at the rate of Rs. 15000 to 20000 per acre in three installments. For credit facilities, a simple interest rate at 8. 5 per cent is followed and the repayment starts after felling. The contract farming system extends no collateral security for loan amount up to Rs.1, 00,000/- per farmer.

Designing and Adaptation of Quad-Partite Value Chain Model

This model (Fig. 4) incorporates research institutes, industries, growers and financial institutions. The research institutions played significant role in advising site specific clones (coupled with the technical advice on pre and post-plantations activities), which helped both the growers and Plantation Supervisors posted by the industries. The industries mass multiply the potential genetic materials identified by the research institutions in a decentralized manner and supply them at subsidized costs to the growers. The industry also facilitates felling of trees and transportation of material at their own costs, which resulted in strong linkage between industry and the growers. The Financial Institutions provide credit facilities to the Tree Growers. The growers should supply the pulp wood on maturity as per the agreement. This model has benefited small and medium farmers. The industry also helps to repay the loan after feeling of trees thereby help the financial institutions in timely repayment of loan, which results in strong institutional mechanism for sustainability of the contract tree farming system in the state. This quad-partite model proved to be lucrative in terms of technological adoptions and profitability of plantations.

Technology Development and Adoption

The Forest College and Research Institute (FC&RI) has developed high yielding and short rotation clones

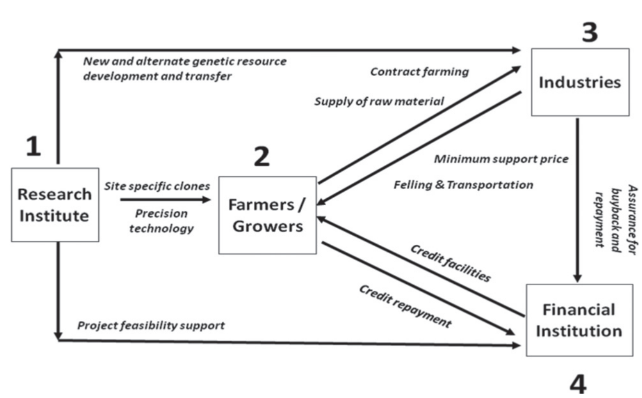

Fig. 4. Quad-Partite Model

(HYSR) in *Casuarina*, which could be harvested in less than 36 months with an average yield of around 150 tones per ha against the existing local seed sources with an average yield of 75 tones per ha and a long rotation of five years. These elite planting materials coupled with precision silvicultural technology has been transferred successfully to the stakeholders in the value chain. This improved clones are expected to yield uniform pulp recovery of 49 per cent coupled with kappa number of around 19 against the erratic pulp recovery in a shorter period, which is a long term need of the pulpwood industry. Hence the current study helps to satisfy both growers (high yielding) and industries (uniform pulp recovery), which thus help to create a profitable value chain as indicated in improving the business performance (Oswald *et al*., 2004). The clones developed and promoted in the current value chain is a technological innovation in terms of high yielding and short rotation and system innovation in terms of promotional activity through quad-partite model value chain and hence focus more on product development and marketing and thus attests the earlier reports of value chain projects (Feller *et al*., 2006).

Demonstration and Horizontal Expansion

To promote the concept of clone based industrial wood value chain system, Pilot demonstrations in 5 districts covering an area of 200 ha were established and the value chain system has been demonstrated involving 212 beneficiaries. This clone based industrial wood value chain model has made significant impact resulting in horizontal expansion of the model in another 11284 ha benefiting 4389 farmers.

Buy Back Arrangement

The strong linkages among Tree Growers and Industrial Partners has resulted in smooth and timely buy back arrangement for the farm grown industrial wood species with a minimum support price of INR 2000 per tones for pulp wood species at the farm gate. The cost incurred in felling operation and subsequent transportation of the material was borne by the Industrial Partner.

This clone based Industrial wood value chain has resulted higher yield and more price realization. The economics of traditional seed based plantation model is compared with the clone based value chain model (Table 1), which indicated that the current value added clonal plantation increased the yield by 100 per cent and net revenue by 242 per cent.

Augmenting Supply Chain into a Profitable Value Chain

The existing value chain on industrial agroforestry involved multipartite stake holders (Fig. 5a) wherein the farmers or growers get the minimal revenue and the middleman along with the traders gained maximum benefits out of this supply chain (Pandey, 2007). Hence the value chain on industrial agroforestry has been augmented with quad-partite model supply chain wherein the growers get maximum benefit (BCR 1:3.88 to 1:5.05) compared to (BCR 1:1.66 to 1:1.91) in the existing system. Hence the current value chain resulted in maximum net revenue to the growers besides getting additional revenue from the value addition due to briquetting technology. The flow of value chain is depicted in Fig. 5b.

Impacts of Industrial Wood Value Chain

The industrial agroforestry project has created adequate social and environmental benefits through income and employment generation activities coupled with carbon sequestration potential.

Table 1. Benefit cost analysis of value added clone based models

Particulars	Total revenue (INR)	Net revenue (INR)	B:C ratio
Casuarina seedling plantation			
Pulp wood only	150000	72400	1.66
Pulp and pole market	172500	94900	1.91
Value added clone based plantation system			
Casuarina clonal plantation system			
Pulp wood only	300000	234225	3.88
Pulp and pole market	390000	324225	5.05
Casuarina based inter cropping			
Pulpwood + Intercropping (black gram)	340000	261925	3.78
Pulpwood and Pole + Intercropping (black gram)	430000	351925	4.76
Pulpwood + Intercropping (groundnut)	360000	264725	4.04
Pulpwood and Pole + Intercropping (groundnut)	450000	354725	5.01

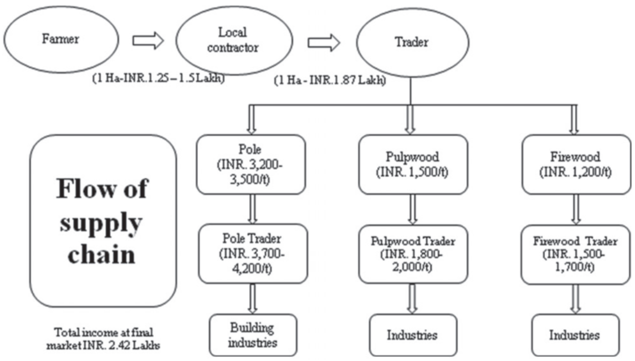

Fig.5a. Flow of traditional Supply Chain

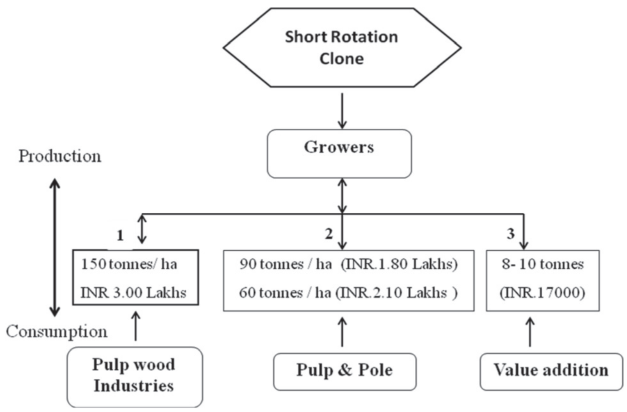

Fig.5b. Profitable value chain

Income and Employment Generation

It is estimated that 300 man days are required for establishment of one ha of plantation from seedling up to harvesting and transportation. These flow of operations created 60000 man days (income generation – 0.13 million USD) directly in the project operational area (200 ha) and around 3.0 million man days (income generation – 6.5 million USD) through horizontal expansion (>10000 ha) and created adequate employment and income generation to the landless labourers, small farmers and self-help groups, particularly women members. The project also created enough scope and established farmer and industrial linked decentralized clonal propagation centers, which created 0.1 million man days of work to land less women members. These activities have created an income generation of nearly ten million rupees (0.2 million USD) and the benefit was distributed to various stake holders viz., farmers landless labourers and women self-help groups.

Carbon Sequestration and Climate Mitigation

The sub-project has excellent scope of mitigating the climate change through carbon sequestration. It is estimated that 50 tones of carbon is sequestered in one ha of plantation. The current plantation established in this sub-project has the potential of sequestering 500000 tones of carbon yielding revenue of INR 5 crores. This carbon sequestration potential may help to augment the environment and may result in clean development mechanism.

Before implementation of the current value chain in the state of Tamil Nadu (India), the supply chain in forestry sector was multipartite and unorganized. The farmers traditionally raised tree crops from unimproved seed sources resulted in poor yield and income. The wood based industries were predominately obtaining raw material from unimproved and unorganized plantations, which expressed uncertainty in raw material availability coupled with varied degree of wood resulting in poor and erratic pulp recovery. The low productivity from existing plantations and the unorganized supply chain ushered in a total mismatch between the demand and supply. Hence, a value chain model has been developed suitably integrating all stakeholders to augment the production-consumption systems in forestry sector. In this system, high yielding short rotation clones were introduced against the unimproved seed sources which resulted in higher productivity and concomitant profitability to the growers. The industries in turn benefited through assured and quality raw materials supply needed by them. The conversion of plantation residues into briquettes is yet another intervention in the value addition process, which augmented the value chain system through income and employment generation besides creating provision for clean development mechanism through carbon sequestration. Hence, the value chain on industrial agroforestry is a technology, system and socio-economic value based integrated approach that benefit the production-consumption systems in forestry and has enough scope of scalability, replicability and adaptability across the value chain based forestry enterprises.

ACKNOWLEDGEMENT

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Symbiosis among Effluents Utilisation, Irrigated Plantation and Energy Production

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***Abstract*:** Collectively, the Department of Primary Industry and Forestry (DPI&F), Central Queensland University (CQU), Livingstone Shire Council (Yeppoon, Qld, Australia) raised models of effluents disposal through dedicated plantations to identify efficient plantation to utilise municipal effluent. These plantations included both, the monoculture as well as agroforestry plantations of pangola grass, flooded gum (eucalypts) and Ma bamboo. Although flooded gum (monoculture) was found consistently efficient in utilizing effluents, other agroforestry plantations were good for utilising effluents as well as providing additional short term commercial crops. Data showed a decline in water use with the age of plantations as well as the absorption of hazardous element like sodium. To avoid accumulation of hazardous elements in the soil, renewal of crops is essential, which necessitates early harvest of tree crops. Young tree crops (2 – 3 yrs) often produce pole crop that may be preferably removed to produce biomass power rather than feeding paper mills or scaffolding industries.

Key Words: Dendro-remediation, Short rotation forestry, Bioenergy

Effluents, the water that carries wastes from homes, businesses and industries, usually contains 98 per cent water and 2 per cent dissolved or suspended solids. Globally, large quantities of effluents are being used for agriculture irrigation, industrial reuse and groundwater recharge. Municipal effluents are also being used in hydroponics and constructed wetlands in France, Greece, Israel, Spain, Portugal, India and China (DPI, 2000). For ecological sustainability, effluents must be disposed off in an environmental-friendly way to avoid groundwater contamination, eutrophication of water bodies and degradation of soil (DPI, 1991) and to minimize health hazard to aquatic fauna through direct disposal in to rivers and oceans (Gardner, 1995; Myers *et al.,* 1996; CSIRO, 2000).

Industrial and municipal effluents are used for land irrigation. This option is better than the hazardous and costly options of direct disposal in rivers or tertiary treatments, respectively. In developed countries effluents are irrigated in dedicated plantations, play grounds, parks, golf courses, and race courses. However, in developing countries, most of the industrial and municipal effluents are un-treated. These un-characterised and un-managed effluents are often disposed in either rivers or agriculture fields. Raising plantations with effluent irrigation is a known, economically suitable, practically easy, logically feasible and vastly replicable practice. The use of trees has been popular because of their reported fast growth (Stewart and Flinn, 1984), high water use, and socio-economic benefits (Myers *et al.,* 1994). The attractiveness of effluent reuse may increase further by growing pulpwood, energy crop or scaffolding-poles. However, effluents, a nutrient rich, biochemical and microbial source, also initiates many biotic processes the consequences of which are yet to be understood. Due to lack of sufficient information about the fate of water, nutrients, salts, biochemicals and toxins, many effluent-irrigated plantations could have caused short as well as long-term degradation of soils and water resources (Myers *et al.,* 1998). Thus, land disposal of effluents has introduced scepticisms which need to be addressed to identify suitable best practices. Research was conducted in plant growth, water-use, nutrient cycling, and microbial growth under different plantations to identify best management practices for effluents irrigated plantations. This present paper deals with the synergic model of effluent disposal to raise short-term forestry plantations. This research has been mentioned only to build logic, thus, several scientific details have been omitted.

MATERIAL AND METHODS

Seven agroforestry (AF) systems consisting of pangola grass *(Digitaria decumbens*; P*),* ma bamboo *(Dendrocalamus latiflorus*; B*)* and flooded gum *(Eucalyptus gran*dis; E*)* were irrigated with municipal effluents at Yeppoon, Queensland, Australia (23° 07.703´S and 150° 42.361´E at an elevation of 59 masl). The agroforestry systems were either monoculture or mixed cropping system i.e., pangola grass alone (P), flooded gum alone (E), ma bamboo alone (B), BP, EP, BE and BEP (Sharma *et al.,* 2010).

The plantations were irrigated with treated municipal effluent at a rate of 1.8 ML yr^{-1} over 1.26 ha (143 mm ha^{-1}). This irrigation rate was determined for this site using the MEDLI (Model for Effluent Disposal using Land Irrigation) - specialised model software for this purpose. Periodically drawn soil samples from the irrigated plots, water samples from on-site piezometers, near-by ponds and effluents used were analysed for microbial populations, as well as nutrient status. Plant growth and changes in soil properties were monitored every six months until two years age (by then most of the plantations had closed their canopies; and started shedding leaves)[1].

RESULTS AND DISCUSSION

Conservative Irrigation Suits Effluents Plantation Sites

Based on the soil hydrology, soil nitrogen, soil phosphorus and biomass production potential in the site, the MEDLI predicted the optimum irrigation rate of 1.43 ML ha^{-1} yr^{-1}. At this rate, soil evaporation was highest and runoff and drainage were lowest. MEDLI also predicted that an irrigation rate in excess of 1.43 ML ha^{-1} yr^{-1} (optimum rate according to MEDLI) would result in higher runoff or drainage threatening groundwater and near by water bodies. The crop would suffer or fail due to waterlogging and a rise in salinity. Thus, overlooking these parameters could initiate environmental degradation.

Changes in water-table observed in the on-site piezometers proved that the MEDLI forecasts were befitting. It was observed that the water table in the study site was initially being influenced by rainfall (Fig. 1). When the irrigation rate was increased from 1.8 ML yr^{-1} (for 1.26 ha site) to 3.3 ML yr^{-1} during April 2004, the watertable rose in spite of the prolonged dry season and the absence of rain. Furthermore, the water table receded in September 2004 within a week of changing the irrigation rate to original level (Fig. 1). The watertable kept declining though out the second year of plantation (April 2003 – April 2005) although sporadic rains were received during this period. This reduction was attributed to rapid water use by the plantations. During the third year, the plantations could not utilise as much water as they did in second year and hence the watertable rose even in a relatively dry season. The rise and fall in watertable was linked to irrigation, thus confirming the MEDLI predictions. Although the amount of water drained could not be quantified, but it can be inferred from these data that

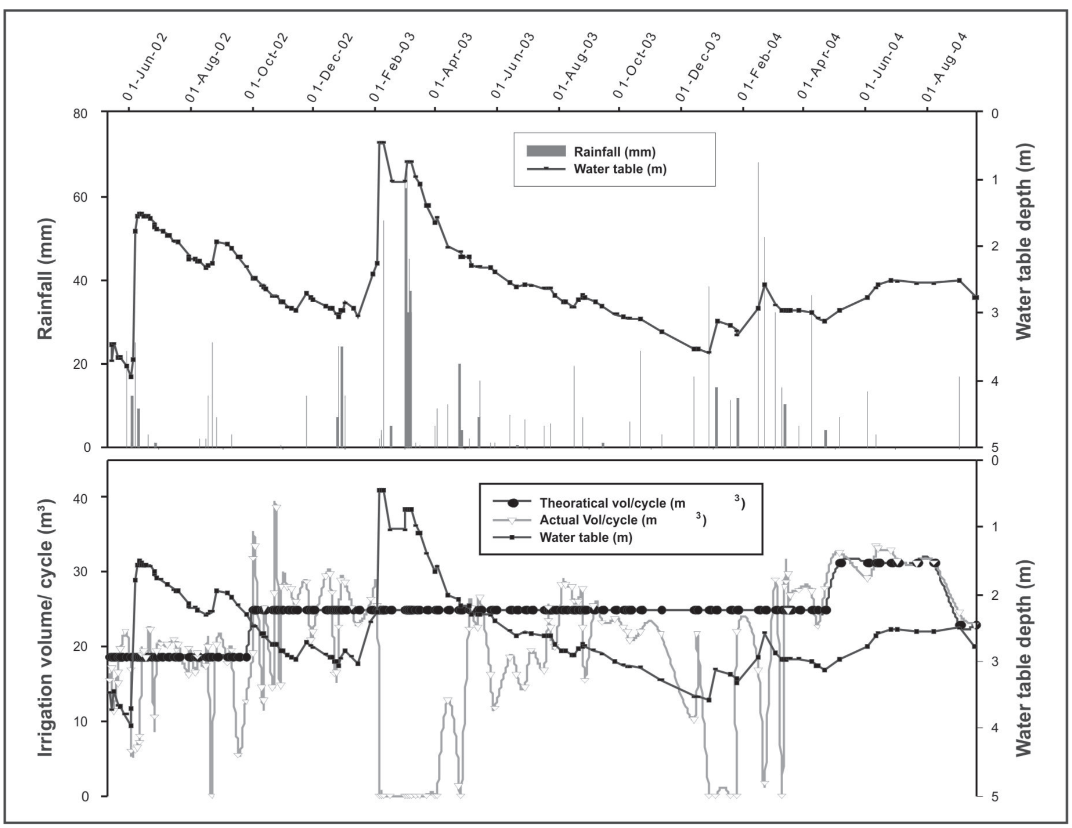

Fig. 1. Changes in ground watertable in response to the increased irrigation rate during April – September 04

the drainage was likely to have increased at higher irrigation rates.

Success of establishing effluent irrigated plantations depend on the level of water treatment, local hydrology, irrigation management and scheduling, crop management, soil type, regional rainfall and adequate plantation management (Stevens *et al.,* 2003). Overloaded effluents reuse plantations may only be propagating ecological threats, and lose sustainability (Gardner *et al.,* 1993; Gardner *et al.,* 1997). Gradually, groundwater chloride and nitrate-nitrogen concentrations rise (Nutter *et al.,* 1996), microbial populations build up (Al-Nakshabandi *et al.,* 1997), soil compaction and salinisation occurs (Shahalam *et al.,* 1998), and sodicity reaches hazardous levels (Surapaneni *et al.,* 1996; Balks *et al.,* 1998). Careful irrigation management including irrigation management, especially during the first 12 – 18 months, or until the canopy closure occurs, determine the success of establishing effluent irrigated plantations (Beaver, 1993; 1996). The cited literature and current research revealed that all effluents irrigation sites have a 'utility life span'. Un-monitored effluents irrigation cannot continue in-definitely. Build-up of nutrients, salts, sodium and hazardous elements has to be maintained at the minimum by using a phytoremediation system (plantation). However, plants cannot consume all the nutrients, salts and chemicals provided via effluents irrigation. To maximise the nutrient removal, the effluents plantations needs to be removed before the leaf shedding (nutrient cycling to soil) starts (usually at canopy closure).

Rapid Nutrient Removal Essential

After applying 3.8 ML (over 1.26 ha) effluents in two years (too meagre; equivalent to two days production by the Yeppoon sewage treatment plant), it was observed that the flooded gum plantations could utilise up to six times more nitrogen and four times more phosphorus than that being added via effluent irrigation (Table 1). However, the plantations could not utilise the sodium that was contributed in abundance by the effluent. Ma bamboo and Pangola grass were more in-efficient in taking up the soil degrading and environmentally hazardous sodium (Van de Graaff and Patterson, 2001). A failure to remove these chemicals may degrade soil and contaminate groundwater, eventually degrading water bodies.

Table 1. Total plant nutrient contents (ha^{-1}) in various plantations

Nutrient	Supplied through effluent (kg)*	Nutrient uptake in kg (including ground flora)		
		Ma bamboo	Flooded gum	Pangola
Nitrogen	109.8	220.4	725.1	242.4
Phosphorus	28.4	39.2	90.3	42.04
Potassium	40.9	304.5	396.3	361.8
Sodium	385.3	21.7	325.4	32.5
Calcium	66.4	44.1	371.7	70.74
Magnesium	28.8	27.4	116.7	33.4
Iron	0.42	1.8	5.5	1.9

*Total of 3.8 ML effluent was irrigated in two years over an area of 1.26 ha.

Irrespective of the agroforestry systems, the ESP increased from 13 to approx. 20 within first two years of effluents irrigation (Fig. 2). The proportion of unused sodium and rise in ESP may threaten the soil environment. A soil with an ESP of >15 is classified as sodic and any further increase in ESP would restrict plant growth.

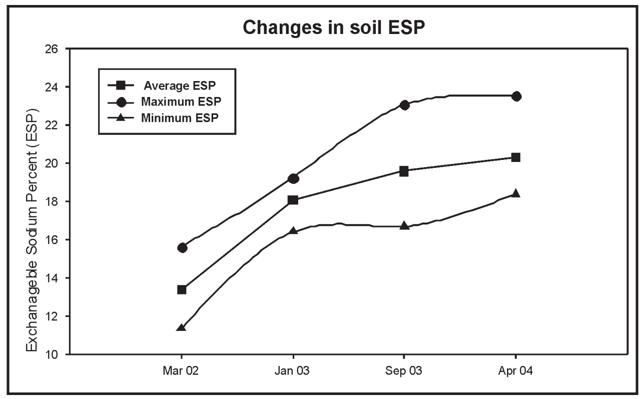

Fig. 2. Soil ESP changed over two years of effluent-irrigation. The values are averages of three soil depths and seven agroforestry systems.

The plantations could utilise all the major-nutrients, except S, but were selective about micro-nutrients and Na. Plantations act as an efficient but temporary storage of nutrients (leaf shedding bring nutrients back to soil – nutrient cycling) Thus, for sustainable nutrient management, the plantations should be harvested before the nutrients are recycled back into the soil.

Maximise Plantation Water Use

Sapflow monitored in the two-year old agroforestry plantations and the adjacent four-year old different spaced flooded gum plantations using thermal dissipation technology (Granier, 1987) revealed that the two-year old flooded gum in the current trial was taking up more water than the 3 m x 3 m spaced flooded gum plantation. The flooded gum plantation spaced at 2.5 m x 2.5 m (1600 trees ha^{-1}) used 8481 to 25348 kg d^{-1} ha^{-1} water (5086 m^3 yr^{-1} ha^{-1}) in a year (Table 2) having at least 330 days of sunny conditions.

The number of surviving stems influences water-use

Table 2. Seasonal sapflow (g h^{-1}) in a four-year old flooded gum plantation.

Plantation spacing	Avg. Flow		Trees		Annual sapflow* (m^3 ha^{-1})	
	Dec 03	July 04	Planted	Survival	Dec 03	July 04
1m x 1m flooded gum	80		10000	95 %	6019.2	
3m x 1m flooded gum	248	135	3333	93 %	6088.3	3314.2
3m x 3m flooded gum	429	176	1111	91 %	3435.1	1409.3
Flooded gum, 2yr old, AF	401.35		1600	100 %	5085.9	
Ma bamboo, 2yr old, AF	152.41		3200	100 %	3862.6	
Pangola grass (herbaceous)**					7899.2	

* A year of 330 sunny days (having normal transpiration); ** Estimation based on mass balance and is not comparable with other monitored value; Dec 03 was a summer and the trees were 3.5 years old and July 04 was winter and the trees were 4 years old.

of that plantation. Tree water use reduces with the age (Chhabra and Thakur, 1998) and with decline in tree survival percentage. This would ultimately forfeit the very purpose of effluent irrigation. Thus, consideration should be given to maintaining high survival percentage and harvesting of the plantations at and early age than allowing them to produce timber. Effluents irrigated plantations should be valued more for their environmental impacts rather than timber production, or aesthetic value. It is therefore more appreciable to maintain an efficient effluent consuming plantation (young plantation) rather than producing timber (long term plantation) at the cost of environmental degradation.

Biomass Production

Effluent irrigation resulted in mean annual increment (MAI) of 25m^3 ha^{-1} yr^{-1} and a potential biomass production of 200 m^3 in a monoculture flooded gum plantation at eight years (DPI, 2003). The two-year old agroforestry plantations, under study, also produced substantial biomass. The biomass data (Table 3) showed that non-woody components make substantial contribution even in tree plantations. The leaf and twig biomass are liable to slashing or senescence. If this biomass is not removed in a planned manner, part of the biomass will be added (via senescence or slashing) to soil pool. Later, this loss in biomass will reduce water uptake and increase nutrient cycling in the plantations. Thus, the traditional practice of raising long term plantation for timber will threaten the purpose of raising effluent irrigated plantations. Thus, an early harvest is essential for maintaining efficiency of effluent irrigated plantations. Furthermore, the traditional biomass market (timber/pole/mulch/pulp) may not use the non-woody component. To facilitate early harvest, specialised marketing strategies need to be adopted.

Table 3. Biomass yield (tonne) in two-year old agroforestry plantations.

	Ground flora	Non-woody	Woody	Total yield
Flooded gum	6.35	39.2	26.0	71.6
Ma bamboo	7.69	2.31	4.2	14.2
Pangola grass	14.05	-	-	14.1

Although industries as well as municipal bodies use their effluents, mainly farmers have the opportunity to use effluents for raising agricultural, horticultural or forestry crops. In Australia, growing an effluent irrigated tree crop for 3-4 years and then selling that for \$20 – 23 $tonne^{-1}$ was not an economical business (ANU, 2003). Thus Australian found that tree crop becomes economical once the crop yields 200 m^3 biomass comprising of 100 m^3 wood per ha (ANU, 2003). In India also, *Eucalyptus, Casuarina* and *Leucenea* pulpwood plantations are considered economically attractive at a productivity level of 30 m^3 ha^{-1} yr^{-1} (dry wt) only, which is the productivity of pulpwood plantations in coastal Andhra Pradesh and Tamilnadu (APPM, 2000, 2006).

All effluent irrigated plantations, essentially a short rotation forestry crop, shall yield wood suitable for different end uses. Invariably there will be some over grown stems that shall attract premium price from scaffolding or plywood industries. Remaining material will be useful to paper, particle board, brick kilns (fuelwood) and bioenergy industries. In presence of several restrictions on felling as well as transportation, and in absence of formal biomass market (supply chain agencies), most of the short rotation tree crops are either sold illegally or at very poor price (low income to farmers). In spite of presence of poplar and eucalypts in vast areas of North India, these species are traded usually through in-formal wood traders. Rapid growth of private casuarina and subabul plantations in Andhra Pradesh, that made the State a major pulpwood procurement region, could be possible once eucalypts, casuarina, and subabul were completely freed from any restrictions and were declared ‘farm crops’. Likewise, the bioenergy plantations also shall have to be spared from all restrictions, and biomass markets have to be formalised (bank and insurance sector should support biomass trade as well as biomass traders, including crop residue traders).

CONCLUSION

Land irrigation will continue to be a preferred option for municipal effluent disposal. Conventional methods of managing plantations may defeat the purpose of raising effluent plantations, as they will reduce the water consumption and cease nutrient uptake after canop closure. Results of this study reveal that strict control of irrigation application rate is essential for maintaining ecological sustainability of effluent irrigated plantations. To maintain high rate of water and nutrients uptake, it is essential that the tree crops be harvested in short rotation instead of allowing the trees to produce timber. The biomass produced from the trees in short rotations will have to be utilised through non-conventional markets. Decentralised bioenergy production may utilise the biomass produced from thousands of hectares of plantations annually, and provide regional biomass market for the produce obtained through the effluent irrigated plantations. Additional policy inputs are needed to increase use of effluents for wood production under short term forestry; formalise wood as well as biomass trade by facilitating institutions like banks, insurance companies, informal traders as well as farmer co-operatives; and increase macro as well as micro level decentralised biomass energy production.

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Short Rotation Forestry for Sustainable Power Production

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Abstract: Severe shortage of energy has led to search for alternative sources of energy. Energy from biomass is one attractive option as it is a renewable resource. Currently the focus is on obtaining power from lingocellulosic biomass like agricultural residues which are available in large quantities and are not required for human consumption. The drawback of agricultural residue for power generation is its low bulk density and seasonal availability, which increases its transportation and storage cost for continuous power generation. These factors limit the scale of power generation, raising serious concerns about the economic viability of lignocellulosic biomass based power generation systems. Biomass from short rotation forestry (SRF) is an attractive source for sustainable production of power from biomass. Biomass from SRF can be harvested year round and its higher bulk density allows for a concentrated source of energy for power generation. These factors allow for power generation on a higher scale, thereby improving the sustainability of the power generation system. This paper provides an overview of existing commercial technologies and the role of SRF in sustainable power production from lignocellulosic biomass.

Key Words: Bioenergy, Lignocellulosic biomass, Gasification

There is a need to shift from first generation biofuels to second generation biofuels for energy production. First generation biofuels use feedstock like soybean and maize for production of biodiesel and ethanol, respectively. These feedstocks have other competing use as food for human consumption. Hence, their use as fuel has to be restricted. Lignocelullosic biomass is considered to be a second generation biomass feedstock for use as fuel for generation of power and energy. Lignocellulosic biomass like woody biomass from trees is an example of second generation biofuel. Second generation fuels are also more environmental friendly. Various nations have set up different standards for quanlifying a fuel as a second generation fuel based on environmental considerations. For example, renewable fuels standards in the USA mandate that the second generation fuels must save at least 50 % green house gases (GHG).

This paper will focus on the lignocellulosic biomass technologies that are relevant to the developing countries and have the potential to be adopted in the near future. Gasification is one such prominent technology and hence will be in focus for sustainable power generation from short rotation forestry (SRF) biomass (Ravindranath *et al*., 1990).

Biomass Based Renewable Energy Processes

The broad areas for the conversion of biomass to biofuels, with particular emphasis on lignocellulosic biomass have been presented in Fig. 1. There are two main types of processes viz., thermochemical and biochemical for the conversion of lignocellulosic biomass to biofuels. In general, the biochemical processes are employed for wet biomass, while the thermo-chemical processes are employed for the dry biomass. Another important criteria for the choice of conversion process pertains to the amount of lignin in the biomass. As lignin does not degrade easily by biochemical means, the biomass with higher lignin content are converted to fuels via the thermochemical route.

SRF in Perspective

In developing countries, agriculture remains the predominant land use category. Traditional forestry is another important land use category. Forests have a very important role to play in protecting the environment. They are also a renewable source of a wide variety of useful industrial products. Most developing countries need to protect these forests and enhance their forest cover. For example, in India the total forest and tree cover is only 23.84% as against the recommended forest cover of 33 % (FSI 2009). Due to growth in population, land is also being diverted to infrastructure and related activities. Therefore, due to intense pressure on land for various competing uses the scope for increasing area under SRF is limited in developing world.

Estimating biomass availability from SRF in developing countries. In developing countries, most of the farmers have limited land holdings. As such, most farmers need to put their land under conventional farming to have a regular source of income. SRF activities block the money for a few years and this is beyond the reach of most farmers. However, farmer with large land holdings are able to put

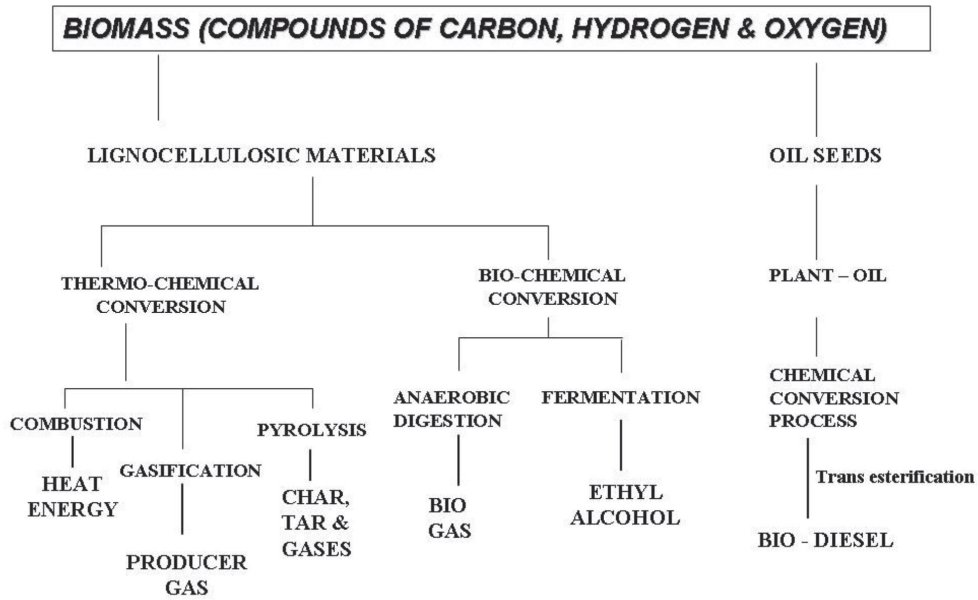


Fig. 1. Routes for conversion of biomass to various fuels

some of their land under SRF plantation. In India, farmer's SRF plantations are generally small as compared to those in the developing countries. Most SRF plantations are less that 50 ha. Taking a sustainable productivity of 20 dry tons/ha/yr for a six year short rotation forestry with *Eucalyptus* clones, the maximum biomass production available with a farmer with 50 ha under SRF comes to be 1000 dry tons/year. This figure is towards the higher side for individual farmers SRF plantations. Although there is no reliable way to estimate the amount of biomass that can be made available through SRF for power production at one decentralized location, an assumption is made here that about ten times the above amount can be made available at one decentralized location at price ranging between Rs 3.50-4.00/kg. We will see later in this paper that restricting the price of wood to this level is important for the economic viability of the electricity generation process from SRF wood.

Overview of Power Production Technologies with SRF Biomass in Developing Countries

Now we look into the possible conversion routes for power production from this SRF biomass. Biochemical conversion processes like fermentation require an order of magnitude more biomass than indicated above for sustainable and economic operation. Hence these processes are absolutely not sustainable with SRF in developing countries. Even in developed countries, at current level of development, the biochemical processes are costlier than the thermo-chemical conversion processes. Thermo-chemical processes like combustion and gasification, which can be operated at medium to small scale, are more relevant for SRF based biomass. Pyrolysis process are still in the developmental stage and have not been commercially exploited for lignocellulosic biomass.

At the level of 10,000 dry tons/year biomass from SRF, the combustion based processes are also not sustainable. This is because combustion processes employ high pressures for power generation. This necessitates careful handling and thus trained technical personnel are required. This in turn increases the cost of production of electricity. In developing countries, biomass from SRF is used only to supplement agricultural residues and other wastes in electricity production in decentralized ways using combustion based processes. The range of electricity generation in this case generally ranges from 5 MWe to 20 MWe and may extend even higher in certain cases.

In contrast, gasification based processes are much simpler since these can be carried out near atmospheric pressure. On very small scale (<50 kWe), they can be even handled by 1-2 semi-skilled workers and all operations can be carried out manually. For small scale gasification (up to 500 kWe), some operations are automated but the operations still much simpler and safer than combustion based processes. However for electricity production at this level and its distribution to end users, the services of few technical persons is required. Hence Gasification process is best suited for SRF biomass in developing countries.

Introduction to Gasification of Biomass

Gasification is a thermal conversion process in which a solid fuel is converted into heat and a combustible product gas. The process may be carried out by direct or indirect heating. For the purpose of power production at small scale in a decentralized way in, the simpler method of gasification by direct heating is employed. In direct gasification, the biomass is partially oxidized using air as the gasifying medium to provide a mixture of gases commonly referred to as producer gas. The overall reaction in biomass gasification can be represented as

$$CH_{1.4}O_{0.6} + n\,(0.21\,O_2 + 0.79\,N_2) \longrightarrow [CO + H_2 + CO_2 + H_2O$$

(Biomass) (Air) (Producer Gas)

$$+ C_mH_{2m+2} + \text{Tars}] + \text{Char} + \text{Ash}$$

Here $CH_{1.4}O_{0.6}$ is the generalized formula of biomass. The producer gas contains Carbon Monoxide and Hydrogen as the main combustible gases. Small amounts of methane and higher hydrocarbons may also be present depending upon the type of gasifier and the reaction conditions. Since air contains 79 % Nitrogen as inert matter, the producer gas obtained by using air as gasifying medium is also diluted by the nitrogen content. This producer gas has a calorific value in the range of 4-6 MJ/Nm^3. The gas also contains various contaminants like tar, solid particulate matter, organic acids, compounds of N, Cl, S and alkali metals. Depending on the end use of producer gas, the gas needs to be cleaned to various degrees.

Different processes and operations occurring in the gasifier reactor are mainly in four reaction zones viz. oxidation, reduction, pyrolysis and drying. The sequence of reaction zones in a gasifier depends on the type of gasifier and direction of flow of fuel and air or gas.

The oxidation zone is also referred to as combustion zone. In the oxidation zone, carbon and hydrogen of the biomass are oxidized to carbon dioxide and water vapor in accordance with the following reactions.

$$C + O2 \longrightarrow CO_2 + 393.8\ \text{MJ kg-mol}^{-1} \quad (1)$$

$$H_2 + 1/2\,O_2 \longrightarrow H_2O\,(g) + 241.5\ \text{MJ kg-mol}^{-1} \quad (2)$$

Almost all the oxygen required in gasification process is used up in the oxidation zone. The temperature in the oxidation zone range from 800 to 1300 °C, depending upon the type of the gasifier and fuel. Carbon dioxide and water vapor at high temperature move into the reduction zone.

In reduction zone, carbon dioxide and water vapors are reduced to carbon monoxide, hydrogen and methane in accordance with the following reactions.

Water gas reaction:

$$H_2O + C \longrightarrow CO + H_2 - 122.6\ \text{MJ kg-mol}^{-1} \quad (3)$$

Boudauard reaction:

$$CO_2 + C \longrightarrow 2CO - 172.6\ \text{MJ kg-mol}^{-1} \quad (4)$$

Water gas shift reaction:

$$CO_2 + H_2 \longrightarrow CO + HO - 41.2\ \text{MJ kg-mol}^{-1} \quad (5)$$

Methane formation reaction:

$$C + 2H_2 \longrightarrow CH_4 + 75.0\ \text{MJ kg-mol}^{-1} \quad (6)$$

Reactions 3 to 6 are the main reduction reactions and are reversible. For reaction 3, the equilibrium temperature is about 900°C. The equilibrium temperature for reaction 4 is about 1100°C. Equilibrium temperature for reactions 5 and 6 is 700 to 600°C. It indicates that the higher reactor temperature during gasification process favors higher concentration of CO and H_2 in the producer gas. The low reactor temperature leads to higher methane in producer gas.

In pyrolysis zone, the volatile matter in biomass gets vaporized due to the available heat in the reactor. The pyrolysis of volatile matter takes place between 200 and 600°C.

In drying zone, the moisture in the biomass is reduced due to the available heat. Temperature in this zone are less than 200°C. (Higher temperatures lead to pyrolysis as indicated above).

Gasifiers Suitable for SRF Biomass in Developing Countries

Three types of gasifiers are generally employed for conversion of coal or biomass to gaseous products. These are generally referred to as fixed bed, fluidized bed and entrained bed gasifiers. For small scale applications with biomass as the solid fuel, fixed bed gasifiers are more appropriate because of the simplicity of their design and ease of operation. The availability of wood from SRF is limited and gasifier operation with this type of wood will be essentially on a small scale. Hence for biomass conversion processes using SRF based wood in developing countries, the fixed bed type gasifier will be employed. The fixed bed gasifiers of interest are the updraft and downdraft gasifiers.

The main features of updraft and downdraft gasifiers are briefly explained below. The details of these gasifier types are readily available in standard text books dealing with renewable energy as well as specific books/handbook dealing with gasification technology (Anon., 1979; Kaupp and Goss, 1984; Reed and Das, 1988). Here the key features of these gasifiers relevant to power production are being discussed.

1. **Updraft gasifiers.** The schematic representation of this type of gasifier is shown in figure 2. In this type of gasifiers, the air is introduced from the bottom and the producer gas is taken from the top. This gasifier has better thermal efficiency than the downdraft gasifier. However, the gas quality is poor and the gas needs to be extensively cleaned for engine and electric power applications. The updraft gasifiers have been mainly used for close coupled thermal applications. There are also a few instances of large scale applications of updraft gasifiers for electric power generation in developing countries.

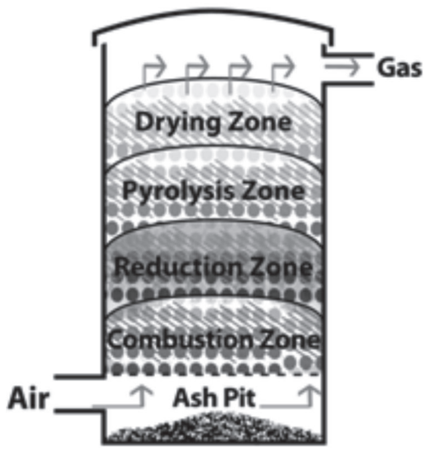


Fig. 2. Schematic diagram of updraft gasifier

2. **Downdraft Gasifiers**

These type of gasifiers come in two broad categories, the *imbert* type, which have a throat or constriction and the *throatless* type. These are discussed below

a) **Imbert (with throat) gasifiers**. This type of gasifier requires fuel of uniform size with good flow properties. The producer gas obtained from this type of gasifier contains the least amount of tar of all the types of gasifiers. Woody biomass (including SRF biomass) is the best feedstock for this type of gasifier if the producer gas is to be used for engine applications (Fig. 3).

b) **Throatless gasifiers.** The schematic diagram of this type of gasifier is shown in figure 4. This type of gasifier is also referred to as stratified or open core gasifier. This type of gasifier is designed basically for fuels with flow problems e.g. rice husk. This gasifier can accommodate a wider variety of fuels and can be easily upscaled. The tar content of producer gas from this gasifier is more than that obtained from the downdraft gasifiers having throat.

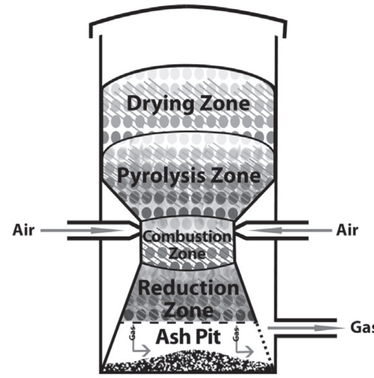


Fig. 3. Schematic diagram of downdraft Imbert type gasifier

This type of gasifier is more suitable for thermal applications. It is also been used for electric power production from agricultural residues, particularly rice husk.

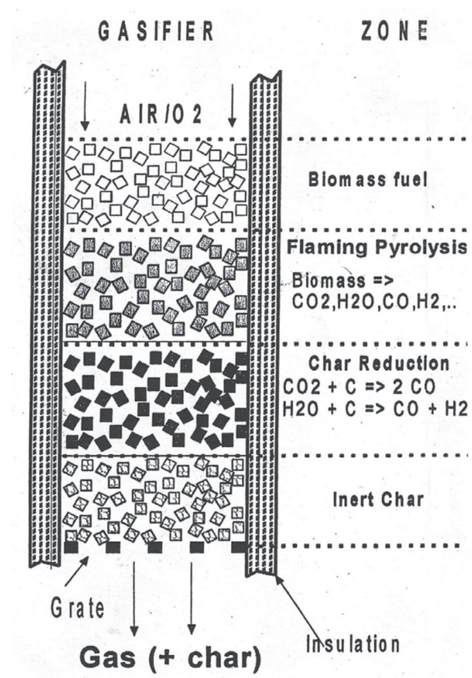


Fig. 4. Schematic of downdraft throatless type gasifier operation

Applications of Producer Gas Obtained from Biomass Gasification

Producer gas is currently being employed commercially for mainly two types of applications

Thermal power applications. There are various applications for thermal power like hot water/steam and hot air requirement in Industry. Mainly updraft gasifiers are employed for this purpose. Roughly 4 kg of sun dried wood can substitute for one litre of furnace oil or diesel. This results in reducing the running cost of the furnaces by atleast 40 per cent in India. Combustion based furnaces are being retrofitted with fixed bed gasifiers (mainly updraft) in significant numbers. Same is true for other applications (hot air/water, etc). Hence, the technology is already sustainable with all kinds of biomass including biomass from SRF. Most low grade solid fuels like cow dung, biomass briquettes, etc., which are usually available at prices lower than the woody biomass can also be used in updraft gasifiers for thermal applications.

Mechanical power through engine (and electricity generation). Biomass gasification on small scale for engine applications is carried out with downdraft gasifiers because these type of gasifiers produce a cleaner gas which is better suited for engine applications. The technology for production of producer gas through the downdraft gasifiers have been established for a variety of biomass based substrates. Schematic of a throatless downdraft gasifier for electric power generation is shown in figure 5 to provide an overview of the electricity generation process with rice/paddy husk as a fuel. In this process, a series of gas cleaning steps are placed for cleaning the gas before it is introduced into the compression ignition engine. At a power output of 10 kWe from such a system run in dual fuel mode, 25 % of the energy in engine is obtained for diesel fuel (used mainly for starting the ignition process) and the rest is obtained from producer gas.

However, the field application of use of gasifiers for engine application on small scale has had limited success. There are various reasons for this. A few important reasons are listed below.

a) For engine applications, the gas needs to be cleaned There are a variety of contaminants in the producer gas. The tar and the solid particulate matter are the more critical contaminants. The Ministry of New and Renewable Energy (MNRE) in India sets a maximum limit for the tar and solid particulate matter in the producer gas as 100 and 50 mg/Nm^3, respectively for engine applications. For obtaining a gas clean enough for engine applications, a series of gas cleaning steps are introduced after the gasifier. These add to the cost of the system and also create a pressure drop in the system, which has to be overcome by the engine.

b) The gas quality from gasifier deteriorates rapidly with deviation from the rated output of the gasifier.

The gasifier must be run near it's rated/design capacity for its proper utilization in engine (Note that this is not critical for thermal applications). So the gasifier has been used in the past for constant load applications like water lifting for irrigation at farmers' fields. Activities like irrigation are seasonal, therefore utilization remains low, hence the benefits of gasification are not fully realized and returns are low.

c) There is an additional fixed cost of engine and alternator for electricity generation activities

All these factors add to complexity of systems used for engine applications over those used for thermal applications of gasifiers. Hence gasifier systems in lower power range, even though economical, are not being used widely.

However, engine application is a more efficient and versatile energy conversion process for power generation than the thermal power route. The short rotation forestry

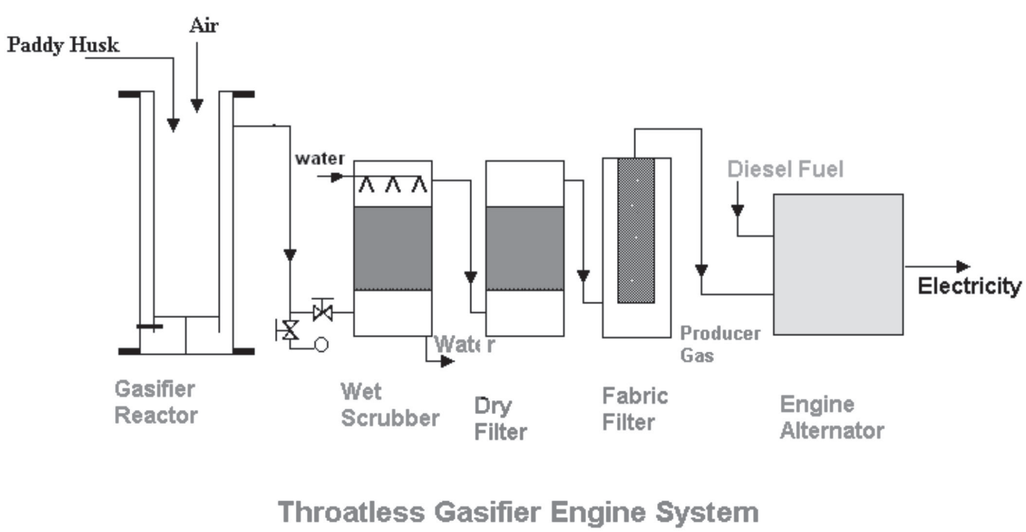
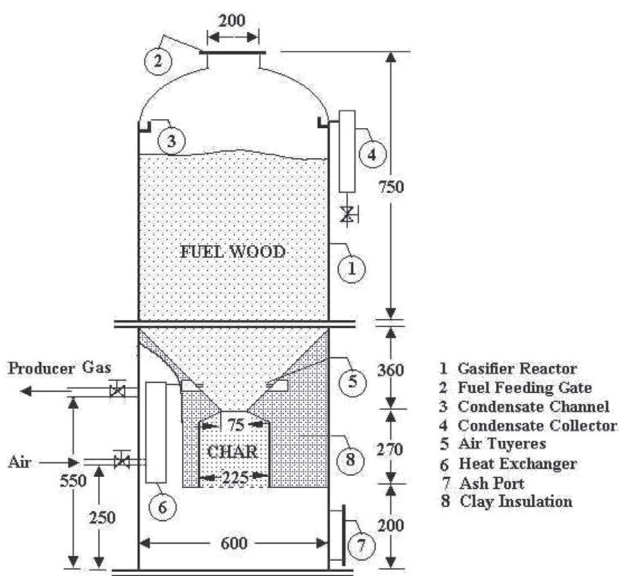


Fig. 5. Schematic of throat less gasifier engine system for electricity production

biomass is also well suited for electricity production, since it can be used as a fuel in the imbert type gasifiers thereby producing a clean gas. This aspect is discussed below with reference to the sustainability of electricity production

Gasification technology for sustainable electric power production from SRF biomass. Gasification technology has been demonstrated with woody biomass for electricity power production. The School of Energy Studies for Agriculture at Punjab Agricultural University, Ludhiana has demonstrated the use of Imbert type downdraft gasifiers for electricity power production at 20 kWe level. The schematic diagram of one such gasifier is shown in figure 6. An economic analysis of this gasifier is considered under two level of operation of the gasifier viz., 1000 and 3000 hours per year. The gasifier is operated under dual fuel mode with about 70 per cent of the energy coming from producer gas and the rest coming from diesel. The following realistic assumptions are made:



All dimesnions are in mm

Fig. 6. Schematic diagram of a 20 kWe Imbert type biomass gasifier

Assumptions for calculating economics of 20 kWe Imbert Gasifier system:

1.	Cost of gasifier system	Rs. 1,30,000
2.	Cost of diesel genset, 25 kWe	Rs 3,20,000
3.	Operating hours per year	a) 1000 b) 3000
4.	Wood consumption	1.2 kg/kWh
5.	Diesel consumption(duel fuel)	0.08 l/kWh
6.	Cost of wood	Rs. 4000/t
7.	Cost of diesel	Rs. 38/l
8.	Interest on fixed cost	@12% PA
9.	Maintenance	@ 10% of fixed cost

With the above assumptions, the cost of electricity generation, Rs/kWh for both the systems under a)1000 and b) 3000 hours of operation is given below

—	Dual fuel mode (with gasifier)	a) 12.54	b) 8.94
—	Diesel engine generator	a) 15.68	b) 13.33

Based on these figures, the payback period of the gasifier come out to be 2.0 years and 0.5 years, respectively. Thus, it can be seen that the technology of biomass gasification with SRF biomass is economically favorable and sustainable.

CONCLUSION

SRF biomass can provide a sustainable source of feedstock for electricity production. The gasification technology with SRF biomass has been successfully demonstrated at a number of places in the India and other countries of the developing world. It has been used by the farmers for individual use at their farms. Several private entrepreneurs have also set up units in the 100 kWe scale for distribution of electric power. However, this has been restricted to areas with poor grid electricity supplies. In this aspect, SRF plantations can play a big role in making substantial amounts of woody biomass available at a reasonable price for the wide scale adaptation of the gasification technology for electricity power generation. This will make a significant contribution in ameliorating the power shortages in the developing world.

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Economic and Environmental Sustainability of using Dendro-energy in Organic Tea Industry in Srilanka

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Abstract: The global energy crisis is profoundly affecting the developing countries, which contain three quarters of the world population. Experiences of Asian countries show that biomass energy plantation projects are not appropriate for achieving the social objective of poverty alleviation. Sri Lanka is gaining popularity in organic tea production as a health beverage. The environmental and economic benefits of using Dendro-thermal energy in organic tea production have not been investigated in Sri Lanka. This study was designed to assess the economic and environmental sustainability of dendro-thermal energy for curing of tea in organic tea production. The data was collected from an organic tea producing factory and 33 randomly selected fuel wood suppliers in the Badulla District in 2008. Extended benefit cost analysis was carried out to evaluate the economic and environmental sustainability of dendro-energy use in drying tea Benefit transfer method was employed to value the environmental sustainability such as reforestation, biodiversity, soil erosion and soil fertility.The study revealed that the annual economical gain of using dendro-power for tea dry was Rs. 7,548,000 with other social and environmental benefits. The economic analysis results showed that the dendro-thermal had an overall benefit. Sensitivity analysis suggests that no uncertainties exist in transferring fossil fuel to dendro-thermal energy use in organic tea curing. Most farmers who supply bio mass had positive perception on continued supply. Since land size of each farm is limited, organizing contract farming with large groups is important to meet the fuel wood demand. These results also show that there is a good level of increase in soil conservation and soil fertility by conserving bio diversity with the dendro-thermal fuel wood supply. Immediate economic benefits and the protection of soil and water can go hand in hand especially when enhanced by collective action.

Key Words: Organic tea, Dendro-thermal energy, Extended benefit-cost analysis

The global energy crisis is profoundly affecting the developing countries, which contain three quarters of the world population. Experiences of Asian countries show that biomass energy plantation projects are not appropriate for achieving the social objective of poverty alleviation. Sri Lanka is gaining popularity in organic tea production as a health beverage. The environmental and economic benefits of using Dendro-thermal energy (DTE) in organic tea production have not been investigated in Sri Lanka. Further development of renewable energy sources has become a national priority in Sri Lanka and in many other Asian countries for energy security. The global energy crisis is profoundly affecting the developing countries, which contain three quarters of the world population. The importance of a policy to facilitate (DTE) generation using biomass for sustainability and decentralization has emerged (Ranasingha, 2006). Experiences of Asian countries show that a biomass energy plantation projects are not appropriate for achieving the social objective of poverty alleviation (Ranasinghe *et al*., 2007). Some factors that increasingly work against biomass production are the higher cost of land caused by increased population pressure of land for food, other purposes and the price of oil, which is still declining in real terms. Hence, supply of biomass fuels should be based on byproducts of agro products and multiple use trees and other trees intercropped with other crops for conservation purposes and soil enrichment purposes (FAO, 2000). However, the present oil prices are zooming up. Since Sri Lanka introduced organic tea to the world market in early 1990's, it is gaining popularity, especially as a health beverage. While hundreds of thousands farmers in the developing countries practice organic agriculture, the potential gain in organic tea production is in a dilemma of how to overcome this problem of mainly being non attractive to the local suppliers of biomass as a renewable energy. According to IAFN (2007) usage of fossil fuel must be limited up to 40 per cent in energy usage in tea estate which are certified under Forest Garden Product Inspection Service (FGPIS). Hence supply of biomass fuels should be based on by products of agro products and multiple use trees and other trees intercropped with other crops for conservation purposes and soil enrichment purposes.

Against the above discussed background, this study was designed to assess the economic and environmental sustainability of DTE for curing of tea in organic tea production to generate much needed foreign exchange for Sri Lanka. The specifically objectives of the study were to carry out an extended benefit cost analysis and to find out the feasibility of establishing a dendro-power unit in tea factories of Sri Lanka.

MATERIAL AND METHODS

The study was carried out in Thotatagala and other organic certified factories tea factories, in Haputale and Haldummulla divisional secretariat divisions in Badulla. Due to high reputation, Thotatagala tea factory was purposely selected for economic investigation for organic tea production. From the two divisional secretariat divisions, 11 organically certified tea small holder farmers, 12 organically certified spices farmers and 10 organic spices farmers were randomly selected. Thus, the fuel wood suppliers were restricted to 33 farmers. Data on biomass production, labour use, cost and returns in fuel wood supply, soil and water conservation, soil erosion, biodiversity, micro climatic change etc., were collected during June and July in 2008 by using a pre-tested interview schedule. In addition, data was collected from 4 *Gliricidia* collectors who collect *Gliricidia* from farmers and supply to the tea factory. Supply base from Thotatagala estate and other organically certified farms were also analyzed. Supply base from Thotatagala estate and other organically certified farms were also analyzed. Extended benefit cost analysis was carried out to evaluate the eco-friendly nature and economic and environmental sustainability of DTE use in drying tea. Benefit transfer method was employed to value the environmental losses avoided such as deforestation, biodiversity losses, vulnerability of landslides, soil erosion and soil fertility losses. The calculation of the environmental valuation in this study was adopted from Gunatillake and Thiruchelvam (2003). Sensitivity analysis was carried out at 6, 10 and 18 per cent discount rates. Cost increase by 10 and 20 per cent were also tested. In transferring market price into economic price, shadow price and conversion factors such as labour 0.92, energy 0.92 and material cost 0.88 were used. In order to investigate the problems faced by fuel wood suppliers, a Likert-scale with ranking the problems was employed. Farmers' perception on contribution of *Gliricidia* in fulfilling the international organic standards was estimated by using ranking method.

RESULTS AND DISCUSSION

Economic analysis showed that for the drying of one kg of tea required 0.8 kg of Dendro fuel and the cost of drying using Dendro fuel was 7.45/kg of tea. The cost of drying with diesel was US $ 0.351/kg. The cost of Dendro fuel was US $ 0.546/ kg. Hence annual saving from usage of dendro fuel was US $ 68,618.18 for the company having the capacity of 240,000 kg of made tea. Annual dendro fuel requirement for Dendro power plant was 300,000 kg and out of which potential company owned farms' supply base was 160,000 kg which was 53 per cent of the requirement dendro fuel (Table 1). Hence 140,000 kg have to be supplied from outside the company owned farms. Production of dendro fuel in organically certified tea gardens and spice gardens under company out grower system was 1,050,000 kg which was over 4.5 times of the requirement. In addition to that 320,000 kg green manure and 19,200 kg wood ash were produced from dendo fuel within company owned farms as by products which will be a support to fertility management of organically certified lands. Both financial and socio-economic analyses show validity of the supplying fuel wood on an environmentally friendly basis. About 90 per cent of the farming population owns sufficient mixed spice gardens and tea gardens with *Gliricidia* plants for the supply of dendro fuel and the storage of Dendro fuel are made possible by the arrangements made by the factories.

A farmer earned US $ 161.9 from fuel wood supply in addition to his primary income from farming. This income was obtained from spending 35 working days annually to prepare dendro-fuel. Further, farmers became convinced of other major advantages, such as reduced soil erosion, moisture conservation, and retention of soil fertility and productivity. Advantages are clearly visible when comparing their fields with those practicing inorganic or conventional farming. It was found that *Gliricidia* can replace 50 per cent required fertility for pepper cultivation that is saving of 700 kg of fertilizer per 0.4 ha. Thus pepper cultivators can supply the total requirement of *Gliricidia*. Replacement cost of fertilizer revealed that US $ 181.82/ha could be saved

Table 1. Potential production base and supply of *Gliricida* stick company owned and received from out growers of mixed spice garden and tea

Source of *Gliricidia*	Amount kg/year for dendro dryer	% of total requirement for dendro dryer	% of actual supply
Annual requirement for dryer	300,000	100	
1 Total from company owned lands	160000	53	62
2 Small scale organic tea farmers	92500	31	-
3 Koswattha estate	60000	20	20
4 Organic mixed spices farmers	1050000	450	18
Total potential production	1522500	507	100

from *Gliricidia* inter-cropping. Likert scaling analysis revealed that most farmers' perception was high in continuing supply of fuel wood. Regarding farmers' degree of satisfaction in drying, storing and transport of sticks, price received for fuel wood, contractual arrangement, it was found that organizing better contractual arrangements with large groups would meet the fuel wood demand. Financial cost and benefits were 3.82 and 2.24 for dendro-energy and fossil fuel energy respectively. These values at 6 per cent discount rate in the economic analysis were 2.65 and 1.46 for dendro-energy and fossil fuel respectively (Table 2). The results of sensitivity analysis revealed that the relative less sensitivity to the benefits and cost changes. The effect was less in the long run. This was mainly due to more environmental benefits gained from the biomass production and use of fuel wood in curing tea. These incremental benefits from environment give many promises for the other factories to follow the use of DTE with the better institutional arrangement with the suppliers. When cost increased by 20 per cent fossil fuel energy use become non economical while dendro-energy use continue to be above BCR of 2.4.

Table 2. Result of extended benefit cost analysis for Dendro-plant and diesel pant for a five year production period

Items	Discount rates (%)		
	6	10	18
Dendro-plant			
NPV US $. Mil	2.34	2.23	2.53
EBCR	2.65	2.65	2.65
Diesel plant			
NPV US $. Mil	1.04	0.95	0.80
EBCR	1.47	1.47	1.45

The study revealed that the annual economical gain of using dendro-power for tea dry was US $ 68618.18 with other social and environmental benefits. The economic analysis results showed that the dendro-thermal had an overall benefit. Sensitivity analysis suggests that no uncertainties exist in transferring fossil fuel to dendro thermal energy use in organic tea curing. Most farmers who supply biomass had positive perception on continued supply. Since land size of each farm is limited, organizing contract farming with large groups is important to meet the fuel wood demand these results also show that there is a good level of increase in soil conservation and soil fertility by conserving bio diversity with the dendro- thermal fuel wood supply. Immediate economic benefits and the protection of soil and water can go hand in hand especially when enhanced by collective action.

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Synergies of Wood Production and Carbon Sequestration through *Acacia* Hybrid Clones

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Abstract: *Acacia* hybrid is a new taxon which is a putative hybrid between the *A auriculiformis* and *A. mangium*. The new taxon is relatively fast growing and in order to capture the heterosis, the taxon is propagated vegetatively. After six years of planting, growth and yield attributes of different clones were assessed. Existence of variation in growth performance of different clones was evident in the study. Considerable variation was also observed in the above ground biomass production of different clones. Out of the 12 clones studied, four clones allocated 50 per cent of the total biomass to bole wood production. Most of the clones had more than 10 per cent of their biomass as clone HD-12. Biomass allocated for bark production was less than 10 per cent of the total above ground biomass in most of the clones and around 15 per cent of the above ground biomass was distributed in for branch wood production in all the clones except clone H-10. Estimated volume of different clones varied from 8.99 m^3/ha to 37.36 m^3/ha with mean annual increment of 1.05 m^3/ha to 6.23 m^3/ha,whereas, above ground biomass varied from 10.20 t/ha to 40.07 t/ha with a mean of 22.85 t/ha. Above ground carbon stock in different clones varied from 5.10 t/ha to 20.03 t/ha with a mean annual above ground carbon sequestration of 0.85 t/ha/yr to 3.34 t/ha/yr.

Key Words: *Acacia* hybrid clones, Biomass partioning, Carbon sequestration

The genus *Acacia* comprises of about 1,200 species that are distributed worldwide spread but with a large number in Australia. Among these, *A. auriculiformis* and *Acacia mangium* are recognized for its ability to grow on poor soils. Both *A. auriculiformis* and *A. mangium* have been planted in many countries such as Indonesia, Thailand, Myanmar, India and Malaysia as wood source especially for pulp making industry. *Acacia* hybrid is a new taxon, which is a putative hybrid between the *A. auriculiformis* and *A. mangium* found in Sabah, Malaysia and such *Acacia* hybrids are also recorded in captive pulpwood plantations of Mysore paper Mill, Bhadrvati, India (Amanulla *et al*., 2004).These hybrids are relatively fast growing and has shown more superior characteristics than the parental species and due to its fast growth and wood production, is gaining prominence as a source of wood fibre for the paper industry (Choong *et al*., 2005). Inter-specific hybrids have a major role in marginal sites as they perform better than the pure species in such problematic areas. The high degree of genetic variation prevalent in the new taxon provides ample scope for tree improvement and clonal propagation and selection/clonal propagation is essential to capture the heterosis.

Capture and storage of CO_2 from the atmosphere is gaining attraction as means to deal with climate change. Role of forests in the global carbon cycle is well-documented (Kirschbaum, 2001) and forest plantation play an important role in carbon dynamics in atmosphere. Establishment of plantations to mitigate increased CO_2 in the atmosphere is one of the key options in reducing global warming. A thorough literature survey revealed that little effort has been made quantification of carbon capture by different genotypes in plantations. Present study envisaged to assess the biomass production of different clones, understand the yield and carbon stock in different clones of *Acacia* hybrid in Mysore.

MATERIAL AND METHODS

The present study was carried out in clonal plantations of *Acacia* hybrid located at Forest Research Station, Madahally near Mysore in Karnataka (Latitude N 12^0 15' 13.2", E 76^0 30' 54.9" longitude and altitude of 808 m above MSL). The area has red laterite soil with gentle slope with pH 6.3. Mean annual rain fall in the area is 771.86 mm and mean temperature is 35.6^o C.

Acacia hybrid clones, which were identified and released by Mysore Paper Mills Limited, Bhadravati (MPM) were planted by the research wing of Karnataka Forest Department. In all, 12 clones were field planted with identity in different blocks of 260 trees.After six years of planting observation on growth parameters like Total height of the tree (H), equivalent diameter (the diameter, corresponding to the total cross-sectional area of multiple stems at breast height) were measured and volume of individual tree was estimated by using formula.

Volume (V) = 3.142 X $(EQDBH)^2$X H X f.f /40,000
Where
EQDBH- Equivalent diameter in centimeter,
H- Total height in meter and
f.f.- Form factor (0.40) for the species.

Representative trees (3 trees/clone) were selected from each clone and were harvested at the ground level. Above ground portions of the felled tree were separated into bole wood, branch wood and foliage. Fresh weight of bole wood, branch wood, and foliage were recorded immediately after felling using spring balance. Immediately bole was debarked and fresh bark weight was recorded. A known quantity (1 Kg) of representative foliage, bark, bole wood and branch wood samples were collected. All the samples were transferred to the laboratory and dried to constant weight at 70°C for leaves and 100° C for bark, branch wood and bole wood. Dry weights of different samples were obtained. Dry: wet ratio for leaves, bark, branch wood and bole wood was computed, which was used to estimate the biomass of different components of the felled trees for determination of field weights per tree basis. In order to estimate the wood basic density (DEN), three representative wood samples from each clone were collected and volume of each wood disc was measured with identity. Oven dried weight of respective wood disc was estimated. Basic density of wood (DEN) was determined by DEN=Mass of wood disc (g)/volume of wood disc (cc). Bole weight of each tree was estimated by Bole wood weight= Wood volume X DEN. Total above ground tree biomass of individual tree was estimated by summation of bole weight, bark weight, branch weight and leaf weight of particular tree. Expansion ratio was obtained by dividing total above ground tree biomass with bole wood weight to account for non- stem biomass such as branches, leaf and bark.

Carbon stock in each tree was estimated by multiplying the total above ground biomass of individual tree with carbon fraction 0.5 (Dixon *et al.*, 1994). Mean Annual Increment i.e. MAI (m^3/ha), productivity (t/ha/yr) and rate of carbon sequestration were determined by dividing volume (m^3/ha), biomass (t/ha) and carbon stock (t/ha) by age respectively.

RESULTS AND DISCUSSION

Significant difference in certain growth attributes of different clones were evident in the present study (Table 1). Among the different growth traits the height of different clones did not differ significantly. Among the different clones planted, normal clone had relatively higher value (8.27 m) followed by H-10 (8.23 m) and the least was observed in B-5 (6.60 m). Average equivalent diameter at breast height (EQDBH) of different clones varied significantly and clone H-4 (10.08 cm) recorded significantly higher value, which was at par with all other clones except K-26. Estimated volume of individual tree of different clones varied significantly (Table 1). Among the different clones, normal clone recorded significantly higher volume (0.025 m^3) which was at par with H-10 (0.024 m^3) and H-4 (0.024 m^3). The least mean volume was recorded by K-26 (0.011 m^3), which

Table 1. Average growth and biomass attributes of *Acacia* hybrid clones

Clone	Height (m)	EQDBH (cm)	Volume (m^3)/tree	Wood basic density (g/cc)	Leaf weight (Kg)	Bark weight (Kg)	Branch weight (Kg)	Bole weight (kg)	Total biomass (Kg)	Expansion ratio
H-4	7.50a	10.08b	0.024b	0.43ab	5.73b	1.99ab	6.98b	11.12ab	25.82b	2.32b
H-10	8.23a	9.55b	0.024b	0.40ab	2.97a	1.91ab	2.51a	14.06b	21.45b	1.53a
B-5	6.60a	7.85ab	0.013a	0.43ab	2.55a	1.17a	3.42ab	9.37ab	16.51ab	1.76ab
B-10	6.73a	8.06ab	0.014ab	0.47ab	2.25a	1.33a	5.28b	8.22ab	17.08ab	2.08b
HD-12	8.10a	8.40ab	0.018ab	0.43ab	1.83a	2.20b	3.48ab	10.69ab	18.20ab	1.70ab
H-12	7.63a	8.27ab	0.017ab	0.47ab	2.84a	1.53ab	3.38ab	11.00ab	18.74ab	1.70ab
HD-16	6.97a	9.97b	0.022b	0.43ab	2.71a	2.38b	5.46b	13.57b	24.11b	1.78ab
HD-20	7.37a	9.76b	0.023b	0.37a	3.23ab	1.97ab	3.46ab	12.18b	20.85ab	1.71ab
K-23	6.77a	7.85ab	0.013a	0.57b	2.08a	1.50ab	3.20ab	8.32ab	15.10a	1.81ab
K-26	6.83a	7.21a	0.011a	0.57b	3.14a	1.34a	4.93ab	7.07a	16.48ab	2.33b
K-40	7.07a	8.70b	0.017ab	0.50b	5.14b	1.33a	4.03ab	8.92ab	19.41ab	2.18b
Normal	8.27a	9.76b	0.025b	0.43ab	5.25b	1.80ab	3.99ab	11.01ab	22.05b	2.00ab
Grand Mean	7.34	8.79	0.018	0.45	3.31	1.71	4.18	10.46	19.65	1.88
S Ed (±)	0.82	0.69	0.005	0.06	0.94	0.40	1.24	2.35	2.90	0.26
L SD (0.05)	NS	1.43	0.009	0.13	1.96	0.83	2.56	4.87	6.01	0.54

was at par with clones B-5 (0.013 m^3), K-23 (0.013 m^3), B-10 (0.014 m^3), H-12 (0.017 m^3), K-40 (0.017 m^3) and HD-12 (0.018 m^3).

Existence of significant differences in growth and yield attributes confirms the presence of inter-clonal variation in the clones. Overall growth of plantations could be ascribed to the genotype, environment and possible interaction between the genotype and environment. In a given environment, the differences in growth attributes of the clones are manifested primarily by the genotype, environment and interaction between genotype and environment. Existence of significant differences in the growth performance of clones of *Acacia* hybrid have also been reported by Amanulla (2007). Identification and selection of planting material, which produces maximum pulp wood in a given period is of paramount importance for pulp wood captive plantations. Wood basic density of different clones varied significantly and the values were from 0.37 g/cc to 0.57 g/cc with a grand mean of 0.45 g/cc (Table 1). Significant difference in the wood density of different clones could be due to genotypic effect.

Among 12 clones, clone H-10 was found significantly superior over other clones followed by HD-16 and HD-20. It is an indication that the clones are best suited for large scale planting programme in the area. However, selection of only two to three clones could bring narrow genetic base of the planting material. Mass selection, further cloning followed by testing is must to have broader genetic base to overcome the problems associated with narrow genetic base.

Allocation of photosynthates to different components of the plant systems is important and biomass allocation strategies of plants need to be understood for an effective short rotation captive plantation programme. A genotype, which allocates relatively more biomass to bole wood, is desirable for pulp wood production. In the present study, most of the clones allocated 50 per cent or more of the total biomass for bole wood production except clones H-4, B-10, K-26 and K-40 (Fig.1). Interestingly, biomass allocated for the bark production was in the range of 7-12 per cent. The amount of biomass allocated for foliage production is also important in understanding the biomass allocation pattern of different clones and it was observed that the biomass allocated for foliage production ranged from 10–26 per cent of the total biomass. Biomass allocated for branch wood production would also play a crucial role in over all pulp wood production in *Acacia* hybrid clones and in the present study the biomass allocated for branch wood production ranged from 12–31 per cent of the total above ground biomass. Thus, biomass allocation strategy of the species could play a crucial role in short rotation forestry for wood production.

Expansion ratio of different clone ranged from 1.53 to 2.33 with a grand mean of 1.88 (Table 1). Among the different clones, K-26 (2.33) recorded the highest expansion ratio followed by H-4 (2.32) and the least expansion ratio was observed in H-10 (1.53), which was at par with B-5, HD-12, H-12, HD-16, HD-20, K-23 and normal clone. Expansion ratio is very important for calculation of total biomass from the bole weight, which would be applied to account the

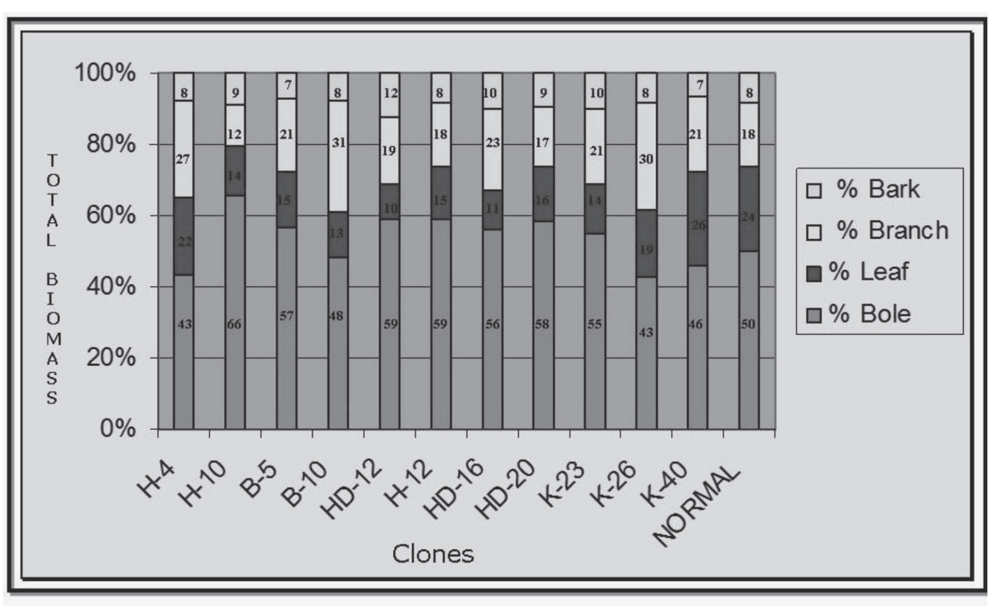

Fig. 1. Biomass allocation pattern of different clones of *Acacia* hybrid

non- bole biomass such as branch wood, bark and foliage biomass. The expansion ratio found in this study is relatively higher than the values reported for hard woods under Indian conditions (Lal and Singh, 2003).Multiple linear regression equation developed to predict total biomass and bole wood biomass based on the easily measurable growth parameters such as EQDBH and height could be used in quantifying the biomass using diameter and height measurements (Table 2).

Table 2. Multiple Linear Regression equation to estimate biomass of trees of *Acacia* hybrid clones

Response variable	Predictive model	Trees sampled
Bole biomass	= 1.96 EQDBH + 0.52 H - 6.47	36
Total biomass	= 1.84 EQDBH + 1.34 H -10.9	36

Note: H = Height in m. and EQDBH = Equivalent diameter at breast height

Productivity and carbon stock. Estimated wood volume per ha, mean annual increment (MAI), total above ground biomass per ha., mean annual biomass production, carbon stock and mean annual carbon sequestration of different clones are presented in Table 3. Among the different clones, clone H-4 produced significantly higher volume of 37.36 m^3 ha^{-1} with MAI of 6.23 m^3 ha^{-1} yr^{-1} followed by normal clone (32.81 m^3 ha^{-1}) and HD-12 (26.21 m^3 ha^{-1}). Clone K-23 produced the least volume (8.99 m^3 ha^{-1}) with MAI of 1.50 m^3 ha^{-1} yr^{-1} and was at par with K-26, K-40 and B-5.

The total biomass for different *Acacia* hybrid clones varied significantly from 10.20 t ha^{-1} (K-23) to 40.07 t ha^{-1} (H-4) with grand mean of 22.85 t ha^{-1}. However, H-4 could record significantly higher carbon stock of 20.03 t ha^{-1} with mean annual carbon sequestration of 3.34 t ha^{-1} yr^{-1} followed by normal clone (14.22 t ha^{-1}) and HD-12 (13.34 t ha^{-1}). The lowest amount of carbon stock was recorded for the clone K-23 (5.10 t ha^{-1}) with mean annual carbon sequestration of 0.85 t ha^{-1} yr^{-1} followed by K-26 (Table 3). The observed productivity of different clones varied significantly and values ranged from 1.70 t ha^{-1} yr^{-1} to 6.68 t ha^{-1} yr^{-1} with a grand mean of 3.81 t ha^{-1} yr^{-1} (Table 3). Among the different clones, H-4 (6.68 t ha^{-1} yr^{-1}) recorded significantly higher productivity followed by HD-12 (4.45 t ha^{-1} yr^{-1}) and the least productivity was observed in K-23 (1.70 t ha^{-1} yr^{-1}), which was at par with K-26 and K-40.One hectare plantation of H-4 could produce 404.55% more yield from the clonal plantations of K-23. However,MAI in the present study is much less than the values reported for the clones of *Acacia* hybrid at Vietnam (Martin, 2004). Also,carbon stock in these clonal plantations are found to be lower than the carbon mitigation potential (74.75 t ha^{-1}) of degraded forestlands in India (Lal and Singh, 2003). However, these short rotation plantations of fast growing clones could be of immense use in increasing the productivity of pulp wood plantations as well as mitigating global warming through higher rate of carbon sequestration.

Table 3. Estimated stand volume, biomass, carbon stock, MAI, productivity and rate of carbon sequestration of *Acacia* hybrid clones

Clone	Stand volume (m^3 ha^{-1})	Biomass (t ha^{-1})	Carbon stock (t ha^{-1})	MAI (m^3 ha^{-1} yr^{-1})	Productivity (t ha^{-1} yr^{-1})	Carbon sequestration (t ha^{-1} yr^{-1})
H-4	37.36c	40.07d	20.03d	6.23c	6.68d	3.34d
H-10	23.76bc	21.29bc	10.64bc	3.96bc	3.55bc	1.77bc
B-5	17.92ab	23.02bc	11.51bc	2.99ab	3.84bc	1.92bc
B-10	20.24b	24.54bc	12.27bc	3.37b	4.09bc	2.05bc
HD-12	26.21bc	26.67c	13.34c	4.37bc	4.45c	2.22c
H-12	23.00bc	26.12c	13.06c	3.83bc	4.35c	2.18c
HD-16	19.97b	22.18bc	11.09bc	3.33b	3.70bc	1.85bc
HD-20	19.72b	17.98b	8.99b	3.29b	3.00b	1.50b
K-23	8.99a	10.20a	5.10a	1.50a	1.70a	0.85a
K-26	11.23ab	16.10ab	8.05ab	1.87ab	2.68ab	1.34ab
K-40	15.76ab	17.57ab	8.79ab	2.63ab	2.93ab	1.46ab
NORMAL	32.81c	28.44c	14.22c	5.47c	4.74c	2.37c
Grand Mean	21.41	22.85	11.42	3.57	3.81	1.90
S Ed (±)	4.93	3.64	1.82	0.82	0.61	0.30
LSD (0.05)	10.23	7.55	3.77	1.71	1.26	0.63

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Forest Composition and Soil Carbon Stock in Oak and Pine Forests along Altitudinal Gradients

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Abstract: The present study was focused on two forest types *Quercus leucotrichophora* (oak) and *Pinus roxburghii* (pine) in Garhwal Himalaya, for vegetation analysis and soil carbon stock along altitudinal gradient and soil depth. The soil carbon was assessed in each forest type by collecting soil samples from three different altitudes and depths. In both the forest types, soil carbon has positive relation with leaf litter production, density and basal cover of the forests which decreased significantly with increasing altitude and soil depth. The results indicate that a change in vegetation type and a shift of vegetation belts as expected in most climate change scenario might have a profound impact on SOC in the Himalayas. Between the forests; oak forest soil has more capacity to sequester carbon compared to pine forest, therefore, to enhance carbon sequestration potential the existed forest should be maintained and promote more regeneration for high density and basal cover within oak forest and where oak is invading in pine forest to mitigate future carbon level.

Key Words: Soil organic carbon, Altitudinal gradient, Oak-pine forests

Soils are the largest carbon reservoirs in the terrestrial carbon cycle. Altogether 3.5% of the earth's carbon reserves are stored in soils, compared with 1.7% in the atmosphere, 8.9% in fossil fuels, 1.0% in biota and 84.9% in the oceans. Soils thus play a key role in the global carbon budget and can have large impact on carbon release under a climate change scenario (Lal *et al*., 1995). To assess the quality and productivity of soils, it is important to know the amount and quality of soil organic carbon in the soil. About 40% of the total SOC stock of the global soils resides in forest ecosystem (Eswaran *et al*., 1999). The Himalayan zones, with dense forest vegetation, cover nearly 19% of India and contain 33% of SOC reserves of the country (Bhattacharyya *et al*., 2008). These forests are recognized for their unique conservation value and richness of economically important biodiversity. Managing these forests may be useful technique to increase soil carbon status because the presence of trees affects carbon dynamics directly or indirectly. Thus study was under taken to understand the effect of altitude and depth on soil organic carbon potential, comparative soil organic carbon sequestration potential differences between the forest types.

MATERIAL AND METHOD

The present study was carried out in two forest types i.e., oak (*Quercus leucotrichophora*) in temperate region and pine (*Pinus roxburghii*) in sub-tropical region. Both the study sites were located in the District Pauri Garhwal, where oak forest were located between 30° 07' 09.9" to 30° 7' 12.3" N latitude and 78° 47'46.5" to 78° 47'42.5" E longitude at an elevation of 1700m, 1800m and 1900m above sea level. However, pine forest were between 30° 12' 51.2" to 30° 12" 51.0" N latitude and 78° 48' 25.2" to 78° 49' 02.2" E longitude at an elevation of 700, 800 and 900m above sea level. The climate of the study area is of monsoon type and can be divisible in three different seasons i.e., summer, winter and rainy. The snow fall occurs in the oak forest during winter season and the mean annual temperature ranges between 1.3°C to 30°C with annual rainfall of 218cm. In pine forest the mean annual minimum and maximum temperature was 16.45°C and 26.80°C with annual rainfall of 252 cm.

In both forest types, each forest type was selected for three representative sample stands (each approx. of 0.5 ha) at different elevation were identified for vegetation study. Ten (10 x 10 m) quadrats for tree were placed at random in each stand. Numbers of individuals of each species were recorded in all quadrats. The circumference at breast height at 1.37m for tree was recorded. The analytical features of vegetation were computed following Saxena and Singh (1982). Litter production of each forest type at different altitudes was done with the sampling of three replicates. The litter traps were established in the forest of a size 1 x 1 m^2 and 15 cm high.

In both the forest types, each forest type has three different altitudes and within altitude the soil sampling was done by nested plot design method. In each site, a plot of 100 × 20 m size was laid, and six sampling points were selected in each plot by the standard method (Hairiah *et al*., 2001).Three soil samples were collected at each sampling point at three depths (0–20, 20–40, 40–60 cm). A total of 108 soil samples (18 from each altitude) were collected by digging soil pits. The soil samples were air dried and sieved (>2 mm diameter) before analysis. Soil organic carbon (SOC) was determined by partial oxidation method (Walkley and Black, 1934). Soil samples from each depth were analysed, however to express the total SOC stock data in 0– 20, 20–40 and 40–60 cm, the weighted mean average were considered. The total SOC stock was estimated by multiplying the values of SOC g kg^{-1} by a factor of 8 million, based in the assumption that a layer of soil 60 cm deep covering an area of 1 ha weighs 8 million kg (Day, 2005).

RESULTS AND DISCUSSION

In oak and pine forests, the density and total basal cover of trees decreased with increasing altitudes (Table 1). The total density and total basal cover of oak forest was 1100 trees ha^{-1} and 58.86 m^2 ha^{-1} (1700m), 1040 trees $ha^{-1}$and 55.64 m^2 ha^{-1} (1800 m) 960 trees ha^{-1} and 40.88 m^2 ha^{-1} (1900m), respectively. The similar pattern of density and total basal cover was also reported in pine forest as 560 trees ha^{-1}, 56.94 m^2 ha^{-1} and (700m), 540 trees ha^{-1}, 53.26 m^2 ha^{-1} (800m), 500 trees ha^{-1}, 26.79 m^2 ha^{-1} (1000m) respectively. In oak forests, *Quercus leucotrichophora* was the dominant species at each altitude and the associated species were *Myrica esculenta, Rhododendron arboreum* and *Pinus roxburghii*. In *Quercus leucotrichophora*, density and basal cover decreased with increasing altitudes. In pine forest, each altitude was dominated by *Pinus roxburghii* which reduced their density and basal cover with altitude. The changes in climate along altitudinal gradients influence the composition and productivity of vegetation and consequently, affect the quantity and turnover of SOM (Quideau *et al*., 2001). Altitude also influences SOM by influencing soil water balance, soil erosion and geological deposition processes (Tan *et al*., 2004). The decrease in density and basal cover at higher altitudes could be due to eco-physiological constraints and low temperature result in low productivity (Wang *et al*., 2004), thus less accumulation of litter and low input of organic carbon in soils with increasing altitude. Altitude has also a significant effect on species richness, which declines with increasing altitude as well as the species composition can also be significantly affected with altitude (Markus *et al.,* 2007). In both the forest types, litter production decreased with increasing altitude. In the oak forest litter production of forest floor was highest at 1700m altitude (221.14 gm^{-2}) followed by 1800m (199.30 gm^{-2}) and 1900m (95.29 gm^{-2}). In pine forest, litter production was 98.09, 96.82 and 96.64 gm^{-2} at altitudes of 700m, 800m and 1000m, respectively (Table 2). The Carbon stock in oak forest was 72 t ha^{-1} (1700m) followed by 70.4 t ha^{-1} (1800m) and 64 t ha^{-1} (1900m) and in pine forest, 60 t ha^{-1} (700m), 50.4 t ha^{-1} (800m) and 49.6 t ha^{-1} (1000m). The carbon stock and litter production showed a positive correlation, both decreasing with increasing altitudes. In humid climates, both production and decomposition of litter increase with temperature, but the relative increases in decomposition are greater (Schlesinger, 1977; Oades, 1988). Litter constitutes an important flux of soil organic carbon. In a study carried in China, the leaf litter production in mixed plantations was higher than that in pure Chinese fir plantation, which increased their surface soil organic carbon concentrations (Wang *et al.,* 2007; 2008). Mo *et al.* (2002) suggested that the changes in the carbon stocks of the top soil in different forest types might reflect the differences in the quantity and quality of litter input, litter C decomposition, and litter biomass C. The conifer litter compared to broadleaved forests, contains more components, that are difficult to decompose, resulting in litter accumulation in the forest floor and less carbon incorporation into the mineral soil (Berg, 2000).

Soil Carbon Stock with Altitude and Depths

The SOC of oak and pine forest at different altitudes and depths is shown in Table 2. In oak forest, the highest SOC (13.0±0.7 g kg^{-1}) was in the upper layer (0-20 cm) of soils at 1700m altitude, followed by the middle layer (10.5±1.6 g kg^{-1}) and lowest layer (3.6±0.8 g kg^{-1}). At an altitude of 1800m, the SOC decreased as 14±2.7 g kg^{-1} (0-20cm), 9±0.3 g kg^{-1} (20-40cm) and 3.5±1.1 g kg^{-1} (40-60cm). At 1900m, the SOC was also again highest (13.0±0.6 g kg^{-1}) in top layer and lowest (2.1±0.7 g kg^{-1}) at the bottom. The SOC at each altitude decreased with increasing soil depth. In pine forest, at 700m altitude the SOC was highest (10.2±0.3 g kg^{-1}) in the top layer followed by the middle

Table 1. SOC stock, leaf litter production, density and TBC in oak and pine forests

Forest type	Elevation (amsl)	SOC(t C ha^{-1})	Leaf litter (g m^{-2})	Density (tree ha^{-1})	TBC (m^2 ha^{-1})
Q. leucotrichophora	1700 m	72	221.14	1100	58.86
	1800 m	70.4	199.3	1040	55.64
	1900 m	64	95.29	960	40.88
P. roxburghii	700 m	60	98.09	560	56.94
	800 m	50.4	96.82	540	53.26
	1000 m	49.6	96.64	500	26.79

Table 2. SOC at different depths in oak and pine forests

Forest type	Altitude (m)	Soil depth (cm)	SOC (g kg^{-1})
Q. leucotrichophora	1700	0-20	13.0±0.7
		20-40	10.5±1.6
		40-60	3.6±0.8
	1800	0-20	14.0±2.7
		20-40	9.0±0.3
		40-60	3.5±1.1
	1900	0-20	13±0.6
		20-40	8.9±0.7
		40-60	2.1±0.7
P. roxburghii	700	0-20	10.2±0.3
		20-40	8.0±0.8
		40-60	4.2±0.3
	800	0-20	10.7±1.5
		20-40	5.3±0.7
		40-60	2.8±0.4
	1000	0-20	11.2±0.7
		20-40	5.0±1.2
		40-60	2.5±1.1

(8.0±0.8 g kg^{-1}) and lowest (4.2±0.3 g kg^{-1}) layers. The SOC at 800m decreased in order of 10.7±1.5 (0-20cm), 5.3±0.7 (20-40 cm) and 2.8±0.4 (40-60 cm). Similarly at 1000m, the maximum (11.2±0.7 g kg^{-1}) and minimum (2.5±1.1 g kg^{-1}) SOC was in the uppermost and lowermost depths respectively. The SOC decreased with increasing altitude and soil depth. Both the forests followed similar trend of SOC, which decreased with increasing altitude. The difference is clearly linked to the vegetation type. A variety of studies showed that the vertical distribution of SOC differ depending on vegetation change (Esteban and Jackson 2000). Higher accumulation of SOC in Maquis vegetation compared to coniferous forests was also recorded (Markus *et al.,* 2007). The litter input (Lal, 1989) and the proliferated root system (Blevines and Frye, 1993) of the growing plants probably influenced the carbon storage in the soil, suggesting a positive correlation of SOC with the quantity of litter fall (Singh, 2005).

CONCLUSION

Altitude played an important role in the forest density, basal cover, which are the main component for litter production and results in the soil carbon stock in the forest floor. In both forest types, SOC decreased with increasing altitude. SOC was also having positive relation with litter production, density and basal cover of trees. Thus, the study could be conceded that conservation and maintenance of higher density and basal cover of trees can be used to enhance carbon stock in the Himalayas forest for further environmental security.

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Harvest Related Nutrient Export from Fast Growing Multipurpose Trees (MPTS): A Case Study from South Gujarat

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Abstract: Nutrient accumulation and export from the site have become an important consideration in short-rotation, high-yielding plantation systems, where nutrients removed through frequent harvests may exceed the natural rates of nutrient inputs such as mineral weathering, atmospheric inputs and biological fixation.The extensive export of nutrients related to intensive biomass extraction has raised the concern for long term fertility of the system. A study on the biomass nutrient content and the harvest related nutrient export from the site for selected MPTs viz. *Albizia procera*, *Casuarina equisetifolia*, *Eucalyptus tereticornis* and *Gmelina arborea* at 20-years-stand age. Results showed considerable variation in nutrient concentration among aboveground tissue fractions, which increased in the order stem wood< branch wood< twigs< leaves. However, the nutrient accumulation in the aboveground biomass components was maximum for stemwood primarily on account of higher biomass contribution. Among the nutrients nitrogen content in the biomass was highest followed by potassium and phosphorus. Since foliage represented sizable share of the aboveground nutrient accumulation, it is suggested that simple stand management practices such as leaving foliage and twigs in the plantation field can reduce the harvest related nutrient export from the site.

Key Words*:* SRF, Nutrients, Growth, Biomass, Gujarat

Plantation forestry is expanding worldwide, especially in the tropics and subtropics. This expansion is driven by factors, which include the urgent need to meet local and global demand for wood from plantation forests community pressure to diminish dependence on native forests for wood harvests, and the increasing opportunity to integrate plantation forests with other land uses to ameliorate land degradation. Large-scale plantings using short-rotation silviculture, intensive management and exotic species with potential for rapid growth are relatively new developments in plantation forestry. However, the opportunities for increasing production over the long term and the potential problems in sustaining yields are poorly understood. Productivity of tropical plantations varies widely, depending on site resources and species. Tropical forest plantations are among the most productive ecosystems in the world. The productivity of tropical plantations is highly dynamic, showing substantial changes with plantation age, site fertility, stand density and species. A fundamental understanding of stand growth and the factors that influence it are vital to achieving and sustaining high rates of production. Doubts have been expressed about the sustainability of tropical plantations both in terms of biological productivity and their potential impact on the environment.

Nutrient dynamics is very important for the understanding of ecosystem functioning and ecological status. Nutrient uptake, their retention and release are the three components of nutrient dynamics in forest ecosystem. More uptake and less return to the soil leads to deterioration of land and ultimately lowering of productivity. Fast growing tropical tree plantations incorporate considerable amounts of nutrients in their biomass over a relatively short period of time and the nutrient concentration in various biomass components varies significantly with tree species. This can lead to site fertility declines, which can limit sustained plantation forestry in tropical regions. Soil fertility can decrease through excessive removal of living biomass, particularly if nutrients in tree crowns are lost through harvest or site preparation. The extensive export of nutrients related to intensive biomass extraction has raised the concern for the long term fertility of the system among forest ecologists (Blanco *et al.,* 2005). The nutrient cost of biomass removal is partly dependent on the nutrient characteristics of the parts of the tree removed (Kumar *et al*., 1998).High concentrations of nutrients in small branches, twigs, and leaves compared to stem are the main reason for this nutrient drain.Very intensive harvesting has also been claimed to have a negative influence on the organic matter content in forest soils due to reduced inputs of dead biomass (Jandl *et al*., 2007).The ratio of nutrient export to the nutrient store is a key measure of long-term ecosystem stability. In this back drop, a study was taken up with the primary objective of estimating biomass nutrient content and the harvest related nutrient export from the site for different selected MPTs.

MATERIAL AND METHODS

The present investigation was conducted during August 2008 to March 2010 at the Instructional farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, situated at an altitude of about 12 meters above mean sea level, at 20^0 58' North latitude and 72^0 54' East longitude. The site experience typical tropical climate characterized by hot summer, moderately cold winter and humid warm monsoon with an average annual rainfall of 1,355 mm, the bulk of which is received from second week of June to first week of October. The soil type of the experimental site was placed under Jabalpur series having great group chromuster, sub order upstart and order vertisol as per seventh approximation. The soil is clay in texture (63% clay), high moisture retention capacity (40.50%), low in organic carbon content (0.26%), medium in available phosphorus (30.39%) and nitrogen content (110.12 kg ha^{-1}). It is not having any problem of sodicity as pH (7.86) and EC (1.75 dSm^{-1}) were below the critical limit. The study involved the biomass nutrient content and the nutrient accumulationin the above ground components of four multipurpose tree species (MPTs) of 20- year-stand age viz. *Casuarina equisetifolia*, *Eucalyptus tereticornis*, *Gmelina arborea* and *Albizia procera.* The trees were established at 2.5x 2.5 m spacing in a randomized block design with four replications.

For estimating the nutrient concentration and accumulation, 12 trees were destructively sampled from each tree species such that there were three trees from each replication.Triplicate samples (component wise for each species) of plant samples were analysed for N, P and K (three sub-samples were drawn from the tissue samples for this purpose). Nitrogen was estimated following the micro-Kjeldahl distillation method. Phosphorus and potassium were estimated after digesting the samples in triple acid mixture (HNO_3, H_2SO_4 and $HClO_4$ in 10:1:3 ratios). Phosphorus was determined following the vanado-molybdo phosphoric yellow colour method and potassium by flame photometry (Jackson, 1958). Nutrient accumulation for each tissue type for each species was calculated by multiplying the mean component biomass (dry weight) by the corresponding nutrient concentrations. Total for the whole trees were obtained by summing results for component parts and average nutrient accumulation per tree was multiplied by the effective number of trees per hectare to get the nutrient accumulation per ha.

RESULTS AND DISCUSSION

Nutrient concentration (N, P and K) in the various plant components for different tree species has been depicted in Fig. 1, 2 and 3. Nutrient concentrations were found to vary markedly among the species and tissue types studied. In general, leaf had the highest concentration of all nutrients, followed by twig, branch and bole. Higher nutrient concentration in leaves were also reported for many species (Wang *et al.,* 1991 and Mohsin *et al*., 2005). Leaf being the centre of maximum photosynthetic activity; it is logical that the highest nutrient concentration was always found in leaves as compared to other components (Sreemannarayanan *et al*., 1994). For instance *Albizia procera* recorded the highest leaf Nitrogen (1.96%) and potassium concentration(0.670%), while *G. arborea* registered the highest foliage P content (0.120%). Among the nutrients nitrogen concentration was highest, followed by potassium and phosphorus among all components of the tree. This trend is supported by many studies. Higher concentration of N (2.32 %) was reported in 5-year-old *Acacia auriculiformis* followed by K (1.08 %) and P (0.08 %) (George, 1993). Similar observation has been reported in *A. auriculiformis, Ailanthus triphysa*, *Artocarpus heterophyllus, Artocarpus hirsutus, C. equisetifolia, Emblica offcinalis, Leucaena leucocephala, Paraserianthes falcataria and Pterocarpus marsupium* (Kumar *et al*., 1998) and in *Acacia mangium* (Kunhamu *et al*., 2005).

Nutrient accumulation and export from the site have become an important consideration in short rotation plantations, where nutrient removed through frequent harvest may exceed the natural rate of nutrient input such as mineral weathering, atmospheric inputs and biological fixation (Kumar *et al*., 1998). The key factors that control the nutrient accumulation in the various biomass components is the rate of biomass production and the nutrient concentration in the respective components. In the present study, maximum accumulation of N, P and K was found in the bole fraction in all the tree species (Table 1). In general, nutrient accumulation in tissue types decreased in theorder: bole>branch>foliage>twig. Nitrogen accumulation followed a varied pattern as branch> bole>twig>foliage in *Gmelina*. Similarly available pattern was observed for potassium and phosphorus accumulation in *Eucalyptus* and *Gmelina* viz. bole>branch> twig>leaf. Maximum accumulation of N, P and K in the bole fraction in the present study indicated that huge quantity of nutrients could be lost from the systems through harvest. Such heavy losses in the subsequent rotations can bring substantial reduction in the soil nutrient base in the long run. Similar trend has been reported in *A. auriculiformis, A. triphysa*, *A. heterophyllus, A. hirsutus, C. equisetifolia, E. offcinalis, L. leucocephala*, *P. falcataria and P. marsupium* (Kumar *et al.,* 1998) in *Dalbergia sissoo* (Das and Chaturvedi, 2003), in *G. arborea* (Swamy and Puri, 2005)

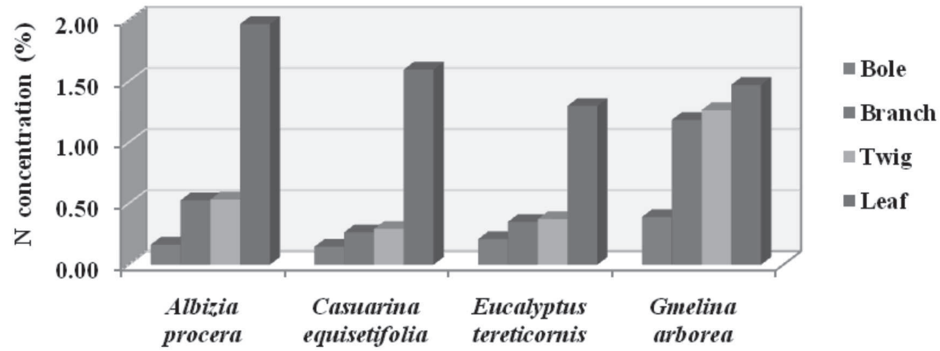

Fig.1. Nitrogen concentration of 20 year old MPT's

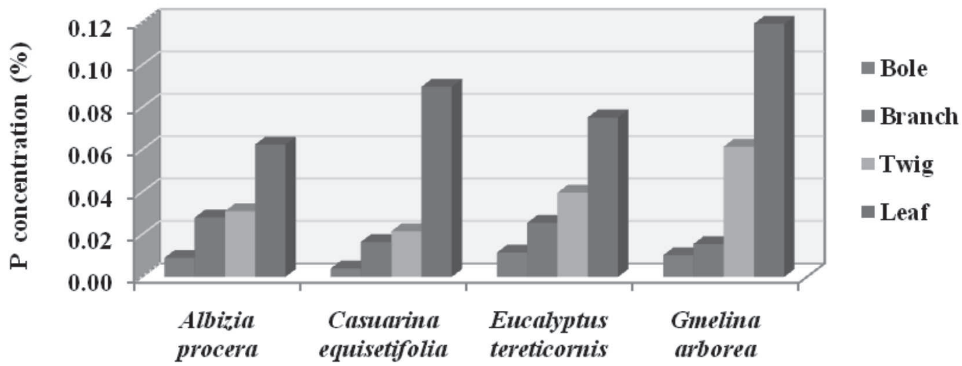

Fig.2. Phosphorus concentration of 20 year old MPT's

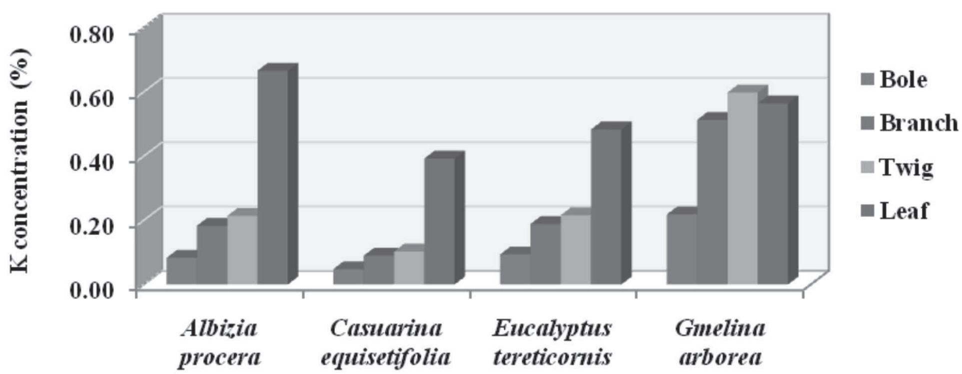

Fig. 3. Potassium concentration of 20 year old MPT's

and in *A. mangium* (Kunhamu *et al.*, 2005).Despite the lower nutrient concentrations, the higher total nutrient content in the bole was primarily on account of the wide gap between the biomass productions compared to foliage and twigs. Leaves, on the other hand, despite their higher nutrient concentration could accumulate less nutrients mainly due to lower leaf biomass production. However, it is important to observe that leaf biomass can bring substantial nutrient turnover to the soil through litter route. Hence, considering the potential nutrient loss on account of harvests, effort should be made to see that maximum foliage and harvest left over lops and tops are returned to the site.

In planning sustainable short-rotation, intensive cultural systems, site nutrient removal must be considered. Present study explicitly revealed the high nutrient export from the site following whole tree harvest. Nutrient exports from the site are strongly influenced by species, stand age and the tree management practices adopted. Tropical MPTs show considerable variability in this respect. Bole fraction, in general accounted for about 50% of the total nutrient export. A slight reduction in the tree parts removed from the site would definitely alter the rate of nutrient export. Therefore, returning leaves and small twigs to the site at the time of harvest may be a worthwhile option to restrain nutrient export

Table 1. Nitrogen, phosphorus and potassium accumulation in the aboveground biomass components for the various MPTs at 20-years-stand age at, Instructional farm, NAU

Species	Nitrogen (kg ha $^{-1}$)				Phosphorus (kg ha $^{-1}$)				Potassium (kg ha $^{-1}$)			
	Bole	Branch	Twig	Leaf	Bole	Branch	Twig	Leaf	Bole	Branch	Twig	Leaf
Albiziaprocera	493.43a	346.24a	37.47	123.43a	27.10a	18.40a	2.17b	3.92b	248.22a	119.90a	14.95	41.70a
Casuarina equisetifolia	417.96a	165.25b	40.56	178.43a	11.37b	10.28b	3.18a	10.02a	135.10b	55.50b	14.15	43.75a
Eucalyptus tereticornis	366.60a	137.25b	37.42	56.20c	20.14a	9.10b	3.98a	3.25b	162.93b	73.57b	21.57	20.85b
Gmelina arborea	98.45b	117.10b	34.47	9.46c	2.59c	1.53c	1.67b	0.77c	54.97c	50.60b	16.28	3.61c
Mean	344.11	191.45	37.47	91.88	15.29	10.05	2.75	4.49	150.29	74.86	16.74	27.48
S.Em.±	45.45	41.36	6.61	18.49	2.40	2.44	0.49	0.78	20.99	16.61	3.09	5.99
LSD at 1%	145.38	132.31	NS	59.16	7.67	7.80	1.57	2.46	67.14	NS	NS	19.16
CV %	26.41	24.32	25.41	31.01	26.33	31.33	24.69	23.29	27.93	30.38	26.88	23.58

Figure with same alphabet did not differ significantly

from the site.

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Tree Legume Rotation in Teak Silviculture: Suitability of *Acacia* species

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Abstract: The paper describes interim results of soil improvement due to planting of *Acacia* species in degraded teak plantation sites. *Acacia auriculiformis* and *Acacia mangium* were raised along with *Tectona grandis* in clear felled teak plantation sites at Nilambur and Thrissur by the Forest Department. Soil amelioration due to legume tree rotation was assessed in these five year old plots by studying the improvement in soil physical, chemical and biological properties. Litter dynamics of the two species of *Acacia* was also compared with that of the prime species of teak. Soil structure and its water stability were found to be influenced by the species. Both the *Acacia* species were found to be capable of retaining more soil moisture than teak which can be attributed to its canopy characteristics and the slow decomposing litter accumulation combined with the deciduous nature of teak. No significant difference between species could be recorded in soil pH and organic carbon though a slightly higher value of calcium was observed in teak soil. Root nodulation was found to be more in *A. mangium* as compared to *A. auriculiformis.* Litter fall, litter decomposition and nutrient release from the fallen litter were studied. Preliminary results indicate that litter fall was highest in *A. mangium* followed by *A. auriculiformis* and *T. grandis*. Litter decomposition on the contrary was faster in the case of *T. grandis,* which was followed by *A. auriculiformis* and *A. mangium*. All the litter of *T. grandis* got decomposed in 9 months time, while 93 per cent of *A. auriculiformis* and 83 per cent of *A. mangium* litter decomposed in an year's time. Nutrient release was found to follow the pattern of litter decomposition.

Key Words*:* Short rotation tree legumes, Soil amelioration, Litter dynamics, *Acacia auriculiformis, Acacia mangium, Tectona grandis*

Teak is one of the most favoured timber all over the world, since it has been used for many centuries for a range of products and services. Kerala has 74872 ha of teak plantations and on an average 1000 ha. is being felled and replanted every year (Prabhu, 2003). But continuous cropping of the same species over such long gestation period make huge demand on the site and soil especially on sloping terrain. Jose and Koshy (1972) reported soil compaction and fertility decline in teak, Alexander *et al.* (1980) observed site quality deterioration in second and third rotation teak while Balagopalan and Jose (1982) and Balagopalan and Chacko (2001) reported decrease in soil organic carbon and nitrogen in second rotation plantation. Thomas *et al.* (1997) quantified soil erosion from young teak plantation to the extent of 4-15 metric tons/ha.

Forestry, being low input as against agriculture, soil and nutrient enrichment by way of high inputs are not feasible. Rotation with tree legumes, though not attempted till now, has been considered an ideal choice to ameliorate the harm done through continuous monoculture. Kerala Forest Department has raised experimental plots of *Acacia auriculiformis, Acacia mangium* and *Tectona grandis* in clear felled teak plantation sites at Nilambur and Thrissur. *A. mangium* and *A. auriculiformis* are fast-growing legume trees belonging to the sub-family Mimosoidae. They are tropical rainforest species, which originated from Australia. Rhizobium spontaneously infect the acacia root system and form root nodules that have the capacity of directly fixing atmospheric nitrogen like most legumes, thus allowing these species to grow on N deficient soils (Brockwell *et al*., 2005). *Acacia* has also been reported to improve soil (Swamy, 1989). They are also widely grown multipurpose trees in the tropics suitable for firewood, charcoal and paper pulp production and light construction wood. Rotation with tree legumes can improve the soil and reverse deterioration to a certain extent. Yang *et al.* (2009) reported that *A. auriculiformis* and *A. mangium* has the ability to fix nitrogen and *A. mangium* has greater facilitating effects due to greater temperature buffering and nutrient amelioration. Sankaran *et al.* (1993) reported 9.3-12 t ha^{-1} annual litter production in *A. auriculiformis* plantation in Kerala, which is considered higher than those reported for other major plantation species. He had also found VAM and rhizhobial association with the roots of the species. Balasundaram *et al.* (2000) had observed that root nodulation in *A. auriculiformis* was affected by soil properties; less fertile soil inducing more nodulation. The present study was carried out in the experimental plots laid out to understand the influence of *A. auriculiformis* and *A. mangium* in site improvement of teak at Cheppilakkode, Thrissur.

MATERIAL AND METHODS

The study was carried out in the established research plots of Kerala Forest Department at Chepppilakode, Thrissur (10°30'N and 76°20' E). Plots of 20x20m of *Tectona grandis, Acacia auriculiformis* and *Acacia mangium* had been established in 2005 with a spacement of 2x2m and with 4 replications. The site received a rainfall of 2885 mm and temperature varied from 14 to 37°C. The soils in general are well drained reddish-yellow oxisols.

Soil samples were collected from the surface upto a depth of 20cm. Three soil samples were taken from each of the 12 plots. Core samples were collected separately for bulk density and big clods for aggregate stability estimation. Soil samples were air dried, passed through 2 mm sieve and subjected to analyses following procedures given in ASA Monograph (1965) and Jackson (1973). Sand, silt and clay (0.02-2, 0.002-.02 and < 0.002mm) were determined by hydrometer and particle density (PD) by using standard flask. Water stable aggregates were quantified using a Yoder type wet sieving apparatus; pH in 20:40 soil: water suspension and organic carbon (OC) by potassium dichromate-sulphuric acid wet digestion. Exchange acidity (EA) was determined by 0.5 N barium acetate and exchangeable bases by 0.1 N hydrochloric acid. Nitrogen (N) and Phosphorus (P) were estimated by autoanalyser, potassium (K) by colorimeter and calcium (Ca) and magnesium (Mg) by atomic absorption spectrometry. Mean Weight Diameter (MWD) was calculated using the formula MWD = Σxiwi; where xi is the mean diameter of a particular size class and wi is the weight in that range as a fraction of the total sample weight.

In each plot, 5 litter traps of 1m diameter bamboo baskets were kept and litter samples collected at monthly interval and quantified. Litter bag technique (Swift and Anderson, 1989) was used to study the pattern and rate of litter decomposition and nutrient release of the three species. Fifty grams of oven-dried leaf litter of *T. grandis, A. auriculiformis* and *A. mangium* were kept in 0.5 cm mesh litter bag of size 35 cm × 35 cm and laid in the respective plots. Thirty six litter bags were laid randomly in each plot so that 3 bags could be retrieved every month. The bags were carefully taken to the laboratory, the contents emptied and extraneous materials such as soil, visible animals and fine roots were removed. The sample was oven-dried at 70 °C to constant weight and analysed for N, P, K, Ca and Mg contents.The exponential model of Olson (1963), $X/X_0= e^{-kt}$ was used to estimate the annual decomposition rate of litter, where 'X' is the weight of litter remaining after time't', 'X_0' is the initial weight of litter, 'e' is the base of natural logarithm and 'k' is the decomposition rate constant. This model was also used to calculate the half life of litter decomposition. Statistical analysis of data was carried out by SPSS package.

RESULTS AND DISCUSSION

Data gathered on litter fall and litter decomposition and consequent nutrient release are given in Table 1. The influence of acacia species on soil properties was both positive and negative. Aggregate stability analysis has brought out some positive influence of acacias. Bigger aggregates were formed in acacia plots compared to teak plots. Among the species, *A. auriculiformis* was found to exert greater influence. Mean weight diameter, the index of aggregate stability was higher in acacia plots. This might be due to higher amounts of finer roots that press the particles on the one hand, the differential pressure exerted by these roots during moisture absorption and their contribution towards humus on senescence. Bulk density (g cc^{-1}) was slightly less and porosity slightly more in acacia plots compared to teak. Proportionately higher contents of bigger aggregates would have helped in reducing the bulk density though the effect was not significant. Thus, it can be seen that both *A. auriculiformis* and *A. mangium* were instrumental in improving the soil structure and its stability. Soil acidity was found to be increased by acacia species as was seen in the pH values of 5.25 and 5.3 compared to 5.8 in teak plots and this difference was significant. Similar results were reported by Sankaran *et al.* (1993). Organic carbon contents were significantly higher in acacia plots with values 16.8 g kg^{-1} in *A. auriculiformis* and 14.2 g kg^{-1} in *A. mangium* as compared to lower accumulation of 12.6 g kg^{-1} in *T. grandis* plots. Exchange acidity was more in acacia plots (64 cmol kg^{-1} in the case of *A. auriculiformis* and 66 cmol kg^{-1} in the case of *A. mangium*) as compared to 62 cmol kg^{-1} in *T. grandis,* while exchangeable bases were more in *T. grandis* (54 cmol kg^{-1}) compared to *A. auriculiformis* (46 cmol kg^{-1}) and *A.mangium* (48 cmol kg^{-1})

Table 1. Litter fall (kg ha^{-1})

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tectona grandis	357±19	337±28	224±21	220±19	240±35	280±19	264±31	310±27	250±30	237±31	342±25	420±19
Acacia auriculiformis	700±40	524±38	206±31	154±32	162±32	237±33	240±29	230±21	251±28	247±25	416±17	815±20
Acacia mangium	574±32	552±30	240±34	235 ±29	210±31	355±22	346±30	284±31	242±21	250±29	376±22	634±15

plots. Higher litter fall (Table. 2) might have compensated for the lower decomposition rate cumulatively over the years.

Table 2. Decomposition rate constant k and half life T $^{1/2}$ decomposition of dry matter litter

Species	*Acacia auriculiformis*	*Acacia mangium*	*Tectona grandis*
k	0.02	0.05	1.2
T(0.5)	270	250	200

There was significant influence of *Acacia* species in improving the nitrogen status of soil. Nitrogen contents were found to be 124 mg kg^{-1} in *T. grandis* while that in *A. auriculiformis* and *A. mangium* were 140 and 138 mg kg^{-1} respectively. Phosphorus was low with around 4-5 mg kg^{-1} and the values did not differ between species. Potassium also was not much influenced by the species; the mean values were around 130 mg kg^{-1}. *T. grandis* exerted significant effect in the calcium content of soil with 325 mg kg^{-1} as compared to 214 mg kg^{-1} in the case of *A. auriculiformis* and 207 mg kg^{-1} in the case of *A. mangium*. Magnesium content on the contrary was greater in acacia plots (240 mg kg^{-1} in *A. auriculiformis* and 237 mg kg^{-1} in *A. mangium*) compared to *T. grandis* with 215 mg kg^{-1} of magnesium.

Litter Fall and Decomposition

Litter fall pattern varied between species and months of the year. Maximum amount of litter fell during December and January months (Table 3). It decreased gradually from February to May and registered slightly higher values from June to November. Total litter in the study year was highest in *A. mangium* plots with 4298 kg ha^{-1} followed by *A. auriculiformis* with 4182 kg ha^{-1} and *T. grandis* contributing 3481 kg ha^{-1} litter. Litter of *A. auriculiformis* consisted of 67 per cent leaf, 6 per cent inflorescence, 14 per cent twig and 13 per cent pod while the respective percentages in *A. mangium* was 70, 5,13 and 12 per cent and in the case of *T. grandis* 90 per cent of litter mass was contributed by leaf and 10 per cent by twigs. Decomposition of litter was found to be more during the wet months starting July and least during the dry summer months of February to May. In an year's time all the litter of *T. grandis* got decomposed while 93 per cent of *A. auriculiformis* and 83 per cent of *A. mangium* got decomposed during the same period. Release of nitrogen through decomposition of litters of *T. grandis* was seen to be 100 per cent in 11 months' time while it was 96% in the case of *A. auriculiformis* and 90 per cent in the case of *A.mangium* in 12 months' time. Decomposition rate constant (k) was lowest in the case of *A. auriculiformis* (0.02), slightly higher in the case of *A. mangium* (0.05) and much greater in *T. grandis* (1.2). Time required for half the litter to decompose, T (0.5) was found to be 270 days for *A. auriculiformis,* 250 days for *A.mangium* and 200 days for *T. grandis.* Plants are capable of taking up maximum nutrients during the wet months and utilizing them for biomass production. As the soil starts drying up, the trees start shedding its foliage to balance the transpiration demand as also reduces the evaporation losses from both foliage and the soil surface. Low rate of decomposition of acacia litter was reported by others also (Swamy, 1989 and Byju, 1989). Teak being an indigenous species has co-evolved with the local climate and the soil organisms and thus its litter is easily decomposible. *Acacia* species that are exotics may not have this advantage. Litters with greater nitrogen content are known to decompose rapidly (Singh and Gupta, 1977; Meentemeyer, 1978). Though *Acacia* litter has this advantage, the decay rate remained low. This can be attributed to the high content of crude fibres in the phyllodes and the presence of thick cuticle (Widjaja, 1980 and Byju, 1989). The lignin content of acacia leaf litter is also more than that of teak (Kumar and Deepu, 1992). It is also reported that decomposition of lignin of nitrogen rich litters is significantly lower than those with poor nitrogen content (Berg *et al.,* 1992).

Table 3. Litter decomposition pattern (%)

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tectona grandis	10	19	21	25	29	35	51	68	82	93	98	100
Acacia auriculiformis	10	18	20	24	27	32	45	56	63	68	78	93
Acacia mangium	18	28	34	38	39	41	49	56	58	64	75	83

Table 4. Nutrient release (%)

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tectona grandis	21	28	33	41	48	56	66	73	88	99	100	
Acacia auriculiformis	16	30	34	39	48	53	63	65	71	74	88	96
Acacia mangium	16	27	33	40	46	51	54	60	65	70	88	90

Nutrient release pattern (Table. 4) calculated based on litter decomposition revealed that 100 per cent release could occur in 11 months time in the case of teak, while release from *A. auriculiformis* was 96 per cent and that from *A. mangium* 90 per cent in an year's time. Decomposition rate constant, k, which gives an indication of the decomposability of litter ranges from 4 for climax tropical African forest to 0.25 for pine forest of south eastern United States to still lower values of 0.0625 for Minnesota pine down to 0.0094 for lodge pole pine at 3000 m altitude (Jenny *et al.*,1949) . The values of 0.02 for *A. auriculiformis* and 0.05 for *A. mangium* can thus be seen to be in the lower range of pine forests with low decomposition rate while k value of 1.2 in the case of teak is definitely indicative of faster decomposition (Table 2).Thus, it can be concluded from the limited period observation of the present study that both the species of acacia, namely *A. auriculiformis* and *A. mangium* has both positive and negative influence on soil and its properties. It has a positive effect in soil aggregation and nitrogen enrichment while the negative influence results from the acidifying nature and the slow rate of decomposition. Litter fall was highest in *A. mangium* followed by *A. auriculiformis* and *T. grandis* while litter decomposition was faster in *T.grandis* followed by *A. auriculiformis* and *A. mangium*.

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Evidence for Nitrogen Fixation in the Salicaceae Family

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Abstract: It was shown frequently that poplars and willows are able to produce high amounts of biomass even at low soil nutrient levels and that the application of N fertilizers resulted regularly in little or no increase in growth. Poplars growing on rocks and gravel in their native riparian habitat were found to be well supplied with N. In different poplar and willow individuals, e.g. of *P. trichocarpa*, a *P. alba* hybrid, and *Salix sitchensis* diverse endophytic bacteria were identified, among them diazotrophic species in which N fixation could be verified. Most fast growing *Populus and Salix* species can be expected to fix N. These findings throw new light on the Salicaceae Family with respect to sustainability of biomass production at low-input energy levels.

Key Words: *Populus*, *Salix*, Nitrogen-fixation, Endophytic bacteria, Diazotrophic bacteria

Due to their fast growth, poplar cultivars are grown widely in plantations mostly in the temperate zone. There are about 10 million ha of poplar plantations world-wide. Many trials have been laid out to find the factors influencing biomass production. These trials show that N fertilization regularly has little or no effect (Coleman *et al*., 2004; DesRochers *et al*., 2006; Heilman and Xie, 1993; Jug *et al.,* 1999; Liesebach *et al*., 1999; Mao *et al*., 2010). In FACE experiments, it was shown that higher CO_2 levels would require higher levels of soil-N availability. However, poplar was able to increase biomass production under elevated CO_2 without additional N (Pregitzer *et al.,* 2000; Luo *et al.,* 2006). Also, no yield response curves and few detailed fertilizer recommendations exist for poplar or willow.

Poplar (*Populus* sp.) and willow (*Salix* sp.) species are early-successional trees with rapid growth, deep roots, and the ability to grow fast, even in nutrient-poor environments. Studies of poplars growing on rocks and gravel in their native riparian habitat were found to have sufficient amounts of N in their tissues, a finding, which was difficult to explain (Coleman *et al.,* 1994, Lawrence *et al.,* 1997). The explanation for the indifference of poplar towards soil N availability has been found recently, which this paper will focus on.

Diazotrophic Bacteria

It is well established that a large endophytic community resides in the stem tissue of poplar and willow species, the function of which is still mostly unknown. Ulrich *et al.* (2008a) found a total of 53 taxa at the genus level that included *Proteobacteria*, *Actinobacteria*, *Firmicutes* and *Bacteroidetes*. In poplar and willow grown in contaminated soil, Taghavi *et al.* (2009) identified 78 endophytic strains, the majority of which (71%) belonged to *Gammaproteobacteria*, with *Serratia* spp., *Rahnella* spp. *Pseudomonas* spp. and *Enterobacter* spp. Among these endophytes several diazotrophic bacteria were identified. They remained undiscovered because of their inconspicuous occurrence in the living tissues of the stem and branches and not in nodules on the roots like in the legume family (Fabaceae).

Legumes form a symbiosis with *Rhizobia*, a genus of soil bacteria capable of biological N fixation, where the plant trades its sugars from photosynthesis for the combined N from its root nodule inhabitants. In this process, atmospheric N (N_2) becomes accessible to the plant by the conversion into ammonia (NH_3). This conversion requires a high amount of energy in the form of adenosine triphosphate (ATP). Through a particular interaction, a specific bacterium associates with a specific legume, resulting in the familiar root nodules, in which N fixation occurs. In addition to the legumes, there are woody plant species of nine Families (Betulaceae Cannabaceae, Casuarinaceae, Coriariaceae, Datiscaceae, Elaeagnaceae, Myricaceae, Rhamnaceae, and Rosaceae) known to associate with other N fixing microbes, among them *Frankia* and these too live in specialized root nodules. Well known is *Alnus* of the Betulaceae.

Verification of N Fixation in Salicaceae

In poplars however, endophytic bacteria were confirmed to be growing inside the living tissue of the stems. These endophytes were not causing disease by living inside the plant but rather were beneficial to the host by providing hormones, peptide antibiotics, enzymes etc. and thus belonging to the plant-growth promoting bacteria (Doty *et al.,* 2005, 2009; Doty, 2010; Scherling *et al.,* 2009; Ulrich *et al*., 2008a). Among this array of growth-promoting substances, ammonia is also present as in a number of other plant species without root nodules like sugar cane, rice, coffee, and sweet potato (Reinhold-Hurek and Hurek, 1998; Xin *et al.,* 2009). Thus, the belief that if a plant species had no root nodules, it would not be associated with N fixing bacteria has shown to be wrong.

Plant-growth promoting bacteria were found in several poplar and willow species (Table 1) representing different Sections, *Populus trichocarpa*, *P. tremula*, *P. × wettsteinii*, [*Populus alba* × (*Populus davidiana* + *Populus simonii*) × *Populus tomentosa*], *P. × canadensis, P. × generosa* and also in *Salix sitchensis* and *S. gooddingii*. It is not clear, if diazotrophic bacteria are present in all Salicaceae species. It can be expected that fast growing poplar and willow species adapted to riparian habitats with sandy soils, poor in N availability are able to fix N. However, with respect to potential uses of plant-growth promoting bacteria it would be important to better quantify possible differences in growth enhancement due to the symbiotic interaction of a certain poplar or willow genotypes with certain bacterial strains.

Growth on Nitrogen Free Medium and Other Verification Methods

In order to definitely verify the ability to fix N, Xin *et al.* (2009) employed a method in which the incorporation of the rare isotope $^{15}N_2$ instead of the common $^{14}N_2$ is analyzed. They could show that a strain of the endophytic bacteria *Burkholderia vietnamensis* isolated from a wild-grown *Populus trichocarpa* tree was able to fix $^{15}N_2$ by a twentyfold higher concentration of this isotope as compared to normal air. This experiment can be accepted as a proof of N fixation of an endophyte associated with poplar.

This endophyte was then inoculated onto Kentucky bluegrass (*Poa pratensis* L.) cultured on an N-free medium. After 50 days the inoculated plants gained 42 per cent in weight and 37 % in N as compared to the uninoculated control plants. These results show that inoculation of N-fixing endophytes may enhance the growth of other plants under N-limiting conditions. It must be added that this particular *B. vietnamensis* strain is also able to provide IAA, a growth promoting hormone to the hosting plant, which may also have played a role in the biomass gain.

Another example of growth enhancement was shown by Ulrich *et al.* (2008b) using an endophytic strain P22 of *Paenibacillus humicus* isolated from poplar. It caused a pronounced increase in root number and root length in poplar compared to uninoculated control plants. The same effect was found when rooting macro-cuttings of this poplar clone (Ulrich *et al.,* 2010). An analysis of the metabolites produced by the inoculated poplar showed that the poplar reacted pronouncedly to the presence of this endophyte by producing much higher amounts of asparagines and plant accessible urea (CH_4N_2O) but reduced amounts of organic acids of the tricarboxylic acid cycle. This effect on the metabolite profiles reflects remarkable changes in N assimilation in the plant (Scherling *et al.,* 2009).

Opportunities for Practical Use

The technical fixation process of plant accessible ammonia from molecular N_2 requires an energy-input of 946 Kilojoules per mole and is thus highly energy consumptive. For this reason, plants favored for renewable energy crops are those able to produce high amounts of biomass with low requirements for synthetic fertilizer. Above that, negative influences of excessive N on the environment (groundwater leaching, emission of detrimental N_2O, etc.) can be avoided, when growing N fixing plants.

The energy source for the biological N fixation is ATP of which an equivalent of 16 moles is hydrolyzed in the process.

Table 1. Hosting tree species, bacteria isolated from these, and proof of nitrogen fixation

Tree species	Bacterial strain	Method of verification	Reference
Populus trichocarpa × *P. deltoides*	*Rhizobium tropici*	culture on N-free medium	Doty *et al.* (2005)
[*Populus alba* × (*P. davidiana* + *P. simonii*) × *P.tomentosa*]	*Paenibacillus humicus* Strain P22	metabolite analysis (urea)	Scherling *et al.* (2009)
P. trichocarpa Salix sitchensis	*Burkholderia, Rahnella, Enterobacter, Acinetobacter,*	culture on N-free medium PCR with *nifH* primeracetylene reduction assay	Doty *et al.* (2009)
P. trichocarpa	*Burkholderia vietnamensis*	culture on N-free mediumPCR with *nifH* primeracetylene reduction assay$^{15}N_2$ incorporation assayinoculation on other organism	Xin *et al.* (2009)

Biological N fixation is more energy efficient then the inorganic process as it is enzyme supported and the N is produced to the required amount and in the place where it is required. N fixing plant species have therefore received much attention both for soil improvement and saving of expenses for fertilizer. Also, methods have been sought to initiate N fixation in crop species by inoculation of diazotrophic endophytes (Cocking, 2005).

Because N fixation is an energy intensive process, N fixing plants make ready use of freely available N in the soil. They can therefore be used to sequester surplus N in N-rich sites. For example, poplars and willows are being used to sequester N from sewage sludge (Dimitriou and Aronsson, 2004), however, there might be other plant species able to sequester higher amounts of N.

In agro forestry systems poplar is being grown admixed with numerous crop plants (Yadava, 2010). These systems have become common in many places yielding good crops and high monetary returns both in the poplars as well as the crop plants (Bangarwa and von Wuehlisch, 2009). Poplars have been grown in agro forestry system with N-fixing plants, e.g. (Mao *et al.,* 2010). Although the soil N increased, there was no biomass increase in the poplars grown in this system. This unexpected result is easily explainable when considering the N-fixing ability of poplar.

Implications for Tree Improvement

Analyses of endophytic bacteria in poplar and willow individuals showed that the bacterial communities differed considerably between trees (Ulrich *et al.,* 2008a, b; Scherling *et al.,* 2009). Obviously the tree and bacteria interact in such a way that a certain bacteria community evolves within a particular tree genotype. The tree can thus acquire supplementary characteristics, which are not encoded by its genes. This may offset predicted gene expressions, e.g. in marker assisted selections. The success of artificial inoculations with growth promoting bacteria depends on the harmony of the bacterial strain and the genotype of the hosting tree.

It would be of practical importance to know, if species or genotypes of the Salicaceae family vary in their ability to fix N. The special spectrum of bacteria found in different host genotypes may suggest this assumption. There may even be species not able to fix N. This could apply to species having evolved on sites where N was not at minimum. A screening method needs to be developed, which permits testing of large numbers of genotypes.

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Pulpwood Characterization and Screening Short Rotation *Eucalyptus* Clones

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Abstract: In India, the pulp and paper industry is segmented as wood, agro and waste paper based accounting 43, 28 and 29 per cent, respectively of the total installed capacity. The demand for raw material is on the ascendancy due to industrial expansion. Considering the widening gap between demand and supply, almost all industries in the country are in the process of establishment of industrial wood plantation. However, due to low productivity and erratic pulp recovery, the achievements on this front are dismally modest. Against this backdrop, the current study was planned to screen and identify superior genetic resources of *Eucalyptus* for higher pulp yield and wood volume. Twenty seven clones in three *Eucalyptus* species viz., *Eucalyptus camaldulensis*, *Eucalyptus tereticornis* and *E. urophylla* were subjected for pulp quality analysis. All clones expressed moderate to high range of physical properties. The proximate analysis indicated the variability among the clones. The lignin content was moderate (23% – 27.8%) for all the clones. The clones differed significantly for holo-cellulose, which ranged between 68.5 – 74.6 per cent. The pulp yield (40.17- 48.38%) and kappa number (19.30-23.40) indicated significant differences among clones. The strength properties of various clones indicated significant difference among clones viz., tensile index (35 - 54 Nm g^{-1}), burst index (1.9 - 3.3 K Pa $m^2 g^{-1}$) and tear index (3.8 -5.6 m $Nm^2 g^{-1}$). All the identified clones were found to be suitable for pulp quality and hence all were included for productivity evaluation. Three clones *viz.*, EC MTP 48, EC MTP 47 and EC MTP 41 recorded superiority in terms of growth characteristics viz., height, diameter and volume. The phenotypic and genotypic coefficient of variance estimates were low to high in range and volume index recorded the highest PCV and GCV. The heritability values were high for all the traits. Considering the pulp quality and productivity conjointly, the clone EC MTP 48 proved superior and this study recommends the suitability of EC MTP 48 for pulpwood plantation programme.

Key Words: Eucalyptus, Clonal evaluation, EC MTP 48, Superior SRC

The extent and diversity of the world's forests are declining and the demand for wood worldwide is on the rise. Much of the world's timber supply is harvested from natural forests, while plantations contribute only 7-10 per cent of the current world industrial wood production (Gauthier, 1991). Coupled with this increasing demand for wood and wood products, there has been a shift in the emphasis from utilization of the often complex natural forests to plantation of species relatively easy to manage and capable of producing large quantities of wood per unit area.

The supply of industrial wood raw material from forest area has been dwindling after the enunciation of 1988 forest policy which guided the wood based industries in the country to raise their own raw material without depending on forest department supplies (GOI, 1988).There are about 660 pulp and paper industries and more than 30 per cent of these industries depend on wood, with 34 in the large scale sector and 560 in the medium and small scale sector (Srivastava, 2005). The demand for industrial wood raw material is also on the ascendancy due to expansion of various paper mills. Considering the widening gap between demand and supply, almost all industries in the country are in the process of establishment of industrial wood plantation (Lal, 2000). However, the low productivity of industrial wood plantations due to non- availability of site specific and genetically improved planting stock is the major concern faced by wood based industries. Hence, there is a need to identify and screen superior short rotation clone for pulpwood, which has the potential for high pulp recovery coupled with high productivity.

MATERIAL AND METHODS

The materials used in the present study consisted of twenty seven clones of three *Eucalyptus* species viz., *Eucalyptus camaldulensis*, *E. tereticornis* and *E. urophylla* selected from the existing seed source evaluation experiments established at Forest College and Research Institute, Mettupalayam and one seed source as control. From each species, a billet of each 1 m length and 50-60 cm girth were collected, debarked and chipped separately and screened. The screened chips were used for pulping experiments. Some chips were converted into dust for proximate chemical analysis. Based on the initial screening study in the laboratory, the wood samples were subjected to analysis of physical and chemical properties. The pulping experiments were also carried out to find out its suitability for papermaking.

The physical characteristics such as bulk density, basic density and moisture content of wood chips are estimated. For the chemical properties analysis, the billets of individual tree species were chipped in pilot chipper; air-dried and converted into wood meal. The wood dust passing through 40 mesh but retained over 60 mesh was subjected to analysis for moisture, ash, hot water soluble, one per cent NaoH soluble, AB extractive, acid insoluble lignin, pentosans, hollocellulose as per TAPPI methods (TAPPI, 1980). The strength properties such as pulping, identification of kappa number, pulp brightness, paper sheet preparation, paper strength measurement, tensile strength, tearing strength, bursting strength measurement, black liquor analysis were analyzed as per standard method (TAPPI, 1980).

Twenty seven *Eucalyptus* clones were multiplied at the clonal complex using a coppice shoot cuttings obtained from selected clones. The existing seed source of *Eucalyptus* hybrid was raised through seeds and used for comparison. The clones and seed source were established in the field in a randomized block design with three replications. In each replication nine ramets/seedlings were used for the experiments. The data on height, diameter and volume index were periodically measured and analysed and the analysis of variance, ANOVA table alone with associated t test were conducted following the methods of Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Pulp Wood Characterization of Eucalyptus Clones

Physical properties of wood chips. The results of the study indicated that the moisture contents of wood sample of all the clones were found to be ranged between 9.76 (EC MTP 47) and 10.90 (EU MTP 8). The bulk density (284 kg m^{-3}) and basic density (542 kg m^{-3}) were found highest in clone EC MTP 48 and lowest in clone EC MTP 41 (Table 1). It

Table 1. Physical characteristics of different *Eucalyptus* clones

S. No.	Clones	Moisture content (%)	Bulk density (OD basis) (kg m^{-3})	Basic density (OD basis) (kg m^{-3})	Chips classification (%)				
					+ 45 mm	+ 8 mm (over thick)	+7 mm (accept)	+ 3 mm (pin chips)	-3 mm (dust)
1	EU MTP 1	10.49	260	499	Nil	6.1	80.1	13.2	0.6
2	EU MTP 2	10.76	270	510	Nil	5.9	78.5	14.8	0.8
3	EU MTP 5	10.02	224	461	Nil	7.1	81.2	11.3	0.4
4	EU MTP 8	10.90	230	455	Nil	5.7	80.4	13.5	0.4
5	EU MTP 9	10.10	235	473	Nil	6.4	75.3	17.6	0.7
6	ET MTP 13	11.20	230	455	Nil	5.5	76.8	17.2	0.5
7	ET MTP 14	10.61	249	469	Nil	6.2	77.8	15.4	0.6
8	ET MTP 24	10.34	210	477	Nil	8.3	79.6	11.8	0.3
9	ET MTP 29	10.47	236	452	Nil	5.2	80.9	13.5	0.4
10	ET MTP 31	10.91	238	484	Nil	4.6	81.5	13.4	0.5
11	EC MTP 41	10.22	234	446	Nil	6.5	82.6	10.1	0.8
12	EC MTP 44	9.93	224	480	Nil	5.1	78.6	15.7	0.6
13	EC MTP 45	10.12	246	460	Nil	4.9	79.2	15.2	0.7
14	EC MTP 47	9.76	270	510	Nil	4.4	82.8	12.4	0.4
15	EC MTP 48	9.98	284	542	Nil	6.5	81.8	11.3	0.4
16	EC MTP 50	10.97	245	540	Nil	7.2	79.9	12.1	0.8
17	EC MTP 53	10.49	240	540	Nil	5.8	81.5	12.3	0.4
18	EC MTP 56	10.61	212	468	Nil	5.1	82.7	11.6	0.6
19	EC MTP 57	9.73	210	484	Nil	6.7	72.6	20.2	0.5
20	EC MTP 58	10.64	214	456	Nil	4.6	72.6	22.3	0.5
21	FC RI 3	10.53	238	475	Nil	6.8	78.9	13.5	0.8
22	FC RI 53	10.09	217	470	Nil	9.7	76.8	12.9	0.6
23	FC RI 56	10.88	242	455	Nil	8.9	78.4	11.9	0.8
24	FCRI 103	10.03	210	454	Nil	5.8	82.7	11.0	0.5
25	C 106	11.78	240	484	Nil	8.6	79.0	12.1	0.3
26	C 413	10.82	220	510	Nil	9.4	71.1	19.0	0.5
27	C 283	9.89	206	425	Nil	6.7	75.3	17.5	0.5
28	seedling (Control)	10.29	220	455	Nil	8.3	78.6	12.8	0.3

showed that increased density to be strongly linked to favourable strength, stiffness, hardness and working properties of sawn timbers, as well as pulp yield and paper making quality. The wood density of *Eucalyptus* pulp wood is possibly one of the most influential factors controlling the strength and several other physical characteristics of the paper sheet. It is relatively simple and inexpensive property to determine, even in unsophisticated environments. The bulk density exhibited wide variation and the maximum density was recorded by the clone EC MTP 48. This variation among tested clones and seed source may be due to the differences between early and late wood, which could have created variation between and within trees. Similarly significant difference was observed among *Eucalyptus* species in basic density, which ranged between 446 kg m^{-3} (EC MTP 41) and 542 kg m^{-3} (EC MTP 48).The wood density properties are of major importance for the production of quality pulp and paper. The amount of wood needed to produce one tone of air dried pulp is calculated from the density and pulp yield (Storebraten, 1990). Persson (1975) found that differences in diameter growth have major impact on basic density of wood. Basic density is again highly correlated with late wood content (Bergstedt and Olsen, 2000). Similarly, the variability exhibited in most physical properties studied among different *Eucalyptus* clones in the current study also attests the results of earlier findings. But it is important to understand the exact relationship between wood density and other fibre characteristics of the test clones that have an effect on pulp and paper quality.

Chemical properties of wood chips. The proximate chemical analysis give an idea of potentiality of raw material for paper making. The chemical analysis in terms of ash content ranged between 0.32 (EC MTP 48) and 0.71 (EU MTP 1) (Table 2). The chemical investigation carried out in

Table 2. Proximate chemical composition of different *Eucalyptus* clones

S. No.	Clones	Ash content (%)	Solubility in		Alcohol benzene extractive (%)	Acid insoluble lignin (%)	Pentosans (ash corrected) (%)	Holocellulose (%)
			Hot water (%)	1% NaOH (%)				
1	EU MTP 1	0.54	3.0	12.9	1.1	24.3	13.4	73.1
2	EU MTP 2	0.45	2.9	12.2	1.1	24.9	13.7	73.1
3	EU MTP 5	0.63	3.3	11.9	1.8	26.0	15.8	68.5
4	EU MTP 8	0.53	2.8	12.5	1.2	24.6	13.2	73.3
5	EU MTP 9	0.50	3.9	12.2	2.7	25.5	15.2	69.8
6	ET MTP 13	0.68	3.5	13.1	2.0	27.8	16.5	68.9
7	ET MTP 14	0.43	2.8	12.8	1.4	24.2	13.8	73.7
8	ET MTP 24	0.55	3.5	14.7	1.8	26.7	14.1	71.4
9	ET MTP 29	0.34	2.7	14.3	1.1	24.3	13.9	73.4
10	ET MTP 31	0.36	3.2	13.9	2.0	25.3	15.1	70.3
11	EC MTP 41	0.43	2.9	13.5	1.2	24.5	13.3	74.6
12	EC MTP 44	0.71	4.1	13.7	1.3	25.4	16.7	71.1
13	EC MTP 45	0.63	3.5	13.6	2.7	27.1	14.8	69.7
14	EC MTP 47	0.46	3.4	12.2	1.4	23.0	13.0	74.8
15	EC MTP 48	0.32	2.7	12.9	1.4	23.2	14.4	75.2
16	EC MTP 50	0.53	3.7	13.8	1.3	24.4	14.8	73.2
17	EC MTP 53	0.48	2.7	12.7	1.3	24.3	14.6	73.2
18	EC MTP 56	0.37	3.3	13.1	1.6	27.6	16.8	72.9
19	EC MTP 57	0.37	3.6	14.2	1.5	26.7	16.2	73.7
20	EC MTP 58	0.48	3.4	12.8	2.4	26.8	15.8	72.3
21	FC RI 3	0.36	3.2	12.5	1.6	27.7	15.2	71.1
22	FC RI 53	0.36	3.6	13.7	2.2	27.8	17.2	70.6
23	FC RI 56	0.63	3.7	14.7	2.1	26.4	17.5	72.8
24	FCRI 103	0.34	3.8	12.2	1.9	26.9	17.2	72.8
25	C 106	0.35	3.4	13.2	1.8	27.3	17.4	72.4
26	C 413	0.31	3.8	12.3	1.6	27.7	14.1	73.3
27	C 283	0.46	3.9	14.5	2.2	27.2	14.2	72.9
28	Seedling (Control)	0.38	3.6	14.0	1.2	25.7	18.5	71.6

wood pulp of *Acacia mangium* recorded high ash content (Saepuloh, 1999). However, all the selected clones in the current study exhibited lower ash content, which thus lend a scope for utilization as improved pulp wood.

The alcohol-benzene solubilities of wood constitute the waxes, fats and resinous matter. In the current study, the extractives were in the range between 1.1 (EU MTP 1, EU MTP 2 and ET MTP 29) and 1.4 (ET MTP 14, EC MTP 47 and EC MTP 48) and potential differences were recorded among the selected clones. Similar variation in alcohol-benzene extractives were observed among various clones of *E. tereticornis*, wherein the extractives ranged between 1.06 and 1.35 (Rao *et al*., 1999). Among the chemical properties, holocellulose is very important because it is a measure of total carbohydrate content of the wood (Tappi, 2001). The holocellulose constituting cellulose and hemicellulose is the major portion of fibrous raw material. The holocellulose content in the study ranged between 71.6 (S.O) and 75.2 (EC MTP 48) and other *Eucalyptus* species recorded in between these. The result indicated the superiority of EC MTP 48 over the existing seed source and other clones.

The content of pentosans ranged between 13.0 per cent (EC MTP 47) and 18.5 per cent (S.O) and acid soluble lignin was found to be in the range of 23.0 per cent (EC MTP 47) to 25.7 per cent (S.O).The over all chemical analysis revealed that the clone EC MTP 48 is most superior among twenty seven clones, which could be preferred for commercial deployment for pulpwood plantation establishment.

Strength properties of wood chips. Bleached strength properties at different freeness levels for each pulp were measured and initial freeness for the pulp was 430 ± 50 ml CSF (Table 3). The refining energy required to get 300 ml CSF was around 3500 revolutions in PFI mill, which gave freeness around 300 ml CSF. The strength properties of paper are directly associated with cellulose and interfibre bonding. The clone EC MTP 48 recorded high holocellulose and low lignin content due to increased pulp yield and is good for interfibre bonding and pulp strength. Similar variations among tree species for various strength properties were also recorded in *E. tereticornis* and *E.*

Table 3. Bleached pulp properties of different *Eucalyptus* clones

S. No.	Clones	Initial Freeness (ML CSF)	Bulk (g cm^{-3})	Unrefined pulpoptical properties				Strength properties of 300 ml CSF		
				Brightness (% ISO)	Opacity (%)	Scattering coefficient (m^2 kg^{-1})	Yellow-ness (%)	Tensile index (Nm g^{-1})	Tear index (m $Nm^2 g^{-1}$)	Burst index (K Pa $m^2 g^{-1}$)
1	EU MTP 1Unrefined	470	1.76	85.4	84.2	54.0	7.6	41.0	4.3	2.6
	Refined pulp	300						74.0	7.5	4.3
2	EU MTP 2Unrefined	480	1.77	85.6	84.0	51.5	8.0	36.8	5.6	2.0
	Refined pulp	300						61.0	7.7	3.4
3	EU MTP 8Unrefined	470	1.92	85.6	83.0	52.2	8.5	41.0	4.3	2.5
	Refined pulp	300						70.0	7.5	4.1
4	ET MTP 14Unrefined	430	1.54	85.0	83.4	47.6	8.7	52.0	4.4	3.3
	Refined pulp	300						77.0	7.6	4.6
5	ET MTP 29Unrefined	430	1.86	85.8	84.6	53.7	7.7	35.0	3.8	1.9
	Refined pulp	300						67.0	7.7	4.3
6	EC MTP 41Unrefined	430	1.80	85.6	84.8	53.5	7.6	41.2	4.3	2.4
	Refined pulp	300						78.0	8.0	4.7
7	EC MTP 47Unrefined	480	1.77	85.6	84.0	51.5	8.0	50.0	4.1	2.7
	Refined pulp	300						78.0	8.0	4.4
8	EC MTP 48Unrefined	450	1.58	85.3	83.0	47.3	8.7	54.0	4.0	3.1
	Refined pulp	300						80.0	8.2	5.0
9	EC MTP 50Unrefined	480	1.87	85.3	84.0	55.2	8.2	42.0	4.1	2.5
	Refined pulp	300						71.0	7.9	4.1
10	EC MTP 53Unrefined	450	1.81	85.0	84.7	55.2	7.6	45.0	3.8	2.2
	Refined pulp	300						78.0	7.8	4.2
11	Seedling (Control)	460	1.91	85.3	84.0	55.2	8.2	40.0	3.9	2.1
	UnrefinedRefined pulp	300						72.0	7.8	4.5

grandis (Patil *et al*., 1997). Within the species, the strength properties varied due to age but in the current study variation occurred among clones of same age which indicated the variation might be due togenetic differences. In the current study, satisfactory levels of strength properties was achieved even in five years of growth, which indicated that the clones tested in the current study could be harvested even in five years as against seven years of current practice by the state forest department.

The comparison of pulping results for yield and strength properties of clones of all the species revealed that EC MTP 48 is most superior compared to Control (S.O) . Among the three species under test, *E. camaldulensis* recorded higher strength properties compared to other two species. The strength properties *viz*., tensile index, tear index, burst index and specific coefficient were recorded superior values in EC MTP 48, EC MTP 47 and EC MTP 41. This might be due to superior fibre characteristic of these geno types. This besides, the chemical requirement to achieve 20 kappa number in this species is only 17 per cent with normal chemical requirement and good bleaching response might also contributed for improved strength properties.

Among the strength properties, tearing strength depends upon fibre length, width etc. Hence, the maximum tearing strength, burst index and tear index in EC MTP 48, EC MTP 47 and EC MTP 41 must be due to superior fibre characteristics. Strength properties are best obtained with EC MTP 48, EC MTP 47 and EC MTP 41, which might be due to higher freeness and optimized kappa number (<20) recorded by the clones. The wood and wood properties are very important not only for production of paper but also the properties of paper (Storebraten, 1990). The pulp and paper property are highly dependent on fibre morphology and sheet forming processes. Wood with different properties give different pulp and paper qualities (Kibblewhite, 1989).However, in the current study, only dominated trees were selected which expressed wide variability. This indicated the genetic differences among clones of different *Eucalyptus* species.

Considering all physical, chemical and strength properties, all the trees subjected for analysis were found suitable as a source of pulpwood. However, considering the pulp yield and kappa number coupled with strength properties (Table 4), the superiority of the EC MTP 48, EC MTP 47 and EC MTP 41 as a source of pulpwood was evident and hence the above three clones are recommended for clonal deployment towards establishment of industrial wood pulpwood plantations.

However, the variation in physical, chemical and strength properties observed among the clones of three *Eucalyptus* species suggest that further improvement could be made via selection, breeding and further clonal deployment of outstanding individuals.

Productivity Studies

Genetically improved and fast growing clonal planting stock has revolutionized productivity and profitability of plantation of many species amenable to vegetative propagation (Lal, 2005). Clonal planting stock is true to type uniform and with all the superior desirable properties

Table 4. Comparison of different *Eucalyptus* clones with respect to yield and strength

Source	Chemical charge for 20 kappa	Unbleached pulp yield (%)	Kappa number	Strength properties at 300 ml CSF		
				Tear index (m Nm^2 g^{-1})	Tensile index (Nm g^{-1})	Burst index (K Pa m^2 g^{-1})
EU MTP 1	17	45.06	20.56	7.5	74.0	4.3
EU MTP 2	17	46.84	20.30	7.7	61.0	3.4
EU MTP 8	17	44.65	20.26	7.5	70.0	4.1
ET MTP 14	17	44.28	20.38	7.6	77.0	4.6
ET MTP 29	17	46.51	20.80	7.7	67.0	4.3
EC MTP 41	17	47.35	20.30	8.0	78.0	4.7
EC MTP 47	17	47.38	20.48	8.0	78.0	4.4
EC MTP 48	17	48.38	19.30	8.2	80.0	5.0
EC MTP 50	17	47.02	20.64	7.9	71.0	4.1
EC MTP 53	17	46.91	20.90	7.8	78.0	4.2
S.O (Control)	17	44.00	24.30	7.8	72.0	4.5

of the elite mother tree (Parthiban *et al.*, 2004). It is absolutely necessary to ensure a wide genetic base of clones to safeguard against possible epidemics and to provide continuous superior genetic resources to meet the demands of wood based industries. The existing genetic superiority of elite trees should be evaluated through comparative trial in order to screen site specific clones with superior wood traits. Genetic improvement of the planting stock through clonal evaluation can play a very significant role in improving productivity, yields, quality of produce and profitability. Against this backdrop, clonal evaluation trial was carried out using twenty seven clones and one seed source as control. The clones differed significantly under field conditions during 2, 4, 6 and 8 MAP for various growth parameters such as plant height, basal diameter, number of branches and volume index (Table 5).

The clonal evaluation trial indicated that one clone *viz.*, EC MTP 48 expressed superiority in all four characters investigated followed by EC MTP 47 and EC MTP 41. Similarly, in *E. tereticornis* four clones *viz.*, ET_{12}, ET_9, ET_1 and ET_6 expressed superiority out of sixteen clones tested (Sasikumar, 2003). Similar results were also reported in the clonal evaluation trials of *E. grandis* (Lambeth *et al.,* 1994). Their study involving sixteen clones and seedling checks indicated that the clones had better yield, straightness and all other growth parameters compared to check lots of seed origin and also significant differences between clones. Vegetative propagation is excellent

Table 5. Mean performance of *Eucalyptus* clones (8 months after planting)

Clones	plant height(cm)	Basal Diameter (cm)	number of branches	volume index(cm^3)
EU MTP 1	184.63**	1.61**	15.37**	480.93**
EU MTP 2	192.30**	1.68**	16.63**	482.03**
EU MTP 5	164.04**	1.34**	7.48**	298.80**
EU MTP 8	178.30**	1.17**	8.56**	245.76**
EU MTP 9	169.70**	1.07**	6.48	194.75*
ET MTP 13	165.19**	1.16**	5.78	222.26**
ET MTP 14	186.07**	1.26**	7.44*	296.88**
ET MTP 24	170.26**	1.34**	8.63**	308.18**
ET MTP 29	176.19**	1.22**	8.15**	262.51**
ET MTP 31	162.30**	0.89	5.52	128.62
EC MTP 41	193.96**	1.65**	10.52**	530.62**
EC MTP 44	162.41**	1.27**	6.89	262.37**
EC MTP 45	154.93**	1.08**	7.48**	182.56
EC MTP 47	196.67**	1.62**	8.63**	540.34**
EC MTP 48	224.93**	1.81**	13.81**	740.65**
EC MTP 50	182.59**	1.13**	9.44**	254.38**
EC MTP 53	175.04**	1.09**	13.15**	209.50*
EC MTP 56	172.81**	1.17**	9.48**	241.78**
EC MTP 57	166.48**	1.18**	9.44**	237.54**
EC MTP 58	161.74**	1.09**	8.85**	191.81*
FC RI 3	164.15**	1.06**	12.74**	186.12
FC RI 53	162.56**	1.19**	10.85**	234.02**
FC RI 56	170.37**	1.27**	9.15**	277.68**
FCRI 103	182.41**	1.08**	8.81**	214.20*
C 106	170.63**	1.11**	8.41**	211.90*
C 413	176.19**	1.15**	8.81**	236.34**
C 283	176.11**	1.07**	10.52**	201.99*
Seedling (Control)	143.85	0.85	5.81	105.65
Mean	174.53	1.24	9.39	285.00
SEd	2.27	0.05	0.62	41.99
CD (0.05)	4.56	0.09	1.25	84.19
CD (0.01)	6.07	0.12	1.67	112.20

*Significant better than seedling (control) source at 5%.

** Significant better than seedling (control) source at 1%.

approach for development of clonal forestry programme (Vivekanandhan *et al.,* 1997) and it helps to exploit non additive characteristics (Zobel and Ikemori, 1983). Similar genetic gain by exploiting clonal forestry approaches was also done in the hybrids clones of *E. grandis* and *E. urophylla*. The hybrid vigour was exploited through clonal forestry (Chopra, 2004), which thus lend support to the current investigation. The superiority of few clones in the current study might be due to the genetic that inherited from the selected mother trees. Hence, the three clones *viz*., EC MTP 48, EC MTP 47 and EC MTP 41, which expressed early superiority could be incorporated in the industrial wood plantation programme.

Considering the wood quality traits coupled with growth attributes the current study recommends three *Eucalyptus* clones *viz*., EC MTP 48, EC MTP 47 and EC MTP 41, for incorporation in the ongoing plantation programme and also in the future breeding programme.

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Selection and Breeding of Willows (*Salix* spp.) for Short Rotation Forestry

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***Abstract**:* The clonal tests of the arborescent willows in Croatia include the autochthonous white willow (*Salix alba*), interracial hybrids of the autochthonous white willow and the English 'cricket' willow (*S. alba* var. *calva*), interspecies hybrids (*S. matsudana* × *S. alba*), as well as multispecies hybrids of willows. Selection for this purpose is done in natural populations of white willow, white willow hybrid families, and hybrid families of white willow interspecies hybrids with other species. These are mainly the Chinese willow (*Salix alba* × *S. matsudana*) of the F_I and F_2 generation, as well as backcrosses. Special attention has been paid to the selection of the plus variants on the basis of transgression variability. Testing of arborescent willows continued aiming at identification of clones with greatest production potential, particularly on so called marginal sites i.e. abandoned agricultural soils and/or sites that are not suitable for growing more valuable tree species. Clonal tests were established with clones originated to white willow (*Salix alba*) and from different crossing combinations of white willow and Chinese willow (*S. matsudana*). In one clonal test, on the heavy clay type of soils, in two-year rotation, mean biomass production of all studied clones (more than 30) was 9.3 t DM ha^{-1}. The highest biomass production of white willow (*Salix alba*) was performed by clones 'B44', 'V093' i 'V052' (17.5, 13.7 and 12.2 t DM ha^{-1}, respectively). Above mentioned clones have shown specific adaptedness on tested conditions through survival and sprouting ability. In other two clonal tests with hybrids of white willow and Chinese willow (more than 50 clones), mean biomass production vary from 10.7 to 28.8 t DM ha^{-1} a^{-1} at the first and second two year rotation period. At one of these experimental plots, with regular agrotechnical treatments, the highest biomass production as well as the best adaptedness and phenotypic stability on testing sites was shown by two clones ('V 374', 'V 461', 25,8 – 27,6 t DM ha^{-1} a^{-1}) originated from backcross hybrid *S. matsudana* × (*S. matsudana* × *S. alba*) and by one *S. alba* clone ('V 95', 28,8 t DM ha^{-1} a^{-1}). These results indicated significant potential of Chinese willow for further breeding aimed at biomass production in short rotations.

***Key Words**:* Biomass production, *Salix* clones, SRC, Croatia

The strategic interest of every country is to increase the level of its energy independence. The only path towards achieving this goal is to test the possibilities of using alternative energy sources. Among alternative energy sources, the so-called renewable energy sources and their advantages in terms of environment protection and sustainable development attract particular attention. By signing certain agreements (e.g. the Kyoto Protocol), the majority of European countries have committed themselves to taking concrete steps in increasing the share of renewable energy sources in the total energy balance.

Biomass is a renewable energy source with the highest potential in Croatia. The national BIOEN programme (Domac *et al.,* 1998, 2001) was initiated with the aim of promoting the use of bioenergy for energy purposes. Both Europe and Croatia are faced with the problems of agricultural production of low profitability on marginal and abandoned soils. More recently, such production has additionally been aggravated by adverse climatic changes, soil and water pollution, lack of energy and depopulation in areas with dominant extensive agricultural production. SRF (Short Rotation Forestry) and biomass production follow world trends and aim to put renewable energy sources to better use without generating additional quantities of CO_2, otherwise largely present in fossil fuels.

Biomass of forest tree species can also be produced by intensive cultivation of fast-growing species in SRF. The basic function is the production of biomass as a renewable and ecologically acceptable energy source. However, these species can also be an alternative "agro" culture (in poorer sites), or they can act as agricultural soil diversifiers, as well as provide the possibility of ecologically more acceptable methods of waste water and soil cleaning (phytoremediation). In addition, they sequester increased quantities of atmospheric carbon dioxide (carbon sequestration) as cited by Verwijst (2003).

In recent research, clones of arborescent willows manifested the highest biomass production potential in short rotations of up to five years on marginal (clay type of soil, reed habitat), but particularly on optimal soils (Komlenoviæ *et al*., 1996; Kajba *et al*., 1998, 2004; Kajba 1999a, 1999b; Bogdan *et al.,* 2006). Tests of different arborescent willow clones continued with the purpose of identifying those with the highest biomass production potential, especially on so-called marginal soils, i.e. abandoned soils with no agricultural production that are not attractive for the cultivation of more valuable forest tree species (Volk *et al*., 2004; Smart *et al*., 2005).

MATERIAL AND METHODS

A test with 14 white willow (*Salix alba*) clones was established with cuttings in the area of Darda Forest Office, in the eastern part of Croatia (FT1) on the poor site (reed habitat). At ramet age 2/3, 2/5 and 2/7 years, breast diameters were measured, survival was determined and the number of shoots per tree stump was identified.

Two clonal tests with 25 clones obtained by different crossing combinations of white willow (*Salix alba* L.) and Chinese willow (*Salix matsudana* Koidz.) were established in the area of Èazma Forest Office (north-western Croatian, FT2 and FT3) on clay type of soil (Table 1).

One experimental test was established with a total of ten clones on a more optimal site within the nursery (FT4) in the area of Valpovo Forest Office.

The tests were established according to the randomized block system design with an equal number of repetitions. Each clone is represented with at least 30 ramets planted in 1.3 x 0.8 m spacing. The offshoots were cut, biomass was measured and evaluated on two-year-old sprouts, and the survival of the tested clones was determined. In the year of test establishment, as well as after the first cutting, weed vegetation was mechanically regulated.

In all the four clonal tests, all two-year-old shoots from the same stump were cut in one repetition and their mass in fresh condition was measured. Mass samples of 0.5 kg were collected randomly from the cut shoots, separately for each clone. The samples were dried at 105°C until constant mass was achieved. The ratio between fresh and dried sample mass was used to determine the average shares of moisture in the wood of each clone. These were then used to assess dry biomass of cut shoots. Breast diameters and dry biomass of cut shoots were equalized by means of a non-linear regression method. Then, using the obtained regression models (for each clone separately) and the previously measured breast diameters, dry biomass of each particular shoot in the tests was assessed. The production of clone biomass per hectare was assessed in relation to the value of dry biomass of mean shoot, survival, distance between the ramets and the average number of shoots per root.

The data obtained from the measurements were processed by means of descriptive statistical analysis to determine the average, minimal, and maximal values, as well as standard deviations for the investigated properties. Non-linear regression analysis was used to assess dry biomass of particular shoots according to the following equation (Telenius and Verwijst, 1995):

$W = a + bD_{1.3}^{c}$; where:

W – dry biomass of shoots

$D_{1.3}$ – breast diameter of shoots

a, b, c – parameters assessed on the basis of the shoot sample cut in one repetition.

RESULTS AND DISCUSSION

Fig. 1 shows total biomass production per surface unit of the investigated clones of arborescent willows in the Darda test (FT1) in three successive two-year rotations. Biomass production of all the investigated clones shows a rising trend in proportion with the test age, except in clones ‘V 158’ and ‘V 160’, in which, after the initial increase, a decrease in the production was recorded between the second and the third rotation. In the first year of research (age 2/3 years), the mean biomass production amounted to 4.0 t ha^{-1}, with values ranging from 2.8 (clone ‘107/65/1’) to 6.4 t ha^{-1} (clone ‘V 052’). In the following rotation (age 2/5 years), the mean production was 6.5 t ha^{-1} and ranged from 2.4 (clone ‘107/65/1’) to 10.2 t ha^{-1} (clone ‘B 44’). At

Table 1. Studied willow clones in four clonal tests (FT1, FT2, FT3 and FT4)

Taxon	Clone
Salix alba	‘107/65/1’, ‘107/65/6’, ‘107/65/7’, ‘107/65/9’, ‘V 158’, ‘B 44’, ‘B 72’, ‘B 84’, ’73/64/8', ‘V 161’, ‘V 160’, ‘V 111’, ‘V 83’, ‘V 95’
S. alba var. *calva* × *S. alba*	‘V 052’, ‘V 0240’
(*S. alba* × *S. alba* var. *vit.*) × *S. alba*	‘V 093’
Salix ×*savensis* (*S. alba* × *S. fragilis* × *S. caprea*)	‘V 221’
S. matsudana × *S. alba*	‘V 277’, ‘V 278’, ‘V 279’,
S. matsudana × [(*S. m.* f. *tortuosa* × *S. alba*) × (*S. m.* f. *tortuosa* × *S. alba*)]	‘V 369’
S. matsudana × *(S. matsudana* × *S. alba)*	‘V 373’, ‘V 374’, ‘V 375’, ‘V 458’, ‘V 459’, ‘V 460’, ‘V 461’,
(S. matsudana × *S. alba)* × unknown	‘V 462’, ‘V 571’, ‘V 572’
S. matsudana × unknown	‘V 573’, ‘V 574’, ‘V 575’, ‘V 576’, ‘V 577’, ‘V 578’, ‘V 580’

clonal tests on marginal sites (FT1, FT2, FT3)

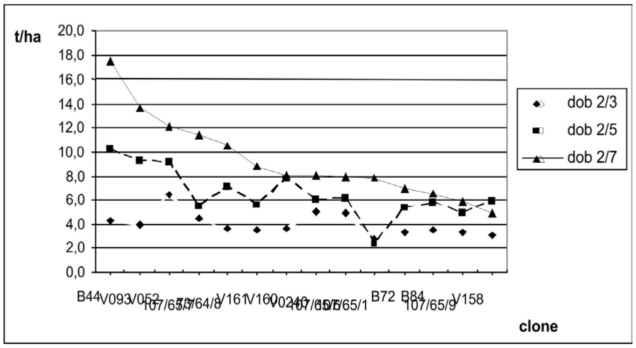

Fig 1 Biomass production of the studied willow clones in Darda test (FT1) in three successive two-year rotations (2/3, 2/5 and 2/7 years).

ramet age of 2/7 years, the mean biomass production amounted to 9.3 t ha^{-1} and ranged from 5.0 (clone ‘V 158’) to 17.5 t ha^{-1} (clone ‘B 44’).

Among all the studied clones, the clones ‘B44’ and ‘V093’ are singled out in terms of their excellent adaptedness to the habitat (reed habitat) and to developmental conditions. In addition, they display above-average values of dry mass of the mean shoot, or total biomass production, as well as sprouting ability. The clones ‘V052’ and ‘V160’ also manifest good adaptedness to the tested conditions through survival and sprouting ability, although biomass values of the mean shoot are average.

Fig. 2 shows biomass production of the studied willow clones in the Èazma test (FT2), in the first two-year rotation at ramet age 2/3 years. The mean biomass production of the 23 tested clones was 11.8 t ha^{-1} and ranged from minimal 1.1 (clone ‘V 463’) to maximal 23.2 t ha^{-1} (clone ‘V 580’).The highest biomass production in the type of heavy clay soil was exhibited by the clones originating from crossing the Chinese willow and an unknown parent (clones ‘V 580’ and ‘V 573’), and by the white willow clone ‘V 95’. Fig. 3 presents the production of all the 25 tested clones and their production in two successive two-year rotations. Mean production of the tested clones amounted to 10.1 t ha^{-1} at age 2/3 years, and 13.8 t ha^{-1} at age 2/5 years. Clone production ranged between 4.0 and 19.0 t ha^{-1} in the first rotation, and between 4.7 and 23.0 t ha^{-1} in the second two-year rotation.

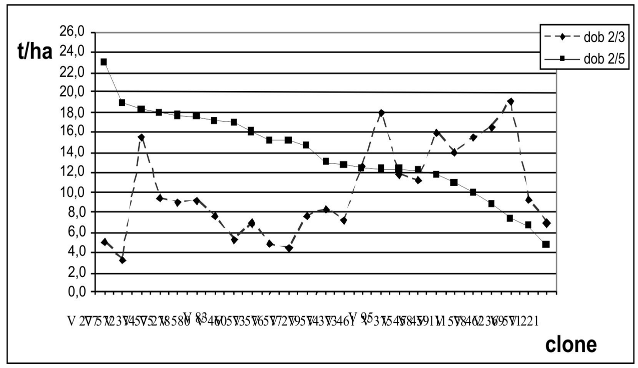

Fig. 3 Biomass production of the studied willow clones in the Èazma test (FT3) in two successive two-year rotations (2/3 and 2/5 years)

In these experiments and in three rotations, the best phenotypic stability and steady production were manifested by two clones, ‘V 374’ and ‘V 461’, originated from backcross hybrids *S. matsudana* × (*S. matsudana* ×*S .alba*), and by ‘V 95’, a white willow clone (*S. alba*). With their average production in two-year rotations varying between 12.4 and 19.8 t ha^{-1}, they manifested considerable potential for dry wood biomass production on these heavy clay soils.

In the clonal test established in the nursery area (Valpovo Forest Office), the already mentioned clones of backcross hybrids *S. matsudana* × (*S. matsudana* × *S. alba*), the clones ‘V 374’ and ‘V 461’, as well as the white willow clone (‘V 95’) manifested the highest production of 25.8 - 28.8 t/ DM ha^{-1} (Fig. 4). These clones, with regard to the partial application of agrotechnical measures in the test and to the fact that they were raised on a better quality site than the previous clones, achieved exceptional production and represent phenotypically highly unstable clones of high productivity with specific adaptability to optimal sites.

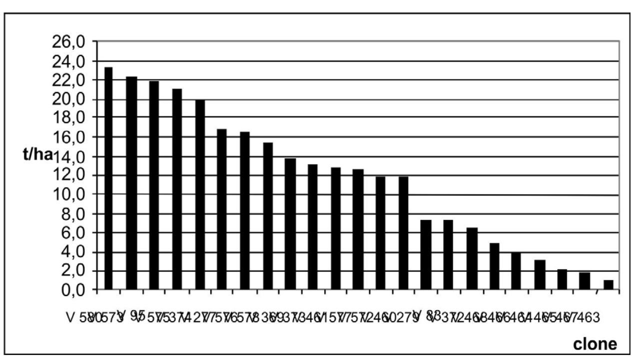

Fig. 2. Biomass production of the studied willow clones in Èazma test (FT2) at age 2/3 years

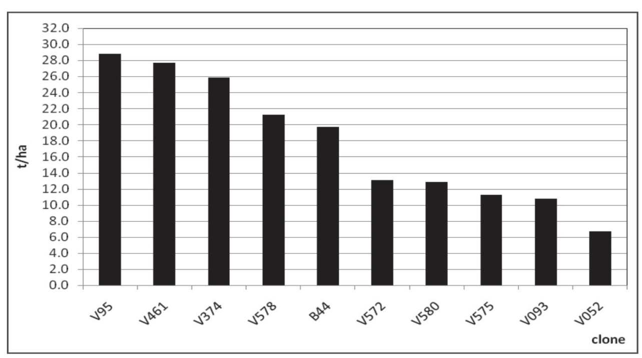

Fig. 4. Biomass production of studied willow clones in Valpovo test (FT4) at the age 2/3 yrs

CONCLUSIONS

Experimental cultures of short rotation coppices with clones of arborescent willows were established on so-called marginal sites, i.e. on abandoned agricultural soils or soils not suitable for the cultivation of more valuable forest tree species (FT1, FT2, FT3). No nutrition or pest control measures were applied (a practice otherwise widely used in intensive cultivation system), while weed vegetation was regulated only at the earliest age. Despite this, the results showed relatively high biomass production of the studied clones. Mean dry biomass production of the studied clones in the Darda test (FT1) at age 2/7 years amounted to 9.3 tons per hectare in the third two-year rotation. The highest production was manifested by the clones 'B 44', 'V 093' and 'V 052' (17.5, 13.7 and 12.2 t ha^{-1}). In the Èazma clonal tests (FT2, FT3), research was conducted in the first and second two-year rotation at ages 2/3 and 2/5 years. The tested clones taxonomically belonged to different crossing combinations of Chinese and white willow. Mean mass production varied between 10.1 and 13.8 t ha^{-1}, while perspective and phenotypically more unstable clones showed mean production of 12.4 to 19.8 t ha^{-1} ('V 374', 'V 461' and 'V 95').

With the application of minimal agrotechnical measures on a more optimal site (FT4) the same clones, the backcross hybrids *S. matsudana × (S. matsudana × S. alba*) and one white willow clone *(S. alba*), had the highest production potential of 25.8 - 28.8 t DM ha^{-1} a^{-1} ('V 374', 'V 461' and 'V 95'). In order to increase clone production, silvicultural measures should be applied so as to reduce the number of shoots to one to two per stump, while production on marginal sites could be considerably increased with the application of intensive silvicultural and agrotechnical measures.

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Improving Growth Performance and Drought Tolerance of *Robinia pseudoacacia* L. – Analysis of Seedlings of European Progenies

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Abstract: Both, the adaptation of climate change and the increasing demand for woody biomass as renewable energy source has focussed attention to improving plant material of black locust (*Robinia pseudoacacia* L.) for short rotation coppices. Its drought tolerance and many other favourable characteristics make it a promising species for biomass production in regions with low water availability in Germany. Samples of 45 progenies of European black locust seed stands from Bulgaria, Germany, Greece, Hungary, Italy, Romania and Slovakia were screened for growth performance after one season inside a greenhouse. Dehydration was measured by chlorophyll fluorescence during a controlled drought treatment of 21 days. The first results show a clear tree-to-tree differentiation as well as differences between progenies. Positive correlations between drought tolerance and biomass production of single genotypes make this approach a promising procedure for the selection of adapted plant material. After further investigation of potential progenies under field conditions, suitable plus trees may be micro-propagated and used directly as clones or for the establishment of seed orchards for the production of improved seed.

Key Words*:* Black locust, Chlorophyll fluorescence, Greenhouse experiment, Seedling, Short rotation coppice

It is necessary to replace fossil fuels by renewable energy sources. The production of biomass by fast-growing tree species can be an important alternative in the future energy-mix. Grünewald *et al.* (2009) showed that, compared with poplar (*Populus* ssp.), willow (*Salix* ssp.), or any annual crop, black locust (*Robinia pseudoacacia* L.) is the best suitable species to produce large quantities of biomass under water-limited conditions in Germany. In a post-mining landscape of NE-Germany (Jänschwalde, Brandenburg), the annual production of black locust was between 6.9 and 7.6 t DM ha^{-1}, whereas, poplar (Hybrid 275) produced 2.6 - 4 t DM ha^{-1} and willow (Carmen) 1 – 2.9 t DM ha^{-1}. In face of predicted climate change with rising temperatures, the area with low water availability in Brandenburg will probably increase (Gerstengarbe *et al.*, 2003). Black locust is undemanding with a high drought tolerance and the wood has a high specific gravity. The ability to fix atmospheric nitrogen and its readily biodegradable litter results in amelioration of the soil (Berthold and Vor, 2003).

To make short rotation coppice plantation economic, a threshold annualized yield of 10-12 t DM ha^{-1} is required (Foster, 1992). Up to now several varieties of black locust have been selected for production of high-quality wood, nectar or biomass for animal feeding (Liesebach *et al.*, 2004), but there is no established variety for short rotation coppices. Improving of growth-performance and drought tolerance is required for future short-rotation cultivation in drier regions of Germany. For this purpose, seedlings of 45 progenies of European sources were screened during their first year of growth. At the end of the vegetation period plant growth and biomass yields were determined as well as the intensity of photosynthesis during a three week period of controlled dehydration. These data allow for the selection of suitable seed sources and individuals being able to produce higher biomass and being drought tolerant at the same time.

MATERIAL AND METHODS

The experiment used seed samples from black locust seed stands of sevenEuropean countries: [Seven Bulgarian (Hasskovo, Dobrich, Varna (I, II), Plovdiv, Nessebar, Stara Zagora), twelve German (Meyenburg, Wriezen, Kusel, Göritz (I, II), Altbrandsleben, Hasenholz, Buckow, Waldsieversdorf (I, II, III, IV)), one Greek (Arnaia Xalkiaikis), three Hungarian (Pusztztavacs, Nyirsegi, Kiskunsagi), three Italian (Rifreddo, Corsagna, Poggio Rosso), seventeen Romanian (Baciu, Viisoara, Cuci, Arginesti, Carlogani, Vidra, Mihaiesti, Topoloveni, Gugesti, Focsani, Calafat, Poiana Mare (I, II, III), Sacueni, Berzeasca, Comana), and two Slovakian (Levice, Sobrance)]. Seven of the German progenies were collected in natural stands, the other samples are commercially available.

Percussion scarification combined with hot water scarification was used to break seed dormancy (Khadduri *et al.*, 2001). During April 2010, 72 seeds per progeny were seeded in 24-Qickpots, filled with commercial germination substrate and were kept inside a greenhouse. The seedlings received sufficient water and were kept at 15 to 25°C. After four weeks all plants were inoculated by different *Rhizobia* strains, ensuring a natural symbiosis with N-fixing bacteria. During June 2010, 20 seedlings per progeny were randomly selected for the growth performance and drought tolerance screening. These plants were transplanted into larger pots of 2 l volume for this purpose.

Determination of drought Tolerance. For the drought tolerance screening (mid-September to mid-October 2010), one half of the plants (n=419) were not watered during a period of three weeks, while the other half of the plants (n=418) were watered for control. Chlorophyll fluorescence (analysis of the maximum quantum yield of photosystem II: PS II) was analysed on dark-adapted plants (90 minutes after sunset) using a portable fluorescence spectrometer (PAM-2100, Walz). At weekly intervals each plant was measured, resulting in four periodic times at days 0, 7, 14, and 21. On each plant three readings on different leaflets of two leaves were taken. At each of the periodic times the same leaves and leaflets were measured. Drought tolerance was assessed by reduction in the Fv/Fm ratio only, because the Fv/Fm ratio is the most frequently used index as a measure for plant vitality and early diagnosis of dehydration stress (Genty *et al.*, 1989).

Determination of growth performance. At the end of the drought experiment plant height and root-collar diameter (RCD) 5 cm above ground were recorded on each plant. The fresh above ground biomass of the stem (SFW) and leaves (LFW) was determined separately. After drying at 103°C for 48 h, biomass of stem (SDW) and leaves (LDW) were recorded again.

Statistical analysis. Descriptive and multivariate analysis were used to describe respectively growth-performance of progenies and dehydration on chlorophyll fluorescence using R version 2.9.1 program. Because a significant effect of dehydration was recorded, the program was restricted to analyze treatment effects. Differences between treatment means were determined by the Mann–Whitney *U* test at $P < 0.05$. The data recorded on the growth-performance parameters were subjected to two-way ANOVA. Means were compared by using Tukey´s test at significance level $P < 0.05$.

RESULTS AND DISCUSSION

Germination rate of progenies was between 7 per cent (Göritz II) and 100 per cent (Dobrich) with a total average of 84.5 per cent. These rates are similar to the 90 per cent reported by Khadduri *et al.* (2001), who used the same scarification method. Unfortunately two complete German progenies (Göritz II, Hasenholz) and 23 plants of other progenies dropped out until September and could not be used for the screening. The two lost progenies also had the lowest germination rate (< 10 %) and poor growth characteristics, probably because of low seed quality. So growth and yield was determined on a total of 837 plants of 43 progenies. These growth and biomass characters were closely correlated among each other. They showed significant differences among the progenies (data not shown). The progeny with the greatest average in height had also the greatest values of RCD, SFW, SDW, LFW and LDW. The smallest progeny had the least values of RCD, SFW, SDW and LDW. Both progenies originated from German stands. A summary with percentage of average is shown on Table 1.

By progeny selection the woody biomass production could improve by 197 per cent. But there are high intra-progeny differences in growth, probably caused by the diversity of genotypes. If only the best clones were selected, the growth-performance after a six month vegetation period could improve by about 200 per cent and the biomass

Table. 1. Summary of mean values with standard deviation and range (min - max) of growth characters for all, the worst and the best progeny (RCD: root-collar diameter, LDW: leaf dry weight, SDW: shoot dry weight).

	all progenies (n=837)	range (n=837)	worst progeny (n=20)	best progeny (n=20)
Height [cm]	66.2 (±22.3)	8 - 131	54.7 (±16.1)	94.5 (±16.9)
Percentage of average [%]		12 - 198	83	143
Root-Collar diameter [cm]	0.45 (±0.12)	0.12 - 0.8	0.36 (±0.09)	0.61 (±0.12)
Percentage of average [%]		27 - 178	80	136
LDW [g]	2.86 (±1.79)	0.03 - 10.78	1.62 (±0.12)	4.31 (±2.05)
Percentage of average [%]		1 - 377	57	151
Biomass of Stem [g]	2.48 (±1.74)	0.3 - 8.93	1.27 (±0.92)	4.88 (±2.02)
percentage of average [%]		12 - 360	51	197

production by more than 350 per cent. From family selection alone, biomass productivity of black locust can be increased by more than 50 per cent (Bongarten *et al.*, 1992). In their study one year old seedlings of different American progenies were established and weighed after one (0.31kg ±0.832), two (1.84kg ±0.868) and three (3.63kg ±0.569) field seasons. Addlestone *et al.* (1999) showed that black locust with a starting height of 72cm and a RCD of 6.1mm growths up to 253cm with a diameter of 26.3mm in the second years attained height.

Chlorophyll Fluorescence

Values of the maximum quantum yield are around 0.8 in sound and unstressed plants (Percival and Sheriffs, 2002), at values below 0.7 a physiological disturbance or stress is signalled (Bolhár-Nordenkampf and Götzl, 1992). At the beginning of the treatment, the values for the plants of the drought treatment (0.76 (±0.03) and those of the control (0.76 ±0.04) did not differ (Fig. 1). After seven days without water, the value dropped already significantly (0.72 ±0.09), remained however above the threshold value of 0.7. At this time the plants obviously still had sufficient amounts of water in the soil. After 14 days of drought the quantum yield value dropped to 0.5 (±0.29) and averaged after 21 days only 0.18 (±0.26). Also in the control plants a distinct drop of this value was observed, especially after 21 days. The cause for this is most probably due to the seasonal change middle of October towards autumn induced by increasingly shorter day lengths. Nevertheless, distinct differences due to the drought treatment were ascertained. Photochemical efficiency (Fv/Fm) of detached leaves of 30 woody plants *in vitro* following a 24 h of dehydration was between 0.801 (*Quercus ilex*) and 0.421 (*Spiraea japonica* ´Shirobana´) (Percival & Sheriffs, 2002).

After the dehydration period the water content of leaves was 46.5% and differs clearly from the control (63.5%). In contrast the water content of shoots was nearly similar between the treatment (drought: 56%, control: 57.3%). With the retention of water in the shoots, the loss over the leaves will decrease (drought adaption).

Selection of plants with good growth performance and high drought tolerance. Drought tolerant plants were selected if after a drought period of 21 days their quantum yield value was above the threshold value of 0.7, which means that these plants show no signs of drought stress. However, larger plants, due to their higher water requirement, suffer earlier from water deficit (Fig. 2). In total, 17 out of 419 plants showed no drought stress symptoms after 21 days of controlled drought. Only one individual of a German progeny (Göritz II) reached a height of 96 cm and met the criteria fast growing and drought tolerance. Six plants from five progenies (Waldsieversdorf I, Carlogani Plovdiv (2), Stara Zagora, Rifreddo) with a quantum yield over 0.7 were between 45 and 90 cm high. Ten plants

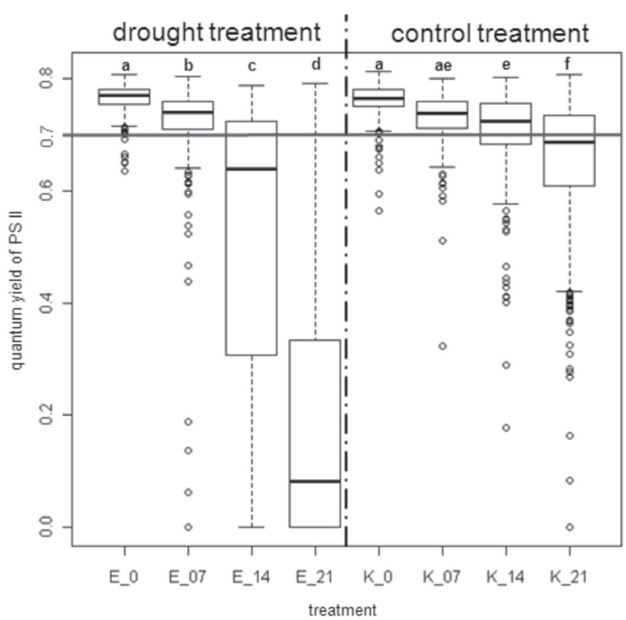

Fig. 1. Quantum yields of PS II in black locust by drought treatment (left ("E"), n=419) and control (right ("K"), n=418) at different periods of treatment ("_0": start of experience, "_7": after one week, "_14": after two weeks, "_21": after three weeks). The straight line in the upper half marks the threshold value of 0.7 under which drought stress of the plant can be assumed. The letters show differences between test intervals of treatments (Mann-Whitney *U* test, P < 0.05).

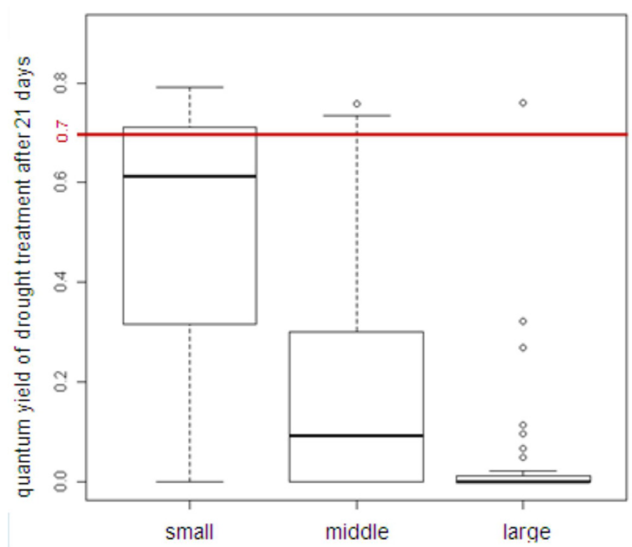

Fig. 2: Quantum yields of PS II of black locust of different height classes (small: 0-45cm (n=185), middle: >45-90cm (n=529), large: >90cm (n=123)) after controlled drought of 21 days. The horizontal line in the upper half marks the threshold value of 0.7.

(Kiskunsagi (2), Wriezen, Buckow (2), Topoloveni, Gugesti, Stara Zagora, Rifreddo, Poggio Rosso) were smaller than 45 cm. Per se there is no especially drought tolerant progeny or country identifiable and therefore, individual selection is necessary.

CONCLUSIONS

These observations focus only on the performance of seedlings under optimal conditions. Also the present selection of drought tolerance focussed only on one parameter. The physiological analysis needs expansion by additional methods and higher plant numbers. Also the observation of growth performance needs to be extended over a longer period to get verified results. So far only European seed sources were analysed. This will be expanded to seed sources from the natural range in America and one Asian seed source. It remains to be seen how the progenies perform under natural conditions where additional factors may act as stressors. For this purpose a total of 50,000 plants of the different seed sources were reared in the nursery. From this stock, suitable plants shall be selected after sufficient time under field testing and compared with the present results. Nevertheless, the first results are promising for successful selection of adapted and improved plant material. Suitable plus trees may be micro-propagated and used either directly as clones or for the establishment of clonal seed orchards for the production of seed for short rotation coppice plantations.

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Phenological Behaviour and Reproductive Biology of Important Fast Growing *Salix* Species

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Abstract: The study on the reproductive biology of nine important tree willows (*Salix* spp.) procured from different countries were conducted to observe the different aspects of their phenological stages and floral biology. *Salix tetrasperma, S. jessonensis, S. gracilistyla and S. acmophylla* were among early flowering species, whereas, *S. udensis* flowered in staggered manner from last week of January to last week of March. *S alba, S. matsudana* and *S. babylonica* flowered between 1st and 3rd week of March. *S. nigra* flowered between last week of March and 1st week of April and was last in flowering among all the species. The male flower buds bursted earlier than the vegetative bud, whereas, female flower buds bursted after the leaves started to emerge in all the species. Although most of the species remained leafless from 1st week of December to last week of February, *S. tetrasperma* became leaf less from 1st week of November. *S. matsudana* remained leafless till 2nd week of March. *S. tetrasperma* and *S. babylonica* fruit took maximum and minimum time, respectively for its development. Seed dispersal was in order of *S. acmophylla*, *S. tetrasperma*, *S. jessonensis* and *S. babylonica* dispersing their seeds in last week of March followed by *S. alba* and *S. matsudana* in 2nd week of April. *S. nigra* dispersed its seeds in last week of April.

Key Words: *Salix*, Phenology, Reproductive biology, Catkin length, Flowering behaviour

The willows belong to the genus *Salix* (Salicaceae) is one of the most important taxonomic entities of the world because of the large number of species and varieties. There are about 330-500 species world wide (Argus, 1997) occurring mostly in the arctic region and north-temperate zone, but few species in the southern hemisphere covering tropical and subtropical zones. In India, about 33 species of *Salix* are reported from temperate regions of the India except *S. tetrasperma* and *S. acmophylla,* which are found in tropical and sub-tropical riparian areas of the entire country (Anonymous, 1972). Few introduced species have been sporadically cultivated in the foot hills and inner valleys of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and the northeastern regions of India for many years. Among them, the most popular is cricket bat willow *Salix alba* var. *Caerulea* cv *culva*, is a female cultivar of hybrid origin between *S. alba* and *S. fragilis,* which was introduced by the Britishers in Jammu and Kashmir state in the beginning of the 20th century. *S. fragilis*, *S. caprea*, *S. babylonica*, *S. matsudana*, *S. amygdaloides*, *S. purpurea*, *S. viminalis*, *S. triandra* and *S. phylisifolia* were the other *Salix* species that were introduced in Jammu and Kashmir during that period (Anonymous, 2000).

The need for precise information about the reproductive and phenological behaviour of the forest tree species came to be appreciated with the gradual development of science in forestry. It helps the breeders in collecting plants at different stages of development and enables them to determine the optimum time for various cultural practices and to develop appropriate breeding strategy in an hybridization programme. Accurate and detailed description of plant growth phenostages is necessary for comparisons between different species and taxa (Margaret and Kuzovkina, 2010). The knowledge of flowering time and mode of pollination in forest trees species is of vital importance for a forest tree breeder. The studies on various aspects viz., blooming period, pollen anthesis, stigma receptivity, pollen viability, pollen germination and its storage are essential to initiate a successful breeding (hybridization) programme. Therefore the knowledge on various aspect of reproductive biology is pre-requisite for development of successful hybrids and harnessing the hybrid vigour.

In species like willows, long traditions of cultivation have resulted in greater understanding of their biology. However, no detailed information of different reproductive and phenological stages of different species/hybrids/ cultivars of willows has been reported. This study was undertaken to characterize the various reproductive and phenological events among six staminate and seven pistillate species introduced from different countries.

MATERIAL AND METHODS

The present investigations were carried out at Nauni, Solan (H.P.) during 2008-2010. The study included six staminate and seven pistillate species of genus *Salix* namely *Salix alba* Linn, *S. tetrasperma* Roxb., *S. matsudana* Koidz., *S. jessoensis* Seeman., *S. udensis* Trautv., *S. nigra* Marsh., *S. babylonica* Linn., *S. acmophylla* Boiss. and *S. gracilistyla* Miq. imported from different countries viz., Italy, New Zealand, USA, Japan, UK including India. For investigations on the phenological behaviour and reproductive biology three competitive trees approximately of the same age and diameter were selected in the field in 2008. On each tree, five branches were tagged with metallic tags and numbered from 1-5 and observations on different phenological and reproductive characters were recorded for two successive years (2008-2009 and 2009-2010) and analyzed separately for pistillate and staminate species.

RESULTS AND DISCUSSION

Analysis of variance revealed significant variation for phenological and reproductive characters for both staminate and pistillate species respectively. Similarly significant variation was revealed for characters viz., fruiting and seed dispersal between different pistillate species in both the years.

Phenological Behaviour

A close appraisal at the Tables 1 and 2 clearly showed that *S. tetrasperma* was pioneer in initiation of vegetative bud swelling during 2nd week of January followed by *S. alba* and *S. gracilistyla* in 1st week of February and last week of February and 1st week of March in 2009 & 2010, respectively. Bud swell continued for 247.40 and 246.40 days for *S. alba* in 2009 and 2010, respectively, which was maximum among different staminate species. Among pistillate species, *S. alba* initiated bud swelling in 3rd week of January followed by *S. tetrasperma* and *S. jessonensis* (Table 3). Bud swelling was late in *S. nigra* (3rd week of February) in 2009 and 2010. *S. alba* continued bud swelling for maximum period of time. Pistillate *S. tetrasperma* was 1st to initiate bursting of buds from 1st and 2nd week of February in 2009 and 2010.

Vegetative bud bursting started first in *S. babylonica* and was very closely followed by *S. tetrasperma* in 2009, whereas, in the year 2010, *S. tetrasperma* pioneered in bud bursting followed by *S. babylonica*. Duration of bud bursting continued for 227.53 mean number of days in *S. babylonica* which was found maximum among the staminate species in 2009 (Table 4). In *S. gracilistyla,* bud bursting continued for minimum duration (199.20 and 198.40 mean number of days) in both the consecutive year i.e., 2009 and 2010. Similarly maximum duration of vegetative bud bursting (237.07 and 237.33) was recorded in pistillate *S. jessonensis* for 2009 and 2010, respectively whereas, *S. nigra* recorded minimum 193.40 and 187.67 mean days for bud bursting among the pistillate species in both the consecutive years. Both staminate and pistillate *S. tetrasperma* and *S. alba* started shedding-off their leaves

Table 1. First and last date of important vegetative characters of different staminate *Salix* species

Species	Bud swell		Bud burst		Leaf fall		Leafing	
	2009	2010	2009	2010	2008-2009	2009-2010	2009	2010
S. tetrasperma	10-01-2009 to 10-09-2009	15-01-2010 to 15-09-2010	25-02-2009 to 17-09-2009	21-02-2010 to 10-09-2010	17-11-2008 to 25-02-2009	16-11-2009 to 21-02-2010	25-02-2009 to 16-11-2009	21-02-2010 to 02-11-2010
S. alba	01-02-2009 to 18-10-2009	05-02-2010 to 12-10-2010	08-03-2009 to 21-10-2009	12-03-2010 to 25-10-2010	25-11-2008 to 08-03-2009	16-11-2009 to 12-03-2010	08-03-2009 to 16-11-2009	12-03-2010 to 18-11-2010
S. babylonica	16-02-2009 to 06-10-2009	19-02-2010 to 03-10-2010	24-02-2009 to 19-10-2009	26-02-2010 to 09-10-2010	17-11-2008 to 24-02-2009	03-12-2009 to 26-02-2010	24-02-2009 to 18-11-2009	26-02-2010 to 05-12-2010
S. matsudana	15-02-2009 to 10-10-2009	15-02-2010 to 11-10-2010	15-03-2009 to 13-10-2009	20-03-2010 to 23-10-2010	27-12-2008 to 15-03-2009	20-12-2009 to 20-03-2010	15-03-2009 to 20-12-2009	20-03-2010 to 25-12-2020
S. gracilistyla	26-02-2009 to 23-09-2009	01-03-2010 to 20-09-2010	11-03-2009 to 29-09-2009	15-03-2010 to 01-10-2010	15-12-2008 to 11-03-2009	10-12-2009 to 15-03-2010	11-03-2009 to 10-12-2009	15-03-2010 to 26-11-2010
S. udensis	21-02-2009 to 04-10-2009	27-02-2010 to 10-10-2010	21-03-2009 to 24-10-2009	26-03-2010 to 30-10-2010	18-12-2008 to 21-03-2009	12-12-2009 to 26-03-2010	21-03-2009 to 12-12-2009	26-03-2010 to 05-12-2010

Vegetative characters (spanning header over all columns)

Table 2. Variation in time taken (mean number of days) for important vegetative characters among different staminate *Salix* species

Species	Bud swell		Bud burst		Leaf fall		Leafing	
	2009	2010	2009	2010	2008-2009	2009-2010	2009	2010
S. tetrasperma	241.00	240.67	201.67	199.40	97.13	95.87	260.33	251.47
S. alba	247.40	246.40	223.07	225.13	101.00	114.67	249.40	250.13
S. babylonica	230.47	224.40	227.53	222.73	95.67	83.93	264.73	270.53
S. matsudana	243.73	236.73	210.20	215.27	75.33	86.93	278.20	278.80
S. gracilistyla	207.13	200.87	199.20	198.40	84.87	94.73	271.87	254.80
S. udensis	222.53	223.80	215.53	198.67	91.47	101.93	263.80	253.67
Mean	232.04	228.01	212.86	209.93	90.91	96.34	264.72	259.90
SE±m	0.31	0.29	0.32	0.34	0.31	0.32	0.35	0.41
$CD_{0.05}$	0.61	0.59	0.64	0.70	0.63	0.65	0.71	0.82

Vegetative characters (mean number of days)

earlier than other species.

Both bud swelling and bud bursting advanced by at least one week in all the species in 2009 as compared to 2010. This may be attributed to the fact that the mean maximum temperature was more during January and February in the year 2009. With early increase in threshold temperature (temperature required for swelling and bursting), the buds started to break early. The present investigations are in agreement with Krammer (1996) who reported that a 3°C increase in temperature would advance bud bursting in *Fagus sylvatica* by 11 days. Tsarouhas (2002) attributed the variation in time of bud flushing to the adaptive response of the particular species in the given environment. The climate variables such as wind, rain, air, humidity, temperature and light intensity are the important factors determining the time and duration of different phonological events in the life history of species. The present findings concur with the earlier studies of Orlandi *et al*. (2007) on winter deciduous species including *Salix acutifolia* and *S. smithiana* in which annual timing of different phonological events were affected to a great extent by temperature. In the beginning of the growing season (January–March), leaf bud development and unfolding should reflect the thermal regime while leaf fall in autumn is more complex process, which is also induced by lack of light and low temperatures (Chmielewski, 2003; Lennartsson, 2003 and Post *et al*., 2008).

Reproductive Characters

Wide variation for reproductive characters was observed among different staminate and pistillate species (Tables 5, 6, 7 and 8). Data presented in Table 5 and 6 showed that bud swelling among staminate species initiated with *S. tetrasperma,* which was closely followed by *S. udensis* in both years. *S. udensis* continued bud swelling and bursting for maximum duration in two consecutive years. Similar trend was observed for bud swelling and bud bursting among pistillate species (Table 7 and 8). Bud swelling and bursting initiated first in *S. tetrasperma* closely followed by *S. acmophylla.* Bud swelling and bursting continued for maximum period (45.53 and 46.67 mean days) and (56.60 and 56.93 mean days) in staminate *S. udensis* in 2009 and 2010, respectively.

The delay in bud swelling and its bursting may be attributed to the climatic factors as such as temperature and rainfall. During 2009, the occurrence of comparatively cooler winter along with less precipitation may have delayed the phonological events. The observations are in line with Nienstaedt (1974) on genetic variation in some phenological characteristics of forest trees, Orlandi *et al.* (2007) on phenological investigation of different winter deciduous species and Lennartsson (2003) on differences in temperature requirements for bud bursting among *Salix* clones.

Flowering among willows were delayed by a week in 2010 as compared to 2009. The strong seasonal differences observed between willows suggested that flowering phenology may be an important promoting barrier to inter-specific pollination and potential gene flow. The present investigation supports the findings of Mosseler and Papadopol (1989) where seasonal isolation was reported as reproductive barrier among four sympatric *Salix* species. An average length of 6-10 days and 8-13 days of flowering period was reported by him in two successive years. Earlier Karrenberg *et al.* (2002) also reported flowering period of 7, 30, 32 and 36 days during studies on inflorescence morphology in *S. daphnoides*, *S. elaeagnos*, *S. triandra* and *S.alba*. Dickmann and Kujovkina (2008) also reported that sequence of flowering and development of shoots may vary among willow species. Delayed flowering in 2010 among

Table 3. First and last date of important vegetative characters of different pistillate *Salix* species

Species	Vegetative characters							
	Bud swell		Bud burst		Leafall		Leafing	
	2009	2010	2009	2010	2008-2009	2009-2010	2009	2010
S. tetrasperma	23-01-2009 to 19-09-2009	26-01-2010 to 12-09-2010	03-02-2009 to 27-09-2009	09-02-2010 to 18-09-2010	17-11-2008 to 03-02-2009	10-11-2009 to 09-02-2010	03-02-2009 to 10-11-2009	09-02-2010 to 15-11-2010
S. alba	18-01-2009 to 05-10-2009	20-01-2010 to 29-09-2010	01-03-2009 to 19-10-2009	28-02-2010 to 09-10-2010	19-11-2008 to 01-03-2009	13-11-2009 to 28-02-2010	01-03-2009 to 10-11-2009	28-02-2010 to 19-11-2010
S. babylonica	09-02-2009 to 15-10-2009	14-02-2010 to 12-10-2010	17-02-2009 to 14-10-2009	22-02-2010 to 11-10-2010	24-11-2008 to 17-02-2009	26-11-2009 to 22-02-2010	17-02-2009 to 26-11-2009	22-02-2010 to 05-12-2010
S. matsudana	13-02-2009 to 19-10-2009	18-02-2010 to 14-10-2010	03-03-2009 to 24-10-2009	10-03-2010 to 12-10-2010	18-12-2008 to 03-03-2009	22-12-2009 to 10-03-2010	03-03-2009 to 22-12-2009	10-03-2010 to 20-12-2010
S. jessonensis	23-01-2009 to 25-09-2009	27-01-2010 to 25-09-2010	08-02-2009 to 02-10-2009	09-02-2010 to 05-10-2010	19-11-2008 to 08-02-2009	21-11-2009 to 09-02-2009	08-02-2009 to 25-11-2009	09-02-2010 to 26-11-2010
S. nigra	21-02-2009 to 18-09-2009	26-02-2010 to 08-09-2010	10-03-2009 to 15-12-2009	12-03-2010 to 20-09-2009	08-12-2008 to 16-09-2010	15-12-2009 to 10-03-2009	10-03-2009 to 12-03-2010	12-03-2010 to 10-12-2010
S. acmophylla	04-02-2009 to 20-09-2009	07-02-2010 to 13-09-2010	10-02-2009 to 28-09-2009	14-02-2010 to 02-10-2010	29-11-2008 to 10-02-2009	25-11-2009 to 14-02-2010	10-02-2009 to 25-11-2009	14-02-2010 to 20-11-2010

Table 4. Variation in time taken (mean number of days) for important vegetative characters among different pistillate *Salix* species

Species	Vegetative characters (Mean number of days)							
	Bud swell		Bud burst		Leaf fall		Leafing	
	2009	2010	2009	2010	2008-2009	2009-2010	2009	2010
S. tetrasperma	237.20	227.13	233.40	220.67	75.93	89.67	278.27	277.93
S. alba	258.27	250.47	231.20	222.6	100.80	103.70	252.73	262.87
S. babylonica	245.33	239.40	236.93	232.33	82.60	87.00	280.53	283.30
S. matsudana	246.60	236.27	233.53	216.13	74.67	75.93	292.67	282.80
S. jessonensis	242.47	239.33	237.07	237.33	75.13	73.93	288.80	288.00
S. nigra	208.07	194.73	193.40	187.67	88.93	83.93	278.33	271.47
S. acmophylla	226.40	217.00	220.80	225.4	72.80	75.40	285.13	277.80
Mean	237.80	229.19	226.62	230.30	81.55	84.21	279.50	277.80
SE±m	0.36	0.28	0.34	0.34	0.35	0.32	0.42	0.37
$CD_{0.05}$	0.72	0.57	0.67	0.67	0.71	0.64	0.84	0.75

willow species suggested that willow flowering demonstrated a strong thermal control, which occur in response to heat pulse and may be delayed by cold spell during January and February 2010 as exhibited by meteorological data of 2008-2010.

Maximum pollen anthesis period was observed for *S. udensis* (18.00 and 16.93 mean days) in 2009 and 2010 and minimum was noticed for *S. babylonica* (4.53 mean days) in 2009. Anthesis started first in *S. tetrasperma* in both the successive years. Mosseler and Papadopol (1989) observed similar pattern of pollen anthesis among sympatric *Salix* species. A critical observation on the timing of pollen anthesis revealed that maximum pollen anthesis in different species took place between 9.00 am to 10.30 am.

Maximum fruit development period, 28.60 and 28.87 mean days was observed for *S. tetrasperma* in 2009 and

Table 5. First and last date of important reproductive characters of different staminate *Salix* species

Species	Reproductive characters							
	Bud swell		Bud burst		Flowering		Anthesis	
	2009	2010	2009	2010	2009	2010	2009	2010
S.tetrasperma	02-01-2009 to 25-01-2009	08-01-2010 to 01-02-2010	20-01-2009 to 11-02-2009	26-01-2010 to 16-02-2010	29-01-2009 to 15-02-2009	04-02-2010 to 23-02-2010	01-02-2009 to 13-02-2009	08-02-2010 to 19-02-2010
S. alba	22-01-2009 to 20-02-2009	29-01-2010 to 28-02-2010	16-02-2009 to 09-03-2009	23-02-2010 to 16-03-2010	22-02-2009 to 12-03-2009	02-03-2010 to 20-03-2010	26-02-2009 to 09-03-2009	07-03-2010 to 17-03-2010
S. babylonica	-	11-02-2010 to 25-02-2010	-	21-02-2010 to 02-03-2010	-	25-02-2010 to 05-03-2010	-	28-02-2010 to 04-03-2010
S. matsudana	-	03-02-2010 to 06-03-2010	-	28-02-2010 to 13-03-2010	-	10-03-2010 to 25-03-2010	-	15-03-2010 to 20-03-2010
S. gracilystica	12-01-2009 to 13-02-2009	19-01-2010 to 21-02-2010	02-02-2009 to 28-02-2009	06-02-2010 to 04-03-2010	07-02-2009 to 02-03-2009	14-02-2010 to 07-03-2010	14-02-2009 to 27-02-2009	18-02-2010 to 03-03-2010
S.udensis	18-01-2010 to 05-03-2010	20-01-2010 to 08-03-2010	22-01-2009 to 20-03-2009	27-01-2010 to 25-03-2010	27-01-2009 to 23-03-2009	02-02-2010 to 26-03-2010	14-02-2009 to 04-03-2009	18-02-2010 to 07-03-2010

- Not flowered in 2009

Table 6. Variation in time taken (mean number of days) for important reproductive characters among different staminate *Salix* species

Species	Reproductive characters (Mean number of days)							
	Bud swell		Bud burst		Flowering		Anthesis	
	2009	2010	2009	2010	2009	2010	2009	2010
S. tetrasperma	22.73	23.13	18.33	18.87	16.67	17.33	11.73	10.67
S. alba	29.07	29.20	20.40	20.93	17.87	18.07	11.13	9.87
S. babylonica	-	14.27	-	9.53	-	8.47	-	4.53
S. matsudana	-	30.20	-	12.53	-	13.93	-	4.87
S. gracilistyla	31.93	32.33	23.87	24.07	20.33	19.53	13.27	13.40
S.udensis	45.53	45.67	56.60	56.93	52.80	53.93	18.00	16.93
Mean	32.31	29.13	29.80	23.81	29.91	21.87	13.53	10.04
SE±m	0.31	0.32	0.40	0.38	0.42	0.32	0.26	0.31
$CD_{0.05}$	0.62	0.66	0.81	0.78	0.85	0.65	0.53	0.62

- Not flowered in 2009

2010, respectively. *S. nigra* was the last species to initiate fruit development in 2010. The present findings lend support to the results of Karrenberg *et al.* (2002), who reported time period of approximately four week for fruit development in *Salix* species. Similar period for fruit development (three to four weeks) was reported by Yan *et al*. (2007) in *S. gordejevii*. Earlier Kuzovkina *et al*. (2008) also reported three to eight weeks fruiting period in willows. Fruit in general matured earlier in 2009 as compared to 2010, which again may be attributed to early initiation of first phenological event in 2009.

Seed of *Salix* are minute with silky hair and seed dispersal is generally affected by wind and running water among *Salix* species. All the pistillate species varied significantly with respect to the duration of seed dispersal. Seed dispersal period spaned over a period of one week with *S. tetrasperma* recording maximum mean number of days for seed dispersal in two consecutive years. In the present studies, the seed matured and dispersed in last week of April and first week of May (three to four weeks after pollination). Yan *et al.* (2007) also reported similar seed

Table 7. First and last date of important reproductive characters of different pistillate *Salix* species

Species	Reproductive characters									
	Bud swell		Bud burst		Flowering		Fruiting		Seed dispersal	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
S. tetrasperma	19-01-2009 to 17-02-2009	27-01-2010 to 24-02-2010	08-02-2009 to 22-02-2009	15-02-2010 to 01-03-2010	14-02-2009 to 24-02-2009	19-02-2010 to 02-03-2010	24-02-2009 to 25-03-2009	02-03-2010 to 31-03-2010	25-03-2009 to 02-04-2009	31-03-2010 to 07-04-2010
S. alba	-	06-02-2010 to 10-03-2010	-	28-02-2010 to 19-03-2010	-	07-03-2010 to 22-03-2010	-	22-03-2010 to 12-04-2010	-	12-04-2010 to 18-04-2010
S. babylonica	13-02-2009 to 26-02-2009	18-02-2010 to 03-03-2010	20-02-2009 to 03-03-2009	24-02-2010 to 08-03-2010	28-02-2009 to 06-03-2009	02-03-2010 to 11-03-2010	06-03-2009 to 22-03-2009	11-03-2010 to 27-03-2010	22-03-2009 to 28-03-2009	27-03-2010 to 21-04-2010
S. matsudana	-	12-02-2010 to 16-03-2010	-	12-03-2010 to 24-03-2010	-	16-03-2010 to 29-03-2010	-	29-03-2010 to 14-04-2010	-	14-04-2010 to 21-04-2010
S. jessonensis	-	29-01-2010 to 17-02-2010	-	11-02-2010 to 25-02-2010	-	17-02-2010 to 28-02-2010	-	28-02-2010 to 27-03-2010	-	27-03-2010 to 02-04-2010
S. nigra	-	07-03-2010 to 20-03-2010	-	14-03-2010 to 25-03-2010	-	21-03-2010 to 31-03-2010	-	31-03-2010 to 24-04-2010	-	24-04-2010 to 01-05-2010
S. acmophylla	21-01-2009 to 08-02-2009	28-01-2010 to 15-02-2010	05-02-2009 to 19-02-2009	07-02-2010 to 21-02-2010	13-02-2009 to 23-02-2009	12-02-2010 to 25-02-2010	23-02-2009 to 21-03-2009	25-02-2010 to 23-03-2010	-	-

- Not flowered in 2009

Table 8. Variation in time taken (mean number of days) for important reproductive characters among different pistillate *Salix species*

Species	Bud Swell		Bud burst		Flowering		Fruiting		Seed dispersal	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
S. tetrasperma	28.73	28.87	14.07	14.27	10.07	10.13	28.60	28.87	7.80	7.27
S. alba	-	30.73	-	18.60	-	14.13	-	20.53	-	6.20
S. babylonica	12.33	12.87	11.93	11.87	7.20	8.67	15.53	15.67	5.80	5.93
S. matsudana	-	31.60	-	12.00	-	12.80	-	16.07	-	7.13
S. jessonensis	-	18.73	-	13.73	-	10.67	-	25.33	-	5.93
S. nigra	-	12.33	-	10.93	-	9.80	-	24.27	-	7.13
S. acmophylla	17.73	18.07	12.13	12.20	8.67	13.20	25.87	26.20	5.87	6.07
Mean	19.60	21.90	12.74	13.37	8.64	11.34	23.30	22.40	6.49	6.52
SE±m	*0.27*	*0.29*	*0.26*	*0.31*	*0.24*	*0.28*	*0.35*	*0.31*	*0.26*	*0.25*
$CD_{0.05}$	*0.54*	*0.60*	*0.53*	*0.63*	*0.50*	*0.58*	*0.71*	*0.63*	*0.52*	*0.51*

Reproductive characters (Mean number of days)

- *Not flowered in 2009*

Table 9. Flowering behaviour of different *Salix* species

Time of Flowering	Early flowering(last week of January and 2nd week of February)	*S. acmophylla*, *S. udensis*, *S. tetrasperma, S. jessonensis* and *S. gracilistyla*
	Mid Flowering(between last week of February and 1st week of March)	*S. babylonica* and *S. alba*
	Late flowering (2nd and 4th week of March.)	*S. matsudana* and *S. nigra*
Mode of Flowering	Precocious	*S. udensis* and *S. gracilistyla*
	Sub-precocious	*Staminate S. tetrasperma*
	Coetaneous	Staminate and pistillate *S. alba*, *S. babylonica, S. matsudana* and Pistillate *S. jessonensis, S. acmophylla, S. tetrasperma* and *S. nigra*
Pattern of Flowering	Synchronous	*S. alba*, *S. babylonica, S. matsudana S. jessonensis, S. acmophylla, S. tetrasperma* and *S. nigra*
	Staggered	*S. udensis* and *S. gracilistyla*

dispersal period (before rainy season) in *Salix gordejevii*. Seeds in *S. gordajevii* started to mature on first May and dispersal lasted from 8th to 20th May.

Flowering Behaviour

Based on the timing of flowering, different *Salix* species were grouped into three categories (Table 9) supports the findings of Mosseler and Papadopol (1989). Based on the timing of flowering, they grouped different *Salix* species into early flowering and late flowering species. The mode of flowering is another important feature, which determines success of breeding programme. After critical observations on the mode of flowering different species were grouped into precocious, sub-precocious and coetaneous flowering species. The placement of different species accordingly is in agreement with the reports of Zhenfu *et al*. (1999), Skrovtsov (1999) on classification of *Salicacea*e, Kuzokvina *et al*. (2008) and Dickmann and Kuzokvina (2008) on poplars and willows in the world. They classified different *Salix* species into four basic categories viz., precocious, sub-precocious, coetaneous and seritnous.

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Growth Performance of Twelve New Clones of Poplar In Punjab, India

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Abstract: Height, diameter growth and volume production of 12 clones of poplar were evaluated at Kharkan Research Station, Hoshiarpur (Punjab) at the age of 3 years. The clone WSL - 39 achieved the best growth and maximum volume, attaining diameter of 14.74 cm; height 14.42 m and volume 0.1040 m^3/tree. This clone out performed the clones for growth and volume since the beginning. The volume production of clone Udai was at par with WSL – 39 at 2 and 3 years of age. On the basis of present results, WSL-39 and Udai clones can be included for plantation to broaden the genetic base and more importantly for productivity enhancement.

Key Words: Poplars, Height, Diameter growth, Volume, Mean annual increment.

Establishing plantations of fast-growing tree species is currently being advanced around the world as a means to meet the timber needs of the wood based industry as well as realising goals of sequestering carbon (Sedjo, 1999; McKenney *et al.,* 2004). *Populus deltoides* Bartr. ex Marsh. from the USA is economically the most important poplar species being grown under agroforestry plantations in Punjab, Haryana, Uttar Pradesh, Himachal Pradesh and Bihar states of India (Land and Singh, 1996). Plantation forestry in India has been dominated by this taxonomic group in the past three decades. In India about 225 clones of various poplars were introduced and some of them performed well (Chauhan *et al*., 2008). The species was introduced in India to enhance the productivity and to maintain the ecological balance and to cater the increasing demand of paper and plywood industry. Recently poplar has got much attention because of its preference by the plywood and paper industry.

Six species of poplars *(Populus ciliata, P. euphratica, P. gamblei, P. glauca, P. alba* and *P. suaveolens)* are indigenous to India, representing five sections of *Populus* (Khurana, 1998). Substantiating the importance of the species, India in 1965 became the member of the International Poplar Commission and constituted the National Poplar Commission with the basic objective of cultivating poplars extensively to meet the requirements of timber for industrial as well as packaging cases and match box splinters. It is a well established fact that limited numbers of clones always bears the risk of disease/pest outbreak and further continuous vegetative propagation also deteriorate the quality of clones. Due to large scale plantations and consequent demand for entire transplants (ETPs), clonal material got mixed, which affects the productivity and hence low returns. Therefore, for sustaining supplies in the future, the new clones are continuously introduced and old ones are replaced by the new ones to broaden the genetic base and obtain higher productivity (Chauhan *et al.,* 2008). However, in the last two decades large scale block, boundary and agroforestry plantations done by farmers in most of the states of north western in India have depended on narrow genetic base consisting of only a few best performing clones (Dhillon *et al*., 2010). The study and evaluation of growth performance of new poplar clones is of great importance in order to ensure high wood production and hence more economic returns. The evaluation of new clones would be helpful in selecting the locality specific clones. This article reports the performance of 12 new poplar clones in Punjab.

MATERIAL AND METHODS

The study was conducted at Kharkan Research Station Hoshiarpur, Research Circle Hoshiarpur, Punjab Forest Department. The site is located between 31^0 31’ 03.58" N latitudes and 76^0 03’ 07.696" E longitudes at an elevation of 303.40 above msl. The area experiences rain ranging from 945.4 mm to 1242 mm annually, which falls mostly during July to September. The soil is sandy loam and well drained. The surface soil is low in organic carbon (0.15-0.30%) as well as in available nitrogen (150-160 kg ha^{-1}), phosphorus (3-6 kg ha^{-1}) and potassium (40-60 kg ha^{-1}) and neutral in reaction (pH 7.0).

Table 1. Details of clones used in the study

S. No.	Clone	Country/ Province of origin
1	G_{48}	Canberra (Australia)
2	Udai	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.
3	S_7C_{15}	Stoneville Mississippii (USA)
4	WSL-26	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.
5	WSL-49	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.
6	WSL-22	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.
7	WSL-32	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.
8	WSL-39	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.
9	S_7C_8	Stoneville Mississippii (USA)
10	Kranti	Selections of WIMCO Pvt. Ltd.
11	Bahar	Selections of WIMCO Pvt. Ltd.
12	WSL-27	India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.

The details of 12 clones used in the study are presented in the Table 1. The one year old and about 5 m tall bare root plants were transported to the experimental site during the first week of February, 2005. The plants were planted at a spacing of 5m x 4 m in pits of 1 m depth and 20 cm diameter dug with planting augur. The recommended silvicultural practices (Chauhan and Mahey, 2008) were followed throughout the investigations. The experiment was conducted using randomised block design with clones as treatments replicated four times. The data on tree height and diameter at breast height (DBH, 1.37 m from ground level) were recorded every year in the last week of February. Volume of individual tree of each clone and replication was estimated by using the equation developed for central plain region of Punjab by Dhanda and Verma (2001). The data obtained were subjected to statistical analysis as per the procedure suggested by Gomez and Gomez (1984). Wherever the effects exhibited significance at 5 per cent level of probability, the critical difference (CD) was calculated. (on computer using the package "STATISTICS").

RESULTS AND DISCUSSION

The data revealed significant differences amongst the clones for diameter and height growth at all ages i.e., 1st, 2nd and 3rd year (Table 2). The clones WSL-39 and S_7 C_8 showed higher diameter in the 1st and 2nd year, whereas, in the 3rd year former outperformed for diameter growth. An increment of 6.42 cm and 2.90 cm was registered in diameter over the 1st and 2nd year, respectively. The clone WSL-39 outperformed significantly at all ages with an increment of 4.61 m and 3.49 m over the 1st and 2nd year. This superiority may be ascribed to the difference in the genetic potential among the clones as the treatment given to all clones was the same.

The study revealed significant differences in volume per tree among the clones (Table 3). The clone WSL – 39 gave maximum volume 0.013, 0.0556 and 0.104 m^3 at the age of 1, 2 and 3 years, respectively. Though the volume of clones S_7 C_8 and clone Udai was at par with WSL-39 at the age of 2 years, only Udai remained at par with clone WSL-39 at 3 years. Clone Kranti had minimum volume at the age of 1 year; however, G-48 gave minimum volume at the age of 2 and 3 years.

Table 2. Diameter and height growth of poplar clones at various ages.

Clone	DBH (cm)			Height (m)		
	1 year	2 year	3 year	1 year	2 year	3 year
G-48	4.46	9.57	11.58	5.91	9.53	13.50
Udai	4.57	11.75	14.44	5.28	10.44	13.71
S7-C15	4.64	11.01	13.15	5.30	10.24	14.04
WSL-26	4.47	10.22	11.75	5.68	10.11	13.80
WSL-49	4.41	10.31	13.26	5.52	10.04	13.90
WSL-22	5.07	10.99	12.76	6.00	10.32	13.92
WSL-32	4.42	11.62	13.91	5.70	10.53	14.10
WSL-39	5.42	11.84	14.74	6.32	10.93	14.42
S_7 C_8	5.23	11.67	13.87	6.30	10.69	14.11
Kranti	3.64	10.40	13.19	4.24	9.99	13.25
Bahar	3.90	10.68	12.30	4.59	9.93	13.19
WSL-27	4.35	9.70	12.09	5.43	10.04	14.13
CD (P=0.05)	0.32	0.23	0.28	0.35	0.23	0.18

Table 3. Volume (m^3/tree) of poplar clones at various ages

Clone	Volume (over bark) m^3/tree		
	1 year	2 years	3 years
G-48	0.0108	0.0352	0.0653
Udai	0.0106	0.0542	0.1030
S7-C15	0.0107	0.0471	0.0853
WSL-26	0.0107	0.0410	0.0685
WSL-49	0.0105	0.0414	0.0858
WSL-22	0.0120	0.0472	0.0800
WSL-32	0.0106	0.0528	0.0949
WSL-39	0.0130	0.0556	0.1040
S_7C_8	0.0126	0.0539	0.0945
Kranti	0.0089	0.0419	0.0813
Bahar	0.0093	0.0435	0.0714
WSL-27	0.0103	0.0374	0.0735
CD (P=0.05)	0.00063	0.0018	0.0034

The higher volume of clones WSL – 39 and Udai, may be attributed to their genetic potential. Field performance of the clones of WSL series have been found better in the Indo-Gangetic plains with volume production up to 0.132 m^3 at the age of 3 years (Sidhu and Dhillon, 2007). High clonal variation in many clones of *Populus* species was also recorded by Dunlop *et al*. (1994), Singh *et al*. (2001), Chauhan *et al.* (2008) and Dhillon *et al*. (2010).

The current and mean annual increment of different clones, being the function of growth parameters exhibited similar results as were obtained for diameter, height and volume. CAI and MAI was maximum for the clones WSL–39 and Udai, whereas, it was minimum for G-48.

The present study evinced that out of the twelve new clones tested in the field, WSL-39 and Udai [(India (Seedlings raised from open pollinated naturalized clones) WIMCO Pvt. Ltd.)], out performed in the field giving higher volume per tree. Thus, results on growth performance and volume production of tested clones put forth scope for the deployment and will provide opportunity for maximum production as well as broaden the shrinking genetic base of poplar plantations.

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Genotype × Envionment Interaction among Different Clones of *Eucalyptus tereticornis* Smith

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Abstract: Due to predominantly out-crossing in nature, *Eucalyptus tereticornis* shows high degree of individual heterozygosity. Most plantations have low productivity and large genetic variation. Clonal propagation of this tree species offers vast possibilities of taking advantage of the natural variation for immediate gains in productivity. But there is a need to screen large number of trees to identify clones with superior traits. In the present study, a set of twenty similar clones were evaluated at two sites to determine the magnitude of clone X site interaction, which revealed that clones interacted significantly with the environments. Clone number 132 ranked first for total height, diameter at breast height, clear bole height and unforked height followed by clone number 71 at site 1, whereas, at site 2, clone number 6 recorded the maximum total height, clear bole height and unforked height. Clone number 147 performed best in environment 2 for diameter at breast height. A simultaneous consideration of mean performance and regression revealed the superiority of clone number 71 and 7 indicating their better suitability for superior environment, whereas, clone number 132 and 130 were found superior for diameter at breast height for their above average response (bi>1.0). These results indicate the scope of genetic improvement through selection of superior clones.

KeyWords: *Eucalyptus tereticornis*, Clone, Growth, G X E interaction

Genetically improved, high yielding clones of poplars and Eucalypts with a production potential of 50 m^3/ha/yr and large domestic demand for timber, have made farm forestry plantations an economically attractive land use option. National Forest Policy (1988) also directed the wood based industrial units to meet their future raw material requirements through developing partnerships with farmers. Therefore, most of the veneer/plywood mills, safety match industries and wood based pulp/paper mills currently meet the bulk of their raw material requirements from farm grown fast growing trees. India has tremendous potential to expand the farm forestry plantations and wood based industries because of its comparative advantage of a huge domestic market, a large land mass, good rainfall and water resources, tropical climate, ample sunshine for rapid growth of trees and sufficient labour.

Eucalyptus tereticornis is widely planted in farm forestry system throughout the world and more particularly in India. It is highly productive and well adapted to dry, infertile sites and is productive user of degraded land no longer suitable for agriculture. Keeping in view the wide range of geographical distribution of the species and the variation that exists, the species provides ample scope for genetic improvement. Clonal propagation of this tree species offers vast possibilities of taking advantage of the natural variation for immediate gains in productivity. Cloning is the ultimate means of capturing useful genetic variation because there is no recombination or segregation of genes. But there is a need to screen large number of trees to identify clones with superior traits. Highest productivity potential of each clone can be achieved through careful matching of clones most adaptable to each category of soils within the climatic regions suitable for the species (Lal, 2003). To do so, it is indispensable that competitive tests with clones be carried out in different sites (Campinhos, 1999). Through genotype and environment tests, selection can be made to obtain clones that are well adapted to specific conditions and others that are well adapted to a range of environmental conditions (Campinhos *et al.*, 1992). Knowledge of the extent of rank changes among clones across various sites is necessary to efficiently deploy clonal material. In spite of its self evident importance in practical utility and great potential as a short rotation valuable species for farm forestry plantations of vast geographical areas, actually very limited work has been done on clonal testing. Therefore, the present study in *Eucalyptus tereticornis* was planned to determine the magnitude of clone x site interaction among different clones of *Eucalyptus tereticornis.*

MATERIAL AND METHODS

Twenty clones of *Eucalyptus tereticornis* planted by State Forest Department at two sites, Seonthi in Distt. Kurukshetra (Latitude 29°59´ N, longitude 76°50´ E and altitude 258 m above mean sea level) and Bithmara in Distt. Hisar (Latitude 29°10´ N, longitude 75°46´ E and altitude 215.2 m above mean sea level) in August 1997 at a uniform spacing of 4 x

4 m were laid out in randomized block design. Observations on total height, diameter at breast height, clear bole height and unforked height were recorded at the age of 5 ½ years and 6 ½ years. The texture of the soil at Bithmara was loamy sand (10-30cm depth) and sandy loam (30-120cm depth), whereas, at Seonthi texture of soil was loam at all soil depths. The pH varied from 8.0 to 8.4 at Bithmara which shows alkaline nature of the soil whereas at Seonthi the soil was sodic in nature. The sodic soil and high soluble salt concentration (EC 0.5-0.9 mmhos cm^{-1}) at site 2 is considered detrimental to plant growth. The range of organic carbon was low to medium. The replicated data for all characters recorded for clone x site interaction were analysed statistically.

RESULTS AND DISCUSSION

The mean values of clones for all the characters revealed enough variability among clones. The mean squares due to environments (sites) were significant for all the characters which suggested that the environments (sites) were variable. Genotype x environment interaction were significant for all the characters, which revealed that clones were unable to maintain the consistent performance under different environments (sites) for total height, diameter at breast height, clearbole height and unforked height. Mean performance of various clones of *Eucalyptus tereticornis* under different environments along with regression coefficient in respect of all the characters under study viz., total height, diameter at breast height, clearbole height and unforked height are presented in Table 1 & 2. The mean values of total height, diameter at breast height, clearbole height and unforked height were observed higher in environment 1 (Bithmara) than in environment 2 (Seonthi). The performance of clone number 132 was found extraordinarily superior with the highest values for total height and unforked height on the basis of mean performance of two environments. This clone was also found superior for diameter at breast height, clearbole height. The clone number 71 was found superior for total height and diameter at breast height. The clone numbers 3 and 6 were found superior for clearbole height and unforked height. Besides, the clone number 147 was found significantly superior than general mean for total height and unforked height in both the environments. Simultaneous consideration of mean performance and regression coefficient (bi) revealed the superiority of clone number 132 in better environment with high mean performance and high value of regression for total height and unforked height.

Table 1. Performance of various *Eucalyptus tereticornis* clones for plant height (m) and diameter at breast height (cm) in different environments

	Plant height				DBH			
Clone	Bithmara	Seonthi	Mean	b_i	Bithmara	Seonthi	Mean	b_i
1	18.33	15.03	16.68	0.68	18.13	14.12	16.13	0.72
3	19.61	16.18	17.90	0.71	17.81	12.04	14.92	1.04
4	17.50	13.63	15.57	0.80	19.11	13.34	16.23	1.03
6	20.67	16.49	18.58	0.86	18.31	11.79	15.05	1.17
7	22.32	16.34	19.33	1.24	18.37	13.03	15.70	0.96
8	20.07	15.89	17.98	0.86	17.17	12.35	14.76	0.86
9	20.32	16.17	18.25	0.86	18.08	12.51	15.30	1.00
71	23.27	16.10	19.69	1.48	20.46	14.58	17.52	1.06
83	20.83	15.48	18.16	1.11	19.25	13.12	16.18	1.10
99	22.00	15.46	18.73	1.35	18.98	12.37	15.68	1.18
105	19.27	14.95	17.11	0.89	19.40	14.17	16.79	0.94
115	18.32	15.29	16.81	0.63	16.25	12.23	14.24	0.72
119	19.41	15.53	17.47	0.80	17.30	13.41	15.36	0.70
130	20.58	16.43	18.51	0.86	20.01	13.47	16.74	1.17
132	24.25	15.17	19.71	1.88	21.60	12.84	17.22	1.34
142	21.28	14.91	18.10	1.32	19.29	12.96	16.12	1.13
147	21.75	16.18	18.97	1.15	19.40	14.76	17.08	0.83
157	21.51	15.96	18.74	1.15	17.09	11.48	14.29	1.01
271	19.65	15.27	17.46	0.91	18.53	13.78	16.16	0.85
277	17.65	15.09	16.37	0.53	19.35	13.97	16.66	0.97
Mean	20.43	15.58	18.01		18.69	13.12	15.90	
C.D.(5%)	0.27	0.21			0.76	0.54		

Table 2. Performance of various *Eucalyptus tereticornis* clones for clearbole height (m) and unforked height (cm) in different environments

Clone	Clearbole height				Unforked height			
	Bithmara	Seonthi	Mean	b_i	Bithmara	Seonthi	Mean	b_i
1	13.83	7.21	10.52	2.31	18.25	12.89	15.57	2.20
3	16.83	12.79	14.81	1.41	19.33	15.48	17.41	1.58
4	10.58	7.63	9.11	1.03	15.17	13.63	14.40	0.63
6	13.50	14.52	14.01	-0.36	17.08	16.49	16.79	0.24
7	12.57	10.45	11.51	0.74	15.25	14.38	14.82	0.36
8	11.00	9.49	10.25	0.53	13.25	15.89	14.57	-1.08
9	12.28	11.76	12.02	0.18	16.61	16.17	16.39	0.18
71	12.38	8.58	10.48	1.32	15.83	12.20	14.02	1.49
83	12.94	9.00	10.97	1.37	15.89	14.82	15.36	0.44
99	14.67	8.04	11.36	2.31	16.75	14.80	15.78	0.80
105	11.83	9.89	10.86	0.68	15.00	12.40	13.70	1.07
115	9.17	8.60	8.89	0.20	13.53	9.26	11.40	1.75
119	16.25	8.43	12.34	2.73	19.22	13.37	16.30	1.95
130	10.00	9.48	9.74	0.18	15.00	11.55	13.28	1.41
132	17.25	8.45	12.85	3.07	20.75	14.12	17.44	2.72
142	10.72	8.96	9.84	0.61	15.61	12.41	14.01	1.31
147	12.17	9.05	10.61	1.09	16.75	16.18	16.47	0.23
157	13.25	7.90	10.58	1.86	15.50	13.58	14.54	0.79
271	7.42	7.08	7.25	0.12	11.42	10.48	10.95	0.39
277	11.92	7.66	9.79	1.49	15.33	12.27	13.80	1.25
Mean	12.53	9.25	10.89		16.08	13.63	14.86	
C.D.(5%)	0.19	0.12			0.40	0.17		

Clone number 3 was found superior in better environment for clearbole height. Clone number 71 was also found to have higher ranks for better environment for total height, diameter at breast height. Clone number 6 was found superior for poor environment with high mean performance and below average response of regression coefficient for total height, clearbole height and unforked height. Clone number 147 was also found superior for poor environment for diameter at breast height. The clone number 3 was found most promising for both environments as it was evident from high mean values and near unit values of regression coefficient (bi) for clearbole height and unforked height. Clone number 71 was found superior in both environments for diameter at breast height. The joint regression of environments under which the genotype grew can provide a base for better understanding of physical limits of environments (Breese, 1969). The results obtained from the present investigation indicated that a suitable breeding programme could be designed for desired type of responsiveness. The desired genotypes should have above average performance (Yi>Y) and above average response (bi>1). When both environmental variables are operating simultaneously, the desired genotype would seem to be one having a general level of interaction such that genotypes can be selected which combine low level of interaction with uncontrollable variables. For such a situation, the genotype with high mean performance (Yi>Y) and unit regression (b=1) would be preferred. In the present study, clone number 7 for total height, 71 for diameter at breast height and 3 for clearbole height and unforked height had the high mean and about unit regression.

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Investigations on Pulp and Biomass Production of Subabul Genetic Resources (*Leucaena leucocephala (Lam.) de Wit.*)

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Abstract: Studies were conducted to assess the suitability of *Leucaena leucocephala* for pulp and energy purposes. The study indicated that *L. leucocephala* could be a good pulpable species, which expressed superior characters for all the pulp qualities assessed. The species exhibited an average screened pulp yield of 49.5 per cent coupled with the kappa number of 20.7, which indicated that the species is suitable for pulping quality and exhibited superiority over the eucalyptus based pulpwood. Similarly the species expressed holo-cellulose content of 70.2 per cent, pentosans 18.3 per cent, acid insoluable lignin 26.7 per cent and ash content of 0.5. The strength properties of the species also exhibited comparable pulp qualities and recorded the tensile index of 27.3 and 72 Nm g^{-1}, respectively for unrefined and refined pulp at 300 ml CSF. The strength property also indicated the tear index of 5.14 and 8.50 $mNm^2 g^{-1}$ and burst index of 1.20 and 4.70 K Pa $m^2 g^{-1}$, respectively for unrefined and refined pulp at 300 ml CSF. Similarly the the species has the calorific value of more than 4250 K. Cal indicating the suitability for energy purpose. A tree improvement programme has been initiated by selecting 15 superior genetic resources and evaluated at nursery and field conditions. The seedling growth attributes and total dry matter production studies in the nursery at 12 months after sowing indicated that the progenies differed significantly. Among the 15 genotypes, the genotype FCRI LL 9 exhibited superiority in term of seedling growth (shoot length – 125.1 cm; root length – 43.5 cm collar diameter – 9.94 mm) and total dry matter (total Fresh weight – 38.3 g; total dry weight – 21.6 g) followed by the genotype FCRI LL 15, In toto, the genotypes FCRI LL 9 and FCRI LL 15 out performed over the mean performance of other genotypes to the magnitude of 118 per cent and 120 per cent, respectively, with respect to seedling growth attributes and dry matter production. The progeny evaluation trial in the field also indicated the superiority of genotype FCRI LL 9.

Key Words: *Leucaena leucocephala,* Pulp and energy, Short rotation forestry

Native to Central America, the species *Leucaena luecocephala* was introduced to India during 19th century (NAS, 1980). It grows in an annual rainfall of 500 to 300 mm and up to an altitude of 500 m though adapted to a wide array of environments; it has limitations of intolerance to salinity (Benge, 1982) and limited tolerance to acidic soils (Halliday and Somasegaran, 1982). The nearly 100 varieties that comprise the species differ markedly in size and form and have been classified into three broad types, the Salvador, the Peru and the Hawaiian. Though the plant has a strong appeal for a multitude of uses, its primary reputation is as forage and feed. But Salvador types like K8, K28 and K67 referred to as Hawaiian giants are suitable for wood production. The tree is admirably suited for paper and pulp manufacture. For fuel production, the species is raised at a espacement of 1 x 1 m to 2 x 2 m and felled at the end of 3 to 5 years. Total yields at this rotation averages 100 tonnes per ha. and it coppices prolifically (Pathak and Patil, 1982). A tree legume, it has been credited with high fixation rates of up to 1000 kg Nitrogen per ha (Dykman, 1950). This property of nitrogen fixation made this species to be useful in soil restoration (Vanlauwe *et al.,* 1998; Sharma *et al.,* 1998).

The conventional softwoods and hardwoods used as raw material by pulp, paper and cellulose based industries are depleting day by day and the wood imports are draining country's foreign exchange. Short rotation industrial farmforestry plantations with the fast growing tree species are potential sources to fill this gap and to make the nation self reliance in pulpwood supply. In India, of the 660 paper mills, 26 are wood based and faced challenges with the supply of forest based raw material. Many pulp mills are finding it difficult to gain access to private lands, and wood resources from natural forests (Puri and Nair, 2004). Of the 6.8 million ton of wood producing 1.9 million pulp annually, nearly 20 per cent of wood is procured from forests through Government sources and the remaining 80 per cent comes from private sector (Kulkarni, 2008). The National Forest Commission emphasized that since forest alone cannot meet the increasing wood demand, agroforestry in private and community lands has to be promoted to bridge the short fall (Kirpal *et al.,* 2006). Under such circumstances, many paper industries in the country have promoted *Eucalyptus, Casuarina*, Bamboos, *Populus,* and *Leucaena,* etc. as pulpwood species. Many species are well accepted by the farmers and are integrated in the existing land use system. However, the promotion of *L. luecocephala* as a source of pulp fiber is not evidenced in the state of Tamil Nadu for want of suitable varieties adapted to varied agro climatic zones. Against this backdrop, the current study was designed to assess the pulp and fiber qualities of *L. leucocephala* and to establish tree improvement strategies through selection and evaluation of the available genetic resources in the country.

MATERIAL AND METHODS

The experimental material to the present study consisted of logs collected from *Eucalyptus tereticornis, Casuarina equisetifolia* and *Leucaena leucocephala* grown at Mettupalayam range of Coimbatore division. From each species, a billet of each 1 m length and 50-60 cm girth were collected. The billets were debarked and chipped separately and screened. The screened chips were used for pulping experiments. Few wood chips were converted into dust for proximate chemical analysis. The wood samples were subjected to analysis of physical and chemical properties at the Research and development laboratory of Tamilnadu Newsprint and Paper Ltd. (TNPL), Kagithapuram, Karur. The pulping experiments were also carried out to find out its suitability for papermaking.The procedure followed by Vennila and co-workers (2011) for physical and chemical properties was adopted in present study also.

The predominant subabul growing areas of South India were identified and candidate plus trees were selected based on the following morphological characters viz., height, diameter at breast height (DBH), canopy height, canopy width and canopy length. From the selected 15 candidate plus trees, which represents three states (Andra Pradesh, Maharashtra and Tamil Nadu), seeds were collected from the crown and accession numbers were given. The fresh seeds collected from the 15 Candidate Plus Trees were sown at the Nursery Complex of Department of Tree Breeding, Forest College and Research Institute, Mettupalayam by adopting Randomized Block Design with five replications. Necessary after care silvicultural practices were scrupulously followed for the proper growth and establishment.

The following growth attributes viz., shoot length,r oot length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight and root shoot ratio were recorded on ten seedlings of each genotypes. The mean values of the morphometric traits were transformed into uncorrelated standardized values for statistical analysis.

RESULTS AND DISCUSSION

Screening of Alternate Pulpwood Species

Wood properties are known to vary between species, genotypes and within genotypes. In intensively managed plantations where the raw material is highly heterogeneous, it is important to assess the wood properties of the whole tree. Against this back drop, studies were conducted and the results on physical, chemical and strength properties proved the suitability of *L. leucocephala* as pulpwood. The results of the physical properties indicated that the bulk density and basic density are significantly superior to the traditional pulpwood species viz., *Eucalyptus* hybrid followed by *C. equisetifolia*. The *L. leucocephala* recorded basic density of 546 kg per m^3, which is 1.1 per cent superior to *Eucalyptus* hybrid and 25.51 per cent superior to *C. equisetifolia* indicating the superiority of *L. leucocephala* as pulpwood (Table 1). The wood density properties are of major importance for production of quality pulp and paper. The amount of wood needed to produce one ton of air dried pulp is calculated from the density and pulp yield (Storebraten, 1990). Similarly, the chemical analysis of *L. leucocephala* wood samples indicated that the ash content (0.5 %), solubility in hot water (4.40 %), acid insoluble lignin (26.7 %) and pentosons (14.53 %) were marginally higher than the *Eucalyptus* hybrid pulp. The holocellulose content of *L. leucocephala* is marginally lower (70.20 %) compared to *Eucalyptus* hybrid (70.90 %) and *C. equisetifolia* (71.60 %). Considering all chemical properties into account, the superiority of *L. leucocephala* over *Eucalyptus* hybrid was evident (Table 1). The quantity of hot water and 1 per cent NaoH soluble and Alcohol Benzene Extractives showed similar values when compared with wood materials. The holocellulose content in *L. leucocephala* was recorded at 70.90 per cent, which indicated the superiority of the variety. Lower lignin values suggests that Leucaena may require low pulping time and chemical charge compared to the *Eucalyptus*.The pulp properties viz., screened yield and kappa number are the most significant factor which decides the pulp recovery and the chemical charge required. Considering these two parameters, *L. leucocephala* recorded 49.40 per cent screened yield, which is 12.01 per cent more compared to *Eucalyptus* hybrid and 2.70 per cent higher compared to *C. equisetifolia*. The kappa number indicated that *L. leucocephala* recorded 20.70, which is (-) 3.38 per cent superior over the *Eucalyptus* hybrid pulp (Table 2).

The strength properties viz., tear, tensile and burst factor coupled with the brightness and opacity are the major indicators for pulp quality at 3000 PFI revolutions. Considering tensile (74 Nm per g), tear (8.25 mN m^2 g) and burst index (5.00 k Pa m^2 per g) of *L. leucocephala* wood pulp, it is evidenced that the pulp obtained from this species has superior strength properties compared to the traditional fiber yielding tree *Eucalyptus* hybrid (Table 3; Fig. 1). Similar results was earlier reported in tensile and burst indices of

Table 1. Physical and chemical characteristics of *Leucaena leucocephala* in comparison to *Eucalyptus* and *Casuarina*

S. No.	Parameters	*Eucalyptus hybrid*	*Casuarina equisetifolia*	*Leucaena leucocephala*	General mean	SEd	CD (0.05)	CD (0.01)
1	Moisture (%) as received	11.25	8.67	11.01	10.31	1.27	03.11	04.70
2	Bulk density (OD basis) (kg m^{-3})	240.00	191.00	250.00	227.00	8.16	19.97	30.27
3	Basic density (OD basis) (kg m^{-3})	540.00	435.00	546.00	507.00	8.16	19.97	30.27
Chips classification (%)								
1	+ 45 mm	Nil	Nil	Nil				
2	+ 8mm (over thick)	12.60	5.90	5.10				
3	+ 7 mm (accepts)	81.00	80.40	77.80				
4	+ 3 mm (pin chips)	6.00	13.20	16.60				
5	- 3mm (dust)	0.40	0.50	0.50				
Chemical composition								
1	Ash	0.35	0.38	0.50	0.41	0.08	0.19	0.30
2	Solubility in Hot water	3.80	3.60	4.40	3.93	0.82	1.99	3.03
3	Solubility in 1% NaOH	13.30	14.00	10.70	13.00	0.82	1.99	3.03
4	Alcohol benzene	3.50	1.20	2.90	2.53	0.48	1.15	1.75
5	Acid insoluble lignin	25.80	25.70	26.70	26.07	1.16	2.83	4.29
6	Pentosans (ash corrected)	6.80	18.50	18.30	14.53	1.16	2.83	4.29
7	Hollo cellulose (ash corrected)	70.90	71.60	70.20	70.90	1.33	3.26	4.95

Table 2. Pulping results of *Leucaena leucocephala* in comparison to *Eucalyptus* and *Casuarina*

S. No.	Parameters	*Eucalyptus hybrid*	*Casuarina equisetifolia*	*Leucaena leucocephala*
1	Chemical charge as Na_2O (%)	16.00	15.00	16.00
2	Unbleached pulp yield (%)	44.20	48.5	49.50
3	Screen rejects (%)	0.12	0.40	0.10
4	Screened yield (%)	44.10	48.10	49.40
5	Kappa number	21.40	16.50	20.70
Black liquor				
7	pH	11.80	13.00	12.20
8	Total solid (gpl)	233.00	241.00	228.00
9	TTA * as Na_2O	30.40	32.11	30.00
10	RAA* as Na_2O	3.85	8.90	6.20

Table 3. Strength properties of bleached pulp at different freeness level

S. No.	Parameters	PFI revolutions										
		Eucalyptus hybrid				*Casuarina equisetifolia*			*Leucaena leucocephala*			
		0	2000	3000	4000	0	2000	3000	0	2000	3000	4000
1	Freeness (ml CSF)	530	370	310	260	665	430	300	580	440	330	270
2	Bulk (g cm^{-3})	2.06	1.87	1.75	1.68	2.06	1.61	1.39	1.99	1.60	1.56	1.46
3	Tensile index (Nm g^{-1})	38.50	66.90	74.00	77.00	17.90	47.50	63.50	35.40	63.00	74.00	78.00
4	Breaking length (m)	3927	6824	7548	7854	1800	4800	6400	3611	6426	7548	7956
5	Tear index (mN.m^2 g)	5.78	7.80	8.10	8.20	3.20	6.00	8.20	6.20	7.83	8.25	8.30
6	Tear factor	59.00	79.60	82.60	83.60	32.00	60.00	82	63.20	79.90	84.20	84.70
7	Burst index (kPa.m^2 g^{-1})	2.30	4.00	4.40	4.60	0.70	3.90	5.00	1.94	4.20	5.00	5.20
8	Burst factor	23.50	40.80	44.90	46.90	7.00	39.00	50	19.80	42.80	51.00	53.00
9	Brightness (% ISO)	82.30	81.70	81.00	80.60	79.00	78.20	77.50	81.80	80.40	79.10	78.80
10	Opacity (%)	85.20	83.70	82.00	81.30	78.20	77.70	76.50	83.20	78.80	78.40	78.60
11	Scattering coefficient (m^2 kg^{-1})	54.70	48.10	45.00	41.70	54.20	49.70	46.50	43.40	35.20	34.80	33.60
12	Yellowness (%)	10.20	10.60	10.70	10.70	7.60	7.90	8.10	9.70	9.80	10.00	10.10

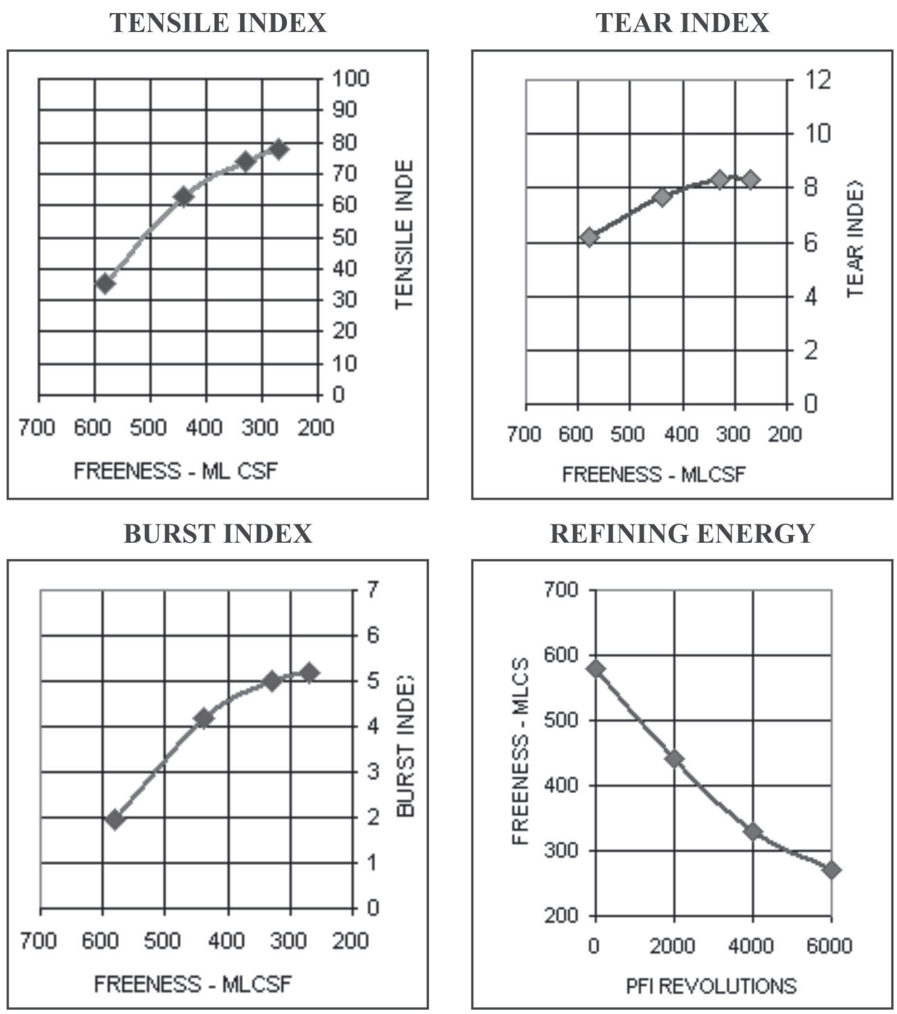

Fig. 1. Strength properties of *Leucaena leucocephala* bleached pulp at different freeness level

paper obtained from one year old *L. leucocephala* (Lopez *et al.,* 2008).

In a holistic perspective, considering pulp yield (49.50 %) and kappa number (20.70) the superiority of *L. leucocephala* was evident over the *Eucalyptus* hybrid. Similarly, the *L. leucocephala* wood pulp exhibited acceptable and in certain cases superior strength properties as furnished in Table 4 and the study the suitability of *L. leucocephala* genetic resources as a source of superior pulp.

Screening of Short Rotation Genotypes

Based on the superiority of *Leucaena leucocephala* as pulpwood, improvement programmes were carried out through selection and evaluation. Accordingly, fifteen progenies were selected from three dominant *L.*

Table 4. Comparison of *Leucaena leucocephala* with *Eucalyptus* and *Casuarina* in respect of pulp yield and strength properties

S. No.	Parameters	*Eucalyptus hybrid*	*Casuarina equisetifolia*	*Leucaena leucocephala*	General mean	SEd	CD (0.05)	CD (0.01)
1	Pulp yield (%)	44.20	48.50	49.50	47.40	0.82	1.99	3.03
2	Kappa number	21.40	16.50	20.70	19.53	0.67	1.63	2.48
3	Tear Index at 3000 PFI Revolutions	8.10	8.20	8.25	8.18	0.47	1.16	1.76
4	Tensile Index at 3000 PFI Revolutions	74.00	63.50	74.00	70.50	2.54	6.21	9.41
5	Burst Index at 3000 PFI Revolutions	4.40	5.00	5.00	4.80	0.69	1.69	2.57

Table 5. Performance of *Leucaena leucocephala* genotypes six months after sowing at nursery condition

Genetic resources	Shoot length (cm)	Root length (cm)	Collar diameter (cm)	Volume index (cm^3)	Fresh weight		Dry weight		Root shoot ratio
					Shoot weight (g)	root weight (g)	Shoot weight (g)	root weight (g)	
MTP LL 1	109.20	21.98	7.55	61.93	19.47	8.78	9.61	3.65	0.37
MTP LL 2	116.68	21.12	8.92	96.01	24.95	12.95	12.68	4.76	0.37
MTP LL 3	125.08	29.38	6.76	62.16	19.73	6.11	10.48	3.04	0.30
MTP LL 4	121.20	30.60	7.93	77.32	17.91	5.23	9.04	2.56	0.29
MTP LL 5	120.92	29.20	8.46	87.38	20.78	12.09	10.63	4.83	0.46
MTP LL 6	107.36	30.70	9.52	103.04	19.51	9.54	10.00	4.43	0.51
MTP LL 7	114.74	23.76	8.68	93.17	23.43	9.65	13.42	4.98	0.35
MTP LL 8	98.70	25.60	7.28	52.68	15.78	7.50	8.26	3.29	0.40
MTP LL 9	139.00	42.34	10.52	153.83	34.67	16.23	18.81	7.76	0.43
MTP LL 10	85.74	27.76	7.86	73.25	26.04	10.30	13.10	5.09	0.44
MTP LL 11	95.46	21.40	8.88	83.94	23.74	9.99	12.13	5.38	0.47
MTP LL 12	79.82	23.20	9.40	72.42	17.79	12.33	9.44	6.50	0.81
MTP LL 13	83.94	22.30	9.94	83.04	29.11	15.03	14.12	7.51	0.55
MTP LL 14	78.94	29.32	7.97	51.96	11.63	6.46	6.36	2.98	0.47
MTP LL 15	107.54	29.24	8.10	75.40	26.85	11.12	14.62	5.15	0.34
General Mean	105.62	27.19	8.52	79.15	22.09	10.22	11.51	4.79	0.44
SEd	12.14	5.65	0.92	21.97	5.46	3.24	3.03	1.41	0.14
CD (0.05)	24.33	11.29	1.84	44.01	10.92	6.48	6.06	2.81	0.29
CD (0.01)	32.39	15.03	2.44	58.59	14.52	8.62	8.05	3.74	0.38

leucocephala growing states viz., Maharashtra, Andhra Pradesh and Tamil Nadu. The progenies were evaluated and the study indicated that the progenies differed significantly due to growth attributes. Considering shoot length, the progeny MTP LL 9 recorded significantly higher shoot length and the increase was 31.60 per cent than the general mean of the population. Similarly root length differed significantly due to progenies which ranged between 21.12 cm (MTP LL 2) and 42.34 cm (MTP LL 9). The progeny MTP LL 9 exhibited 55.72 per cent superiority over the general mean. The collar diameter also exhibited the same trend, which ranged between 6.76 mm (MTP LL 3) (Table 5) and 10.52 mm (MTP LL 9). Considering all the parameters in the form of volume index, the superiority of MTP LL 9 was established through higher volume index (123.16 cm^3). This overall volume index increase was 38.75 per cent over the average value of the population.

Progenies also differed significantly due to fresh and dry weights of shoot and root weight. Higher fresh weight biomass was evidenced both for shoot (34.67 g) and root (16.23 g) and the increase was 56.95 and 58.81 per cent higher than the general mean. Similar trend was also observed for shoot (18.81 g) and root (7.76 g) dry weights (Table 5). Among various species of *Leucaena* evaluated, the highest total dry biomass recorded in *L. leucocephala* (Diaz *et al.,* 2007), which lends support to the current investigation. However, no significant differences were found among the various species of *Leucaena* for total biomass production (Lopez *et al*., 2008). During the first year study however, significantly different results were recorded during second year, which indicated the superiority of *L. leucocephala* in total dry biomass yield compared to other species. The superiority of one variety MTP LL 9 in the current investigation lends support to the earlier findings.

In an overall perspective, the progeny MTP LL 9 proved significantly superior in terms of biomass productivity and pulp recovery, therefore,it can be focused for further improvement programme.

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Variation in Oil Content among the Genotypes of *Pongamia pinnata* Linn.

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***Abstract**: Pongamia pinnata* Linn. is an indigenous tree to the Indian sub-continent, which fixes atmospheric nitrogen fixing tree to help its establishment in poor and marginal lands. The use of vegetable oil from *P. pinnata* has been in great demand due to its potential in the production of bio-fuel. The bio-fuel is an environmental friendly alternate of fossil-fuel with reduced engine emissions. It contributes significant in fuel feed-stock as the seeds contain around 30–40% of oil. The species has rich medicinal properties for the treatment of skin troubles, particularly of cancer. In India, though millions of seedlings of bio-fuel species are planted every year under various schemes but the productivity did not commensurate with expected yield potential basically due to poor genetic quality of the planting stock. Though the species has number of promising attributes, few of the drawbacks such as low productivity for pods, seeds and oil content can easily be solved by judicious application of different tools of genetics and tree breeding. The understanding of natural variation and genetic control of important traits is essential for conservation, genetic improvement and breeding. The genetic parameters could be very useful tools in predicting the amount of gain to be expected progeny trials. The variation among progenies is commonly used as an estimate of total genetic variation and to calculate degree of genetic control to the particular trait(s). Though the selection of plus trees is carried with high selection intensity, genetic superiority *par se* needs to be estimated using analytical tools like heritability and genetic advances. Genetic divergence would be essential to determine the genetic distance among the selected genotypes. The plus trees of the *Pongamia pinnata* were therefore selected in different geographical locations during 2009 to utilize the existing genetic variability for the improvement of the species, particularly the oil yield. The oil content was assessed by utilizing soluble property of oils with petroleum ether using Soxhlet Apparatus. Once the petroleum ether evaporated, the weight of solvent free oil was determined, which varied from 25.4 % (Phagwara, Jalandhar, Punjab) to 37.87 % (Barnawa, Meerut, Uttar Pradesh). The study on nature and degree of variation for oil yield among the genotypes will be helpful in selecting potential lines to be recommended for commercial deployment and further improvement programme.

***Key Words**: Pongamia pinnata* Linn., Plus trees, Oil content, Genetic variability, Divergence

Pongamia pinnata (Linn.) belongs to the family Leguminoceae and sub-family of Papilionoideae, commonly known as Indian-beech, poonga-oil-tree, pongam tree, karanja tree, karum and kanji. This medium-sized tree is indigenous to Indian subcontinent (Allen and Allen, 1981) which has been introduced to humid tropical lowlands in Philippines, Malaysia, Australia, Seychelles, United States and Indonesia (Hooda *et al.*, 2009). The species is endowed with high degree of climatic adaptability. It is one of the nitrogen fixing trees which fix atmospheric nitrogen to help its establishment in poor and marginal lands. It is also drought resistant tree known to withstand water logging and mild frost, with high tolerance to salinity (Anon, 1985). It is a medium sized tree that generally attains a height of 8 m and a trunk diameter of more than 50 cm. The trunk is generally short with thick branches spreading into a dense hemispherical crown of dark green leaves. The natural distribution is reported along coasts and river banks in lands and is also cultivated along roadsides, canal banks and open farm lands. It is preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots (Hooda *et al.*, 2009).

P. pinnata is an excellent multi-purpose tree with various parts of the tree is used in different end uses. The green leaves of the trees are used as fodder, especially in arid regions and also as a green manure and dried leaves are used as insects repellent in grain storage. Various parts of plants are utilized for preparing soaps, candles, lubricants, medicines, pesticides, green manure, strings and ropes (Dhillon *et al.*, 2009). The tree has substantially been used for medicinal uses as flowers are used to treat diabetes; roots for cleaning gums, teeth, ulcers and bark for bleeding piles (Duke, 1983). The wood is used for cabinet making, cartwheels, posts and fuel. The wood ash is used in dyeing (Allen and Allen, 1981). The seedcake is used as cattle and poultry feed and biogas production and the waste pulp is an excellent source of organic fertilizer (Shrinivas, 2001). The most important use of this species is the seeds which contain 30-40% oil (Natanam *et al.,* 1989; Nagaraj and Mukta, 2004). Pongam oil is a potential source of bio-fuel in countries where the resources to import fossil fuel are poor. It could serve as a substitute for energy storage in future world. The bio-fuel is an environmental friendly alternate of fossil-fuel with reduced engine emissions considering the importance of the species, a study was carried out to estimate oil content variation in *P. pinnata* seeds collected from the different locations and altitudes of Northern India.

A wild germplasm exploration survey was conducted to identify high yielding candidate plus trees of *P. pinnata* at fruiting stage from different predominant naturalized locations in Northern India. The selection was made on phenotypic assessment of economic interest characters adopting index method of selection (Cotterill and Dean, 1990). A total of sixty eight plus tree were screened on the basis of phenotypic characters. In the months of May and June 2009, matured pods were collected from plus trees selected from the states of Punjab, Haryana, Uttar Pradesh and Uttarakhand. An experiment was also conducted with selected seeds from plus trees for analyses of oil yield adopting randomised block design with three replications. To estimate the oil content, the seeds were cleaned and the seed coats were removed and grinded to make fine powder before placing in soxhlet apparatus. The main principle of this extraction method is to utilize soluble property of oil. The seeds were extracted with non-polar solvent such as petroleum ether using soxhlet apparatus. The solvent was thereafter evaporated and weight of solvent free oil was determined. In the present study, by following the above mentioned principle, oil content of different genotype was estimated. Around 5 g of powdered *Pongamia* seeds were weighed and placed in the filter paper folded to a sample wise individually. Sample packets were placed for extraction in soxhlet apparatus after placing some absorbent cotton at the bottom so that sample powder does not fall in the soxlet flask. Around 150 ml of petroleum ether was taken in the soxhlet flask of 250ml capacity which was set on heating mantle and its condenser was connected with running tap water. The seed meal was extracted at 60 degree Celsius for 6-8 hrs. The oil was extracted with petroleum ether was collected in the flask. After the extraction was completed, soxhlet flask was removed and was evaporated on a hot plate under a fuming hood. After cooling the flask was weighed and repeated the heating process until constant weight was recorded. Then the oil content was calculated by using the following formula:

$$\text{Oil per cent} = \frac{\text{Weight of oil (gm)}}{\text{Weight of sample (gm)}} \times 100$$

In the present study, oil content was determined in the seeds collected from 68 plus trees of Haryana, Punjab, Uttar Pradesh and Uttarakhand (Table 1). The oil content for all the trees was ranging from 25.40 to 37.87 per cent (32.12 $\pm$ 2.45) with maximum of 37.87% (226, originated from Barnawa, Uttar Pradesh) followed by 37.47 % (245, Meerut, Uttar Pradesh), 36.33 per cent (233, Meerut, Uttar Pradesh), 35.53 per cent (191, Hapur, Uttar Pradesh and in 298, Phagwara, Punjab), and 35 per cent (109, Fatehabad, Haryana and 276, Saharanpur, Uttar Pradesh). The minimum oil content (25.40%) was recorded in a plus tree selected at Phagwara, Punjab (25.40%). Out of 68 genotypes studied for oil production, 50 per cent (34) genotypes yielded more oil than average oil content (32.12%) and rest 50 per cent genotypes yielded less than average value of oil content. Of the 50 per cent genotypes with more oil content than average, majority of them were from different locations of Uttar Pradesh (15 genotypes) followed by Punjab (12 genotypes), Haryana (6 genotypes) and Uttarakhand (1 genotype). The results revealed that the oil content for the plus trees selected from Uttar Pradesh showed maximum oil content and minimum was in genotypes selected from the state of Punjab.

While studying the genetic improvement of *Jatropha cursas,* Heller (1996) reported that not many systematic studies have been carried out in the species, it seems that the same case is with *Pongamia pinnata* where hardly any literature is available on the genetic improvement. Nonetheless, while studying seed source variation for oil content in *Jatropha curcus* in the states of Himachal Pradesh, Punjab and Jammu and Kashmir, Luna *et al.* (2008) collected seeds from different locations and found that seeds collected from Dunera and Dhar location of Punjab had maximum oil content and Sahura Kandi and Jahan Khelan locations of the same state reported with minimum oil content. Adaptive trials on *Jatropha curcus* and *Jatropha gossypiifolia* were established at Hissar, Bangalore and Sardar Krushinagar. The evaluation of five cultivars revealed a good degree of variation for plant height, branches per plant and seed yield per plot at Hissar. One of the cultivars produced high seed yield of 1,733 kg per ha (Heller, 1996). However, no morphological differences were reported between 42 clones of *Jatropha curcus* originating from different locations in Thailand (Sukarin *et al*., 1987). Ginwal *et al.* (2004) evaluated ten seed sources collected from the states of Madhya Pradesh and Maharashtra for genetic variation from nursery (3 months) to field stage (2 years). The oil content ranged from 33.02 to 39.12 per cent in whole seed and 47.08 to 58.12 per cent in kernel. The performance of Kundam (MP), Jabalpur (MP), Bicha (MP), Niwas (M.P) and Nasik (Mah.) sources was found to be satisfactory for oil yield. Ginwal *et al.* (2005) reported significant seed source variation in seed morphology, seed germination and other seedling growth parameters. The phenotypic and genotypic variance, coefficient of variability and broad sense heritability also showed sizable variation. Luna and Sharma (2006) studied variation in seed morphology and fatty oil content among 25 sources of *Jatropha curcus* and found significant differences for various

Table 1. Details of collection sites of plus trees and the oil percentage

S. No.	State	Tree No.	Latitude	Longitude	Oil content (%)
1	Punjab	Jalandhar-4	31°23'35.6"	77°31'42.3"	31.27
2	Punjab	Jalandhar-5	31°23'50.4"	77°31'44.0"	33.27
3	Punjab	Jalandhar-6	31°28'14.4"	75°23'57.5"	32.87
4	Punjab	Jalandhar-9	31°29'48.4"	75°17'48.0"	33.27
5	Punjab	Hoshiarpur-19	31°20'16.1"	75°38'11.8"	32.53
6	Punjab	Hoshiarpur-24	31°23'26.8"	75°39'52.4"	33.73
7	Punjab	Hoshiarpur-33	31°24'56.2"	75°41'20.3"	31.73
8	Punjab	Hoshiarpur-34	31°24'36.0"	75°41'41.11"	29.67
9	Punjab	Ludhiana-40	30°56'56.2"	75°51'46.7"	31.73
10	Haryana	Phagwara-54	31°14'28.6"	75°45'21.4"	28.53
11	Haryana	Phagwara-63	31°7'27.5"	75°26'57.6"	32.00
12	Punjab	Jalandhar-67	31°7'27.9"	75°25'51.4"	28.53
13	Punjab	Jalandhar-68	31°7'27.6"	75°25'50.2"	31.27
14	Haryana	Fatehabad-81	29°31'7.6"	75°31'25.2"	32.13
15	Haryana	Fatehabad-90	29°31'22.8"	75°31'50"	29.93
16	Haryana	Fatehabad-95	29°31'19.2"	75°31'19.3"	30.80
17	Haryana	Fatehabad-102	29°31'9.4"	75°31'26.4"	32.67
18	Haryana	Fatehabad-109	29°31'14.4"	75°31'19.2"	35.00
19	Haryana	Fatehabad-115	29°31'18.8"	75°31'27.8"	34.00
20	Haryana	Fatehabad-117	29°31'12.8"	75°31'26.4"	33.60
21	Haryana	Hissar-125	29°18'50.8"	76°38'0.4"	31.40
22	Haryana	Hissar-126	29°18'52.2"	76°38'1.8"	31.67
23	Haryana	Hissar-127	29°18'52.2"	76°38'2.9"	34.07
24	Uttar Pradesh	Baraut-152	29°9'23.4"	77°16'19.1"	28.07
25	Uttar Pradesh	Sardhana-157	29°04'43.8"	77°37'14.3"	34.40
26	Uttar Pradesh	Sardhana-162	29°02'24.8"	77°39'51.8"	32.40
27	Uttar Pradesh	Sardhana-164	29°02'23.4"	77°39'53.5"	34.80
28	Uttar Pradesh	Sardhana-166	29°02'22.6"	77°39'54.2"	31.87
29	Uttar Pradesh	Hapur-173	28°44'36.8"	77°46'6.4"	33.33
30	Uttar Pradesh	Hapur-176	28°45'9"	77°46'7.2"	30.20
31	Uttar Pradesh	Hapur-184	28°46'28.3"	77°45'46.9"	30.40
32	Uttar Pradesh	Hapur-191	28°47'32.6"	77°45'38.9"	35.53
33	Uttarakhand	Rourkee-196	30°2'24.8"	77°44'28.4"	32.67
34	Uttar Pradesh	Chutmalpur-200	30°4'17.2"	77°45'11.8"	31.40
35	Uttar Pradesh	Baghpat-226	29°05'57.5"	77°31'50.2"	**37.87**
36	Uttar Pradesh	Baghpat-230	29°05'57.8"	77°31'50.2"	32.73
37	Uttar Pradesh	Meerut-231	29°05'56.4"	77°31'50.2"	31.60
38	Uttar Pradesh	Meerut-233	28°57'45.9"	77°31'50.2"	36.33
39	Uttar Pradesh	Meerut-245	29°05'54.8"	77°54'19.8"	37.47
40	Uttar Pradesh	Meerut-246	29°05'54.7"	77°54'19.2"	34.93
41	Uttar Pradesh	Saharanpur-260	29°58'40.8"	77°36'8.6"	30.87
42	Uttar Pradesh	Saharanpur-262	30°7'8.6"	77°50'46.7"	33.47
43	Uttar Pradesh	Saharanpur-264	30°6'31.1"	77°50'10.9"	32.27
44	Uttar Pradesh	Saharanpur-265	30°4'43.6"	77°47'41.1"	29.40

S. No.	State	Tree No.	Latitude	Longitude	Oil content (%)
45	Uttar Pradesh	Saharanpur-268	30°1'18.7"	77°44'0.4"	33.60
46	Uttar Pradesh	Saharanpur-271	29°57'3.6"	77°39'26"	33.00
47	Uttar Pradesh	Saharanpur-272	29°58'19.5"	77°37'33.4"	28.80
48	Uttar Pradesh	Saharanpur-276	29°58'32.2"	77°39'14.4"	35.00
49	Haryana	Panchkula -282	28°57'11.8"	77°31'24.6"	29.67
50	Haryana	Panchkula -283	29°58'10.6"	77°24'28.4"	29.33
51	Haryana	Panchkula -284	30°36'48.6"	76°56'35.6"	31.80
52	Punjab	Phagwara-286	30°56'18.2"	75°51'36.6"	33.87
53	Punjab	Phagwara-288	31°14'48.4	75°46'18.4"	32.07
54	Punjab	Phagwara-289	31°14'44.2"	75°46'33.4"	34.67
55	Punjab	Phagwara-291	31°14'34.2"	75°45'28.4"	35.53
56	Punjab	Phagwara-292	31°13'49.5"	75°46'12.7"	34.07
57	Punjab	Phagwara-294	31°14'22.8"	75°46'36.7"	29.73
58	Punjab	Phagwara-295	31°14'39.5"	75°46'29.6"	25.40
59	Punjab	Phagwara-296	31°18'55.3"	75°48'08.9"	33.67
60	Punjab	Phagwara-298	31°17'55.5"	75°47'46.4"	35.33
61	Punjab	Phagwara-299	31°17'53.3"	75°47'46.1"	31.33
62	Punjab	Phagwara-300	31°17'36.8"	75°47'25.8"	29.13
63	Punjab	Phagwara-301	31°17'48.4"	75°47'38.4"	31.67
64	Punjab	Hoshiarpur-303	31°17'35.4"	75°45'26.4"	28.33
65	Punjab	Hoshiarpur-304	31°17'28.6"	75°45'25.8"	28.69
66	Punjab	Hoshiarpur-305	31°27'17.2"	75°45'32.2"	32.67
67	Punjab	Hoshiarpur-307	31°24'34.9"	75°46'31.6"	27.07
68	Punjab	Hoshiarpur-308	31°24'50.6"	78°46'33.8"	31.87

seed morphological traits and oil content. The variation among the provenances is commonly used as an estimate of total genetic variation and to calculate the degree of genetic control for a particular trait (Foster and Shaw, 1988). Hence, the seeds collected from the known sources or plus trees become backbone of a successful tree improvement and afforestation programme. The species has a wide range of adaptability and grows well even on the marginal lands, enduring drought, alkalinity/salinity and thus serves as best source to green-up wastelands (Anon., 1985).

Pongamia piñnata is a native to India and distributed widely almost in all the parts of the country. The wide geographical distribution therefore has become a reasonable source of genetic variability in this species, which could well be utilized for screening promising genotypes for commercial deployment. Once an extensive selection programme is carried out with high selection intensity and genetic superiority *per se* is established using analytical tools like heritability and genetic advances, the screening of promising genotypes should not be a far cry. The genetic improvement programmes could produce much faster and promising results, if the genetic diversity of a species studied and utilized through application various genetic tools. In this process, it is essentially component of biodiversity which would make a foundation of the ecosystem stability and forest sustainability (Libby, 1973).

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Microclimatic Amelioration and Yield Potential in Horti-silviculture System

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Abstract: Trees on the farm exhibit a potential to optimize the microclimatic conditions for intercrops. The deterioration or amelioration of microclimatic conditions in agroforestry with the passage of time should be expected because of altered interaction patterns between sunrays and tree canopy resulting from changing solar elevation and angle of sunrays. The present paper studies the micro-climatic interaction and resultant effect on physiology and yield of horticultural trees (peach, kinnow and guava) grown under four year old poplar tree canopy. The stomatal conductance was found to decrease with increasing atmospheric temperature and decreasing relative humidity (RH). The transpiration rate (E) was minimum under shade conditions irrespective of the fruit species used in the experiment leading to more water use efficiency in the shade conditions than in open. Maximum carboxylation efficiency of peach indicated its higher productivity potential over the other fruit crops. Photosynthetic efficiency have been found to be positively correlated with stomatal conductance and water use efficiency indicating the usefulness of these traits for selecting plant genotypes for higher productivity under shade conditions. Fruit yield parameters viz, length, breadth and weight of all the fruits studied was found on higher side in open than under shade except total soluble salts which increased more uniformly in shade than in open condition. However, the additional income from timber trees surpass sole fruit economics.

Key Words : Horti-silviculture, Microclimate, Stomatal conductance, Growth

There is increasing interest in improving plant water use efficiency, since water is increasingly scarce, especially in regions where precipitation is low, it is, therefore, necessary to carry out studies on improving plant-water use efficiency. In all types of vegetation, the ability of individual to grow and reproduce depends on its success in capturing resources from its environment, often in competition with neighbours. When there is only one species in a stand with a uniform genetic base, resources appear to be shared equitably. In stands with more than one species, competition for limited resources is inevitable, both above and below ground. During the initial periods, the trees occupy low volume and the vacant space between the trees can be effectively utilized for intercropping agriculture crops or fruit trees. This interface not only ensures reasonable income to growers from land during initial period, but also helps in maintaining soil health by preventing soil deterioration. The interaction between the components viz., trees, fruit crops and agriculture crops are complex to comprehend. Broadly, such interactions can be classified as aboveground and belowground interactions. The interaction involves several bio-physical factors such as light, space, water, nutrients, etc. The complementarities among these factors are the key for success of an agro-forestry model. As an association of woody and herbaceous plant communities, agro-forestry systems are deliberately designed to optimize the use of spatial, temporal, and physical resources, by maximizing positive interactions (facilitation) and minimizing negative ones (competition) among the components (Jose *et al*., 2000). Trees may act as windbreaks, decrease potential evaporation and increase water use efficiency of wheat. The primary effect of trees on crop energy balance is through the interception of radiation and the reduction of wind speed. The specific elements that may be affected by modifying the crop energy balance are: radiation and photosynthesis and its rate and duration; temperature and plant development; transpiration and its consequences on soil water use and water use efficiency. This article evaluates the under storey micro-climate, and fruit production potential in a horti-silviculture system.

MATERIAL AND METHODS

The study was conducted in the experimental area of Department of Horticulture, Punjab Agricultural University, Ludhiana located at 30° 45 N latitude and 75 ° 18 E longitudes at an elevation of 247m above mean sea level. The climate is sub-tropical with dry season from late September to early June. The area receives annual rainfall of 704mm. The experiments involve two planting geometry and two ages of plantations of poplar and pear(i) One experiment was taken up as pear plantation (6m X 6m spacing) where poplar was planted as filler tree between four plants of pear during January, 2005 (ii) The other plantation taken up in January, 2006 involving 4 fruit trees species (Kinnow, guava, peach and plum at 6m X 6m spacing) and poplar trees (6m X 6m, N-S direction) grown alternatively. The variables measured include photosynthetic active radiation (PAR), stomatal conductance and inter-cellular CO_2, transpiration rate with portable photosynthesis system (CID 340, CID Inc., USA). The diurnal variation in these parameters was also measured at 9 am, 12 noon and 4 pm. The canopy characteristics such as the light interception and leaf area index of poplar trees was measured using digital lux meter and canopy analyzer (CID 310, CID Inc, USA), respectively. The per cent light intercepted by trees was calculated as the reduction in the average light intensity under tree cover over control. The data generated was suitably analysed in statistical package CPCS1 of PAU.

RESULTS AND DISCUSSION

Micro-Environmental Modifications under Tree Canopy

Radiation received below the tree canopy is highly variable and consists of irregular alternate patches of light and shade and keep on changing over time. Such spatial as well as temporal variation also depends on spacing, geometry of planting and age of the trees. The presence of trees modifies site micro-climate in terms of temperature, water vapor content and wind speed, among other factors. Serving as windbreak, trees slow the movement of air and thus in general reduce evaporative stress. Wind speed was substantially reduced under a radiata pine (*Pinus radiata*) silvo-pastoral system due to increased tree stocking (Hawke and Wedderburn, 1994). The variations in temperature and relative humidity under four and five year old poplar plantations for the period of April to September, 2009 were studied. The RH increased under the poplar canopy as the age progressed. The difference of open and under canopy was more marked in the initial years of crop planting in the month of April to June; however this gap became narrow in the more humid months August and September. The maximum RH of 80.57 per cent was recorded in the month of August under five year old poplar canopy. Temperature showed an increase with age of canopy in the month of April but it showed reverse trend for next months till October (Fig. 1). The difference between open and shade conditions for both parameters increased with increase in canopy age and modification in micro-climate became more pronounced. Windbreaks are known to improve the distribution and utilization of irrigation water, reduce evapo-transpiration, and improve crop water use efficiency (Davis and Norman, 1988). Planting windbreaks or shelterbelts in crop fields provides wind protection as well as changes in micro-climate; improved crop quality and yield within the sheltered area (10 to 15H, where H is the height of the windbreak) have also been reported earlier (Brandle *et al*., 2000).

Relationship Between Radiation Flux and Fruit Yield Parameters under Poplar Based Agroforestry System

Diurnal variation in photosynthesis of fruit plants. The diurnal variations in eco-physiological parameters recorded

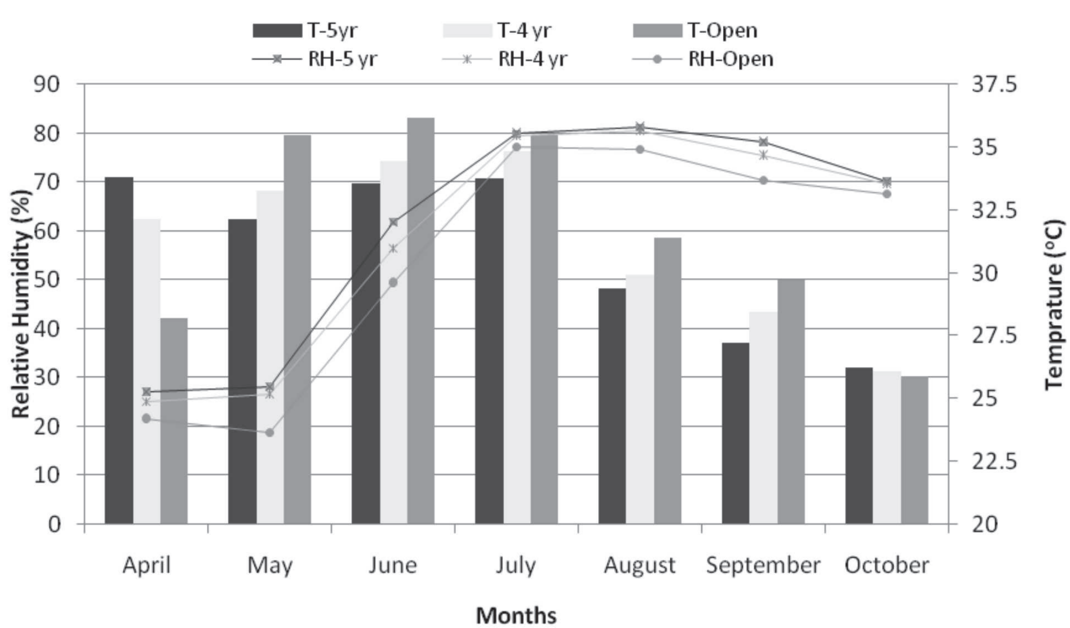
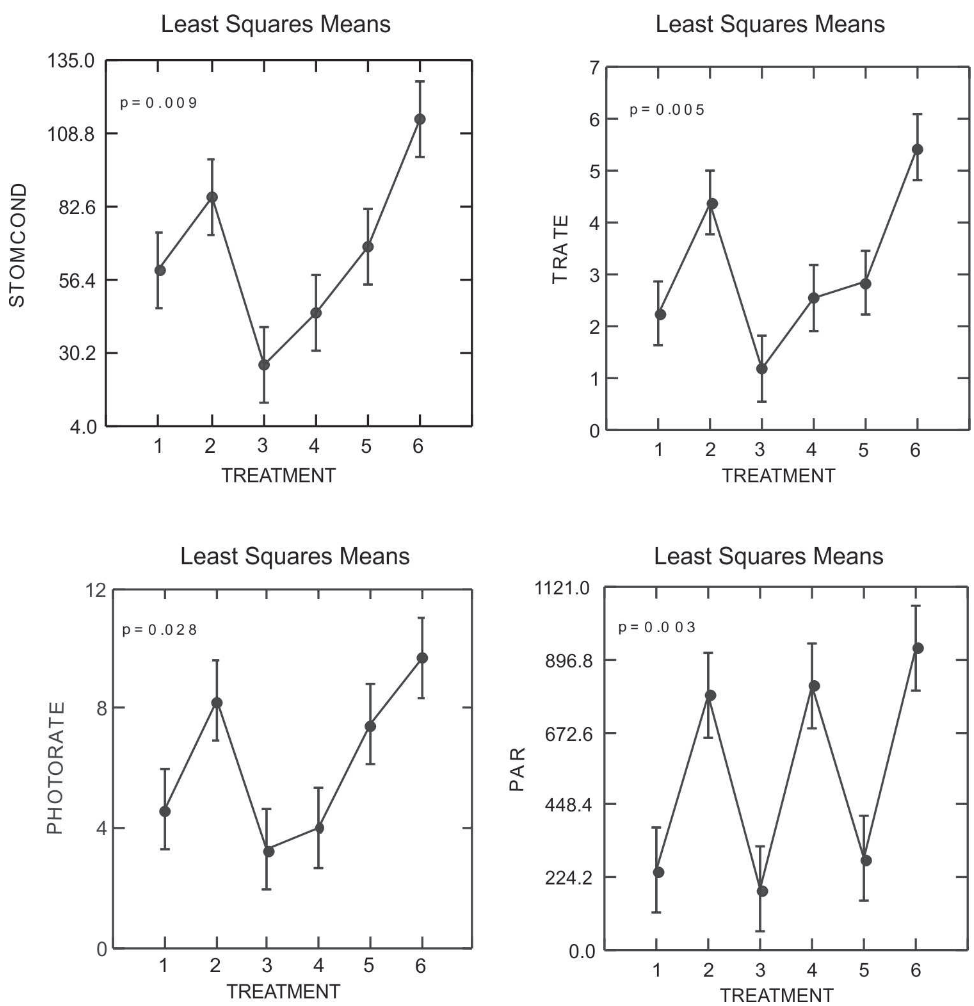


Fig. 1. Micro-climatic modification under poplar tree canopy

in fruit plants inter-planted with three year poplar were recorded (Fig. 2). Various parameters like photosynthetic active radiation (PAR), transpiration rate, photosynthetic rate and stomatal conductance was on higher side in control. The PAR was highest during afternoon with an average of about 1113.48 (μmolm^{-2}s^{-1}), 1216.03 (μmolm^{-2}s^{-1}) and 1123.03 (μmolm^{-2}s^{-1}) in open and 370.13 (μmolm^{-2}s^{-1}), 245.94 (μmolm^{-2}s^{-1}) and 452.60 (μmolm^{-2}s^{-1}) in shade for guava, kinnow and peach, respectively. The least PAR was recorded during evening (4 pm) with 458.53 (μmolm^{-2}s^{-1}) and 727.78 (μmolm^{-2}s^{-1}) for guava and peach and during morning 589.52 (μmolm^{-2}s^{-1}) for kinnow in open and for fruit trees inter-planted with poplar. The value of PAR was least during morning hours in guava (145.70 mmolm^{-2}s^{-1}) and peach (154.46 mmolm^{-2}s^{-1}) and during evening hours in kinnow (144.38 mmolm^{-2}s^{-1}). The transpiration rate was also highest during morning in guava (4.90 mmolm^{-2}s^{-1}), kinnow (3.91 mmolm^{-2}s^{-1}) and peach in control conditions (7.58 mmolm^{-2}s^{-1}) and kinnow (1.45 mmolm^{-2}s^{-1}) and peach (4.05 mmolm^{-2}s^{-1}) under shade conditions except guava where its value (3.22 mmolm^{-2} s^{-1}) was higher during evening hours. The photosynthesis rate was highest during morning hours in guava (12.47 μmolm^{-2}s^{-1}), Kinnow (5.48 μmolm^{-2}s^{-1}) and peach (12.32 μmol m^{-2}s^{-1}) in open plot and 6.65 (μmol m^{-2}s^{-1}) for guava in evening, 5.16 (μmol m^{-2}s$^{-1)}$ for Kinnow and 9.27 (μmol m^{-2}s^{-1}) for peach in morning hours under shade conditions. The lowest rate of photosynthesis was recorded during afternoon in all fruit crops under both conditions except peach where it was least during evening hours under poplar canopy. Photosynthesis is a physiological process that is affected by the environmental factors. The fruit trees in general show daily changes in photosynthetic rate and a mid day depression of photosynthesis depending upon prevailing weather



1 Guava; 2 Guava control; 3 Kinnow;4 Kinnow control; 5 peach; 6 Peach control

Fig. 2. Diurnal variation in photosynthesis of fruit trees in different treatments

conditions during their growth period. Among the three fruit trees, peach recorded highest stomatal conductance, net photosynthesis and transpiration. At mid-day with the stress of high temperature and intense irradiation, net photosynthesis rate may decrease almost near to zero. It is primarily due to the reduction in the stomatal conductance, which leads to short supply of CO_2. The stomatal conductance was found to decrease with increasing atmospheric temperature and decreasing relative humidity (RH). The transpiration (E) rate was lowest under shade conditions irrespective of the fruit species used in the experiment leading to more water use efficiency in the shade conditions than in open. Indeed, higher stomatal conductance and higher CO_2 assimilation rates were observed in shaded plants, during both winter and summer. Medinaa *et al*. (2002) also reported that during both seasons, integrated daily net CO_2 uptake was approximately 20 per cent higher in shaded plants, mainly as a consequence of increased leaf conductances. Higher stomatal conductance and CO_2 assimilation rates under reduced radiation have also been observed in other cases, as in *Macadamia integrifolia* and *Litchi chinensis* (Medinaa *et al.,* 2002).

Maximum carboxylation efficiency of peach indicated its higher productivity potential over the other fruit crops. Photosynthetic rate is positively correlated with stomatal conductance and water use efficiency indicating the usefulness of these traits for selecting plant genotypes for higher productivity under shade conditions.

Fruit productivity studies of guava, peach and plum in open and under partial canopy. Fruit plants like guava and peach were incorporated in the poplar plantation (6 m x 6 m) so that distance between fruit plant to fruit plant remain 6x6m. Uniform branches around the tree were tagged for recording the observations. In peach, date of full bloom was delayed by one week, whereas, in guava there was delay by 4 days under canopy than in open. Fruit length and breadth followed almost similar trend in open and shade conditions in peach with a pronounced rate of fruit length growth than breadth near the maturity in shade conditions. Fruit weight increased gradually in both open and shade conditions, whereas, TSS increased more uniformly in shade than in open. Jifon and Syvertsen (2001) reported that juice and TSS yields in grape fruit increased under shade as compared in control. Acidity reached its peak almost in the middle of season, thereafter, it declined to almost same values in both the conditions. In guava fruits, rate of growth in terms of breadth was more in open conditions than the length of fruit. There was more concurrence of rate of growth of length and breadth in shade than in open. TSS remained almost static near 50-60 days after full bloom in both the cases with the more steep growth in open conditions than shade. Rate of growth was almost similar till 80 days after full bloom in both the cases with more steep increase in open than in shade. Acidity declined continuously in both the cases with little fluctuation in the start of growth of fruit. Though, in shade, there was more gradual decline than in open. Average yield of guava under shade and open conditions was 7.12 kg/tree and 9.53 kg/ tree, respectively and that of peach was 5.24 kg/tree and 6.78 kg/tree under shade and open conditions, respectively. In plum, growth pattern for fruit length, breadth and weight was almost similar under both condition and there was gradual increase in values of these parameters. Increase in acidity for one month after full bloom was sharper in shade conditions as compared to open conditions and afterwards the trend remained same. There was continuous increase in total soluble solids in both conditions. While considering fruit parameters (peach, guava and plum) at full maturity under different experiments like filler, windbreak and intercropping. In peach, different parameters viz, fruit weight, length, breadth and juice acidity were found to differ significantly with highest value in plants raised as control for fruit weight, length and breadth and TSS and acidity. In plum, only fruit breadth was found to be significantly different among other parameters with highest value in plants of control experiment. In case of guava, all the parameters were found to be statically at par with each other. Fruit parameters like fruit length was found greater in peach, likewise fruit breadth was higher in guava but was at par with peach. Total soluble solids were found higher in plum followed by peach, the same trend was found in fruit juice acidity. Fruit yield (kg/tree) was found higher in guava followed by peach. Filler treatment was found best as far as fruit weight, fruit breadth and fruit yield (kg/ tree) was considered, whereas, total soluble solids and acidity was found higher with windbreaks.

Longer term moderate shade can increase total fruit yield and juice content of fruit trees. The stomatal conductance was found to decrease with increasing atmospheric temperature and decreasing relative humidity (RH). The transpiration (E) rate was lowest under shade conditions irrespective of the fruit species used in the experiment leading to more water use efficiency in the shade conditions than in open. Maximum carboxylation efficiency of peach indicates its higher productivity potential over the other fruit crops. Pn/Ci is positively correlated with stomatal conductance and water use efficiency indicating the usefulness of these traits for selecting plant genotypes for higher productivity under shade conditions.

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Agroforestry Systems of Lahaul and Spiti District of Himachal Pradesh, Western Himalaya

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Abstract: Land-use options that increase resilience and reduce vulnerability of contemporary societies are fundamental to livelihood improvement and adaptation to environmental change. Agroforestry as a traditional land-use adaptation may potentially support livelihood improvement through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change. Agroforestry systems in India contribute variously to ecological, social and economic functions, but they are only complementary – and not as an alternative – to natural ecosystems. But, different agroforestry systems prevalent in Lahaul and Spiti area have been categorised into five different types. These identified agroforestry systems are agri-horticultural, agri-silvicultural, agri-silvi-pastoral, silvi-pastora and horti-pastoral.Major tree species of the area arewillow, poplar and apple. These agroforestry systems can play a pivotal role in the era of global warming and climate change in the cold desert of Western India.

Key Words: Agroforestry systems, Lahaul and Spiti, Cold desert

Landuse options that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Traditional resource management adaptations such as agroforestry systems, may potentially provide options for improvement in livelihood through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change (Pandey, 2007). The adverse impact of climate change may be more severely felt by the poor, who are more vulnerable than the rich. Appropriate policy responses combining agroecosystems as key assets can strengthen adaptation and help build the resilience of communities and households to local and global change. Tree-growing in combination with agriculture (agroforestry systems) as well as numerous vegetation management regimes in cultural landscape (ethnoforestry systems), including individual farms, watersheds and re-gional landscape can be integrated to take advantage of the services provided by adjacent natural, semi-natural or restored ecosystems. Agroforestry systems include trees on farms, community forestry and a variety of local forest management and ethnoforestry practices. These systems have been presented as a solution to rising fuelwood prices in India resulting from increase in demand and decrease in supply of fuel-wood due to forest degradation (Bowonder *et al.*, 1988). In India, a lot of work has been done in all the agro-climatic zones and a number of traditional agroforestry systems have been identified and documented. From the Himalayan region, which is one zone of India, a number of traditional agroforestry systems have been documented from Himachal Pradesh and Uttarakhand. Atul *et al.* (1990) have identified three most extensively practiced agroforestry systems in H.P. (agri-silviculture, agri-horticulture and agri-horti-silviculture). Kumari *et al.* (2008) also reported five most extensively used agroforestry systems in dry zone of Lahaul and Kinaur district of Himachal Pradesh.Similarly, Dadhwal *et al.* (1989), Toky and Khosla (1989), Singh and Singh (1987) and Singh *et al.* (1980) identified the following agroforestry system in Himalayan region along with the major benefits, (1) Fruit trees in combination with agricultural crops and fodder trees for fruit and fodder production, (2) Fodder trees with pasture for fodder production, (3) Trees and grasses for soil conservation, fuel, timber and fodder. Singh and Dagar (1990) have identified agri-silviculture systems, agri-horticultural system, agri-hortisilviculture system, silvi-pastoral system and homesteads in Mussoorie hills in the Western Himalayas. Hence, efforts were made to identify the current tree-based models and their uses in District Lahaul and Spiti (cold deserts) of Himachal Pradesh.

MATERIAL AND METHODS

The work was conducted in the year 2010 in Lahaul area of Lahaul and Spiti District, which lies between latitudes 32° 8' and 32° 59' North and longitudes 76° 43' and 77° 47' East in the Western Himalayas. Within study area, five villages were randomly selected for the purpose of study. In each village, again 10 per cent sampling was done for collecting the information from the households and the information was collected by questionnaire method, informal interviews, transact walk along with the farmers and personal observations.

RESULTS AND DISCUSSION

Agroforestry systems in India include trees on farms, community forestry and a variety of local forest management and ethnoforestry practices. A wider definition of agroforestry encompasses a variety of practices, including trees on farm boundaries, trees grown in close association with village rainwater collection ponds, crop-fallow rotations, and a variety of agroforests, silvopastoral systems, and trees within settlements. These systems have been presented as a solution to rising fuelwood prices, resulting from increase in demand and decrease in supply of fuel-wood due to forest degradation. Agroforestry systems in the area are practiced by the farmers in order to meet their diverse needs from the same unit area. Systems identified are discussed hereunder.

The current tree based agroforestry models in Lahaul area have been presented in Table 1, which reveals that maximum area (7.15 bigha) was found under agri-silvicultural system and crops grown were peas/potato/rajmash/cauliflower/hops + salix, followed by pastoral-silviculture (1.03 bigha) and crops grown were grasses + salix/eucalyptus. Area under agri-horticulture system was 0.24 bighas with crop combinations of peas/potato + apple, area under agri-silivi-pastoral was 0.37 bigha and crops grown were peas+salix+grasses, under pastoral-horticulture system area was 0.23 bigha and the crops grown were grasses+apple. Generally five agroforestry models i.e. agri-horticulture, agri-silvi culture, agri-silvi-pastoral, pastoral-silviculture and pastoral-horticulture were prevalent in the area.

Trees have a special role in the ethos of the people of India. There are several sacred trees and sacred groves valued by the people. India also has a long historical tradition of tree-growing on farms and around homes. Such traditions and indigenous ethics had and continue to have an impact and implications for tree-growing and ecological, economic and social well-being of the people. Sacred elements and traditional practices in cultural landscape of India also have a substantial livelihood and conservation value. Besides these benefits trees have also multipurpose uses. The multifaceted benefits of the tree based

Table 1: Current tree based model in Lahaul and Spiti district*

Name of villages	Agri-horticulture		Agri-silviculture		Agri-silvi-pastoral		Pastoral-silviculture		Pastoral- horticulture	
	Area (bighas)	Crops/ tree	Area (bighas)	Crops/ tree	Area (bighas)	Crops/ tree	Area (bighas)	Crops/ tree	Area (bighas)	Crops/ tree
Goshal	0.5	Peas/ Potato+ Apple	11.4	Peas/ Potato/ Rajmash + Salix	0.20	Peas+ Salix+ Grasses	0.22	Grasses+ Salix + Eucalyptusz	0.35	Grasses+ Apple
Jhalma	0.4	Peas+ Apple	6.7	Peas/ Potato/ Rajmash + Salix	0.4	Peas+ Salix+ Grasses	0.7	Grasses + Salix	0.6	Grasses + Apple
Gondla	0.9	Peas/ Potato + Apple	8.5	Peas/ Potato/ Rajmash+ Salix	0.6	Peas+ Salix+ Grasses	0.4	Grasses+ Salix	0.7	Grasses + Apple
Tandi	0.6	Peas+ Apple	5.8	Salix Peas/ Potato/ Rajmash+ Salix	0.40	Peas+ Salix+ Grasses	1.2	Grasses + Salix	0.6	Grasses + Apple
Tholang	0.7	Peas+ Apple	7.4	Peas/ Potato/ Rajmash+ Salix	0.35	Peas+ Salix+ Grasses	0.8	Grasses+ Salix	0.15	Grasses+ Apple
Average	0.62	Do	7.96	do	0.39	do	0.664	do	0.48	do

*1ha = 12.5 bighas

Table 2. Benefits of tree based model in Lahaul and Spiti district

Benefts	Goshal		Jhalma		Gondla		Tandi		Tholang		Total	Average	
	Score	Ranks	Score	Ranks	Score	Ranks	Score	Ranks	Score	Ranks		Score	Ranks
Fuel wood	43	I	40	I	39	II	41	I	43	I	206	41.2	I
Fodder	32	II	33	II	41	I	35	II	31	II	172	34.4	II
Small timber	22	III	34	III	31	II	27	III	24	III	138	27.6	III
Thatching material	12	IV	11	IV	8	V	16	IV	8	V	55	11	IV
Fruits	7	V	9	V	13	IV	7	V	13	IV	49	9.8	V

agroforestry models found in the region are described below (Table 2). Ranking system was used for analyzing the benefits. On an average, maximum benefits (41.2) were taken as fuel wood, followed by fodder (34.4), small timber (27.6), while minimum (11) benefits were taken as thatching material. The benefit of fruit growing is lowest (9.8), which shows that maximum potential areas can be covered under horticulture tree crops but have not properly been exploited.

Natural ecosystems are often diverse in their species composition and efficient in conservation of site resources. The traditional agroforestry practices to some extent have helped people in meeting some of their diverse needs i.e., food, fodder, fuelwood and timber but the farmers with small land holdings and due to water scarcity, results in low yield of food, fodder and fuelwood from the unit area.

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Evaluation of Nutritive Value of *Leucaena* Supplemented Fodder

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Abstract: *Leucaena* is an important component of tree based farming system for providing complementary beneficial effects on yield of inter-cultivated crops. High protein content makes it very suitable feed source, however, the toxic non-protein amino acid, mimosine limits its use in the feed of farm animals. An attempt has been made to assess the feed quality of *Leucaena* supplemented forage by mixing different proportions of inter-cultivated forage crops. In the present study significant variation in nutritive value of K-8, K-156 and K-743A was recorded. More quantitative data has been generated on *Leucaena* as protein supplemental feed. The contents of all the biochemicals by mixing *Leucaena* leaves in traditional forage were diluted significantly with the increase in proportion of inter-cultivated forages. It is important to notice that utilization of *Leucaena* leaves besides protein supplement dilutes the mimosine as the proportion of the other forages increase. The ratio of mixing of *Leucaena* and all the forage crops i.e., maize+cowpea, ryegrass+berseem and napier bajra hybrid followed the same trend. The intercropped fodders played the role of dilution factor in the anti-quality parameters like mimosine and tannins but still the lower mimosine mixture will not be the perfect combination, as K-743A had lower productivity than K-8. *Leucaena* sources K-8 with high protein content (24.05%) and relatively higher productivity (27.6 and 31 per cent more than K-156 and K-743A, respectively) supplemented in ratio of 1:2 was found a very suitable feed source in terms of quantity and quality fodder.

Key Words: *Leucaena*, Subabul, Silvi-pastoral system, Cultivated forage, Supplemented feed

India with the largest cattle population in the world has insufficient milk production to meet the regular requirements. Inadequacy of feed resources is the key constraint in meeting the increased demand, which necessitates the usage of concentrates and tree forage. A number of indigenous as well as exotic multipurpose tree genera including *Bauhinia, Prosopis, Grewia, Celtis, Robinia, Albizia, Leucaena,* etc., have gained significance for fodder. *Leucaena* (subabul) is one of the potential species, gaining popularity for its adoption under silvi-pastoral systems due to its multipurpose uses, fast growth, coppicing ability, nutritive value, nitrogen fixing ability, wide adaptability, etc. Tree is native to Mexico and Central America and has been found highly acceptable with excellent performance in south-east Asian countries. Foliage of *Leucaena* is highly palatable, nutritious and relished by cattle, goat and wildlife but it cannot be used as sole feed because of presence of non-protein amino acid, mimosine [â{N-3hydroxy-4(H) pyridone} amino propionic acid]. Toxicity of sole *Leucaena* feeding has been observed in sheep, goat and cattle (Jones, 1979; Hegarthy *et al.,* 1976; Meulen and El-Harith, 1983; Norton *et al.*, 1995; Mahanta *et al.,* 2002; Solanki, 2003). Thus, it is important to mix *Leucaena* leaves with other forage crops for feeding to animals.

Punjab is one of the leading agriculture states and represents 3rd position in milk production. Scarcity of green fodder in the state is the major reason for low animal productivity. Since, the cattle have an important role in the state's farming systems, therefore, agroforestry systems designed to improve forage production are expected to make a significant contribution to farm productivity. *Leucaena* has already been recommended for cultivation in Punjab owing to its multipurpose uses but restricted its use as fodder due to its anti-quality properties (mimosine and tannin contents). However, *Leucaena* species contains high concentration of protein (ranging from 20 to 35 per cent in the dry matter) thus making it a valuable protein supplement to low quality forage diet. Therefore, a study was conducted to workout the appropriate proportion of mixing *Leucaena* in other forages to supplement nutrition to domestic animals.

MATERIAL AND METHODS

Three diverse sources viz. K-8 (*Leucaena leucocephala)*, K-156 (*Leucaena diversifolia*) and K-743A (*Leucaena leucocephala x Leucaena diversifolia*) selected on the basis of their mimosine content were raised in four replications with 12 plants per replication at 4x2m spacing in the experimental area of Fodder Section, Punjab Agricultural University, Ludhiana. The analysis of their nutritive values with inter-cultivated fodders i.e., Napier bajra hybrid (PBN-233), maize (J-1006) + cowpea (Cowpea-88) followed by berseem (BL-10) + rye grass (Rye grass No.1) was done in the Laboratory of Animal Nutrition Department, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.

Leucaena leaf samples taken at random from each *Leucaena* source at different maturity stages were mixed, dried and ground to powder, which were mixed with the above mentioned inter-cultivated fodder crops in the proportion of 1:1, 1:2 and 1:3. The nutritional analysis for proteins, carbohydrates, total ash, mimosine and tannins from these dried powder fodder samples was done as per the standard procedures. Crude protein, tannins and ash content were estimated as per the procedure of AOAC (1970); carbohydrates by following Dubois *et al.* (1956) and mimosine by rapid calorimetric method of Mastsumoto and Sherman (1951). The data generated on different quality parameters was suitably analyzed after following the standard procedure of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Leucaena leaves were mixed with forage crops i.e., ryegrass + berseem, maize + cowpea and napier bajra hybrid in the ratio of 1:1, 1:2 and 1:3 to evaluate the qualitative parameters to neutralize the anti-quality factors (mimosine and tannins). Protein and mimosine are two important components among the studied parameters in the feed. Protein is important per se but it has a bearing on mimosine content also, which is an anti-quality factor. The nutritive values of pure *Leucaena* sources presented in Table 1, indicated that the anti-quality bio-chemicals (mimosine and tannins) were comparatively less in K-743A than K-156 and K-8, whereas, other important biochemicals crude protein exhibited reverse trend. There are ample evidences for variation in different bio-chemicals in different species of *Leucaena* and within *Leucaena leucocephala* (Hauad & Foroughbakch, 1991; Gupta *et al.,* 1991; Norton *et al.*, 1995; Khajuria *et al.*, 1997). Though the results from different authors differ widely in absolute terms, yet it is not known how much of apparent variation within species is genetic in nature. In terms of green leaf biomass, all the three *Leucaena* sources differed significantly. K-8 was more productive in terms of leaf biomass followed by K-156 and K-743A i.e., 3.26, 2.36 and 2.25 kg/plant, respectively at the age of four years.

The data on qualitative parameters of *Leucaena* mixed with ryegrass + berseem, maize + cowpea and napier bajra hybrid in different proportion have been presented in Table 2-4. The differences in values with respect to different *Leucaena* sources, the proportion of mixing and their interaction were significant in almost all the parameters. The anti-quality parameters were found in the order of K-743A<K-156<K-8 at all mixture levels. Lahene *et al.* (1987) and Norton *et al.* (1995) also reported the similar trend.

It is evident from the table 2 that the mixing of ryegrass + berseem in different proportion had significant influence on all the fodder qualitative parameters (crude protein, carbohydrates, ash, mimosine and tannin content). Irrespective of the *Leucaena* source, the value of protein, carbohydrate, mimosine and tannins decreased, while the ash content increased with the increase in proportion of ryegrass + berseem fodder. The reduction in the carbohydrate, mimosine and tannin content was drastic (75.08, 69.23 and 74.49 per cent, respectively) but slight in protein (4.28 per cent) when the proportion of ryegrass + berseem in *Leucaena* was increased from 1:1 to 1:3 ratio. The ash content, however, increased by 5.44 per cent. The reduction in values was due to lower quality roughage of inter-cultivated fodder crops.

The mixing of ryegrass + berseem with *Leucaena* (K-743A) in the ratio of 1:3 registered the minimum value for mimosine, however, the content decreased in other *Leucaena* sources also but values were significantly higher. The data on different fodder quality parameters on mixing of *Leucaena* and maize + cowpea and napier bajra hybrid in different proportions also followed the same trend as for ryegrass + berseem (Table 3 & 4). The values of protein, carbohydrate, tannin and mimosine decreased with increase in proportion of maize + cowpea and napier bajra hybrid from 1:1 to 1:3, while the ash content increased with increase in proportion. The overall reduction in carbohydrate, mimosine, tannin and protein content was almost same in both the combinations. The reduction in the carbohydrate, mimosine, tannin and protein contents were 75.5, 70.2, 76.2 and 16.76 per cent, respectively when the proportion of napier bajra hybrid in *Leucaena* was increased from 1:1 to 1:3. The ash content, however, increased by 5.6 per cent. Similarly, the reduction was in the order of 75.08, 71.13, 74.54 and 14.19 per cent, respectively in *Leucaena* supplemented in maize+cowpea

Table 1. Quality parameters of different *Leucaena* sources

Leucaena source	Crude protein (%)	Carbohydrate (%)	Ash (%)	Mimosine (%)	Tannins (%)
K-8 (*Leucaena leucocephala*)	24.05	12.50	8.14	2.30	3.76
K-156 *(L. diversifolia)*	25.20	12.68	7.97	1.87	3.53
K-743A *(L. leucocephala x L.diversifolia)*	24.20	14.77	7.99	1.40	3.35
CD 5%	0.09	0.06	0.16	0.04	0.14

Table 2 . Nutritional value *of Leucaena* : ryegrass + berseem in different proportions

Leucaena	Crude protein (%)				Carbohydrate (%)				Ash (%)				Mimosine (%)				Tannins (%)			
source	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean
K-8	20.63	20.08	19.81	20.17	5.70	2.85	1.42	3.32	9.07	9.38	9.53	9.32	1.16	0.55	0.38	0.69	1.80	0.90	0.40	1.03
K-156	21.50	20.60	20.25	20.78	5.96	2.98	1.47	3.47	8.98	9.32	9.49	9.26	0.90	0.44	0.27	0.53	2.20	1.10	0.50	1.26
K-743A	20.92	20.28	20.29	20.49	6.06	3.03	1.51	3.53	8.99	9.32	9.50	9.27	0.70	0.33	0.19	0.40	1.60	0.80	0.30	0.90
Mean	21.01	20.32	20.11		5.90	2.95	1.47		9.01	9.34	9.50		0.91	0.44	0.28		1.86	0.93	0.40	
C.D. at 5% level																				
Source		0.25				0.06				0.08				0.04				0.08		
Ratio		0.24				0.07				N.S.				0.04				0.06		
Source x Ratio		N.S.				0.10				N.S.				0.06				0.13		

Table 3. Nutritional value of *Leucaena* : maize + cowpea in different proportions

Leucaena	Crude protein (%)				Carbohydrate (%)				Ash (%)				Mimosine (%)				Tannins (%)			
source	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean
K-8	19.52	18.01	16.31	17.88	6.05	3.03	1.51	3.53	8.57	8.85	8.89	8.77	1.20	0.60	0.40	0.73	1.60	0.81	0.42	0.94
K-156	20.31	18.54	17.65	18.83	6.27	3.13	1.56	3.65	8.48	8.88	8.87	8.74	0.93	0.46	0.24	0.54	1.69	0.84	0.41	0.98
K-743A	19.78	18.18	17.39	18.45	7.06	3.53	1.76	4.11	8.50	8.83	8.88	8.73	0.80	0.42	0.22	0.48	1.66	0.83	0.40	0.96
Mean	19.87	18.24	17.05		6.46	3.23	1.61		8.51	8.85	8.88		0.97	0.49	0.28		1.65	0.82	0.42	
C.D. at 5% level																				
Source		N.S.				0.17				N.S.				0.14				0.09		
Ratio		1.70				0.17				N.S.				0.14				0.09		
Source x Ratio		N.S.				0.29				N.S.				N.S.				0.16		

Table 4 . Nutritional value of *Leucaena* : napier bajra hybrid in different proportions

Leucaena	Crude protein (%)				Carbohydrate (%)				Ash (%)				Mimosine (%)				Tannins (%)			
Source	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean
K-8	18.02	16.04	15.34	16.46	6.12	3.06	1.53	3.57	9.70	10.04	10.20	9.98	1.30	0.65	0.40	0.78	1.72	0.86	0.43	1.00
K-156	18.81	16.54	15.40	16.91	6.48	3.07	1.54	3.69	9.43	9.82	9.96	9.74	0.92	0.48	0.26	0.55	1.82	0.91	0.45	1.06
K-743A	18.28	16.18	15.14	16.53	6.90	3.45	1.72	4.02	9.45	9.78	10.00	9.74	0.82	0.44	0.24	0.50	1.66	0.83	0.40	0.96
Mean	18.37	16.25	15.29	-	6.50	3.19	1.59	-	9.53	9.88	10.05	-	1.01	0.52	0.30	-	1.77	0.86	0.42	-
C.D. at 5% level																				
Source		N.S.				0.29				N.S.				0.15				0.62		
Ratio		1.43				0.30				N.S.				0.15				0.62		
Source x Ratio		N.S.				N.S.				N.S.				N.S.				N.S		

fodder from 1:1 to 1:3 ratio.

The objective of mixing as mentioned above was mainly to reduce the anti-quality parameters i.e. mimosine and tannins, it lowered down the quality parameter also, however, the reduction in protein was slight but high in carbohydrate contents. The carbohydrates can be supplemented through other alternative sources but reduction in the mimosine through the mixing of other green fodder in *Leucaena* will provide a viable option for the success of this silvi-pastoral model among the farmers with high productivity. The reduction in both the anti-quality parameters had been drastically high by mixing of *Leucaena* and other fodder crops in the ratio of 1:3. Kaur and Gupta (2003) observed very low concentration of mimosine and tannins in blended fodders of berseem + shaftal : subabul foliage in the ratio of 40:60 and 60:40, which were quite below the toxic level. The level of protein and carbohydrates in blended fodder were also found to be in accordance with the recommended standards. The feeding of *Leucaena* with other forages to minimize the anti-quality factors also find the support of Devendra (1982), where 50 per cent amount of *Leucaena* forage in diet has been recommended. Norton (1994) emphasized 30-50 per cent *Leucaena* in the diet for optimum performance of cattle, sheep and goats. *Leucaena* leaves have also been used successfully to increase the protein content and nutritive value of the silages (Tandraatmadja *et al.,* 1993). Neeru *et al.* (1992) did not observe any ill effects on rumen microbial activity rather it had positive effects by substituting dietary dry matter with 20% sun dried *Leucaena leucocephala* leaves in the diet of buffalo calves. Waipanya and Srichoo (1994) reported reduced cost of milk production by utilizing *Leucaena* leaves as protein supplement and farmers earned more income.

Using a high proportion of K-743A with other fodder crops (1:3) would give lower mimosine and tannin levels, but would also mean lower protein and biomass. *Leucaena* source K-743A was comparatively less productive than K-156 and K-8. Therefore, this ratio may not be acceptable depending on the lower biomass and quality parameters. *Leucaena leucocephala* has great value as a supplement to low quality fodder. The use of most productive source (K-8) at 1:2 ratio will be optimum in terms of quality and quantity. Recently the use of subabul in paper industry has encouraged the farmers for its adoption under farm forestry/ agroforestry. The adoption of subabul based silvi-pastoral system in Punjab and adjoining states will also provide the high level of quality fodder output, stabilize the agro-ecosystem and provide employment to rural people.

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Effect of *Grewia optiva* Pollarded at Different Heights on Biomass Production of Agroforestry Systems in Mid-Hills of Himachal Pradesh of India

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Abstract: The experiments on tree-crop interaction was carried out during *Rabi* and *Kharif* were laid out in replicated factorial randomised block design comprising 18 treatments combination. The study revealed that the yield of both wheat and soybean responded negatively to increasing pollarding heights from 1.5 m to 4.5m and positively to increasing distance of crop from tree rows (1 to 3 m), besides both the crops performed better in southern aspects as compared to the northern. Biomass production of *Grewia optiva* (leaf and branch) increased with increasing pollarding heights from 1.5 to 4.5 m.

Key Words: Agroforestry, Biomass production, Pollarding heights, Interaction

The developing world is today encountered with near crisis situation, both economic and environmental. This region with barely 56% of the land area has to support around 77% of the total population at the global level. The policy makers are therefore finding it very difficult to formulate strategies that would work under the present situation of escalating population on the one hand and diminishing resources on the other. India, which is known as developed among the developing nations, is no exception in this regard. As from the last few decades, the country is witnessing a serious depletion of its resources as well as various concomitant environmental disasters. The impacts of degradation are though visible in all the renewable and non-renewable resources, yet the forest and the land, which are very initial for the sustenance, are perilously affected.

To over come this situation, increasing productivity of existing forest stands, restocking low density areas, afforestation of village, wastelands under social forestry and integration of trees in agricultural/horticultural crops seems to be very visible options. The integration of trees on farm lands (recently coined as agroforestry), however, needs to the given a special preference as this would enable the people to be self sufficient for their basic needs and thereby help directly and indirectly in conserving and improving the public forest land.

Agroforestry land use pattern are biologically more complex and diverse than other farming practices prevalent throughout the world. Such system though hold promising potential to address the various basic issue of the farming communities, yet they have not been given due scientific attention. In fact, vary little information is available on the tree-crop combinations and various interaction involved there in as well as different tree management practice, which is properly applied shall help to minimize the negative effect of trees on accompanying crops. Keeping in the view the significance of problem, the present study was initiated on effect of *Grewia optiva* pollarded at different heights on biomass production.

MATERIAL AND METHODS

The experiment of tree crop interaction was carried out during winter–wheat and summer-soybean in association with6 year old *Grewia optiva* pollarded at different heights (1.5m, 3m and 4.5m). The experimental site falls in the mid hill zone of H.P. at an elevation of 1250m above mean sea level. The climate of the area is transitional between sub humid sub- tropical to sub temperate. There is in general consideration variation in the seasonal and diurnal temperatures (May and June are the hottest months whereas, December and January are the coldest and experience severe frost). The annual temperature ranges from 3^0 C to 31.2^0C, the area receives on an average annual rain fall of 1200-1300mm, most of which is concentrated in the monsoon period mid June- August winter shower are usually mild. The soils of the experimental site are gravelly loam in texture and have granular in structure. The fertility status of these soils reveals that they are medium in available N and high in available K_2O and P_2O_5. Experiments are laid out in replicated factorial randomised block design with three replications and comprising 18 treatment combination with three pollarding heights (P1- 1.5m, P2 – 3.0m and P3 – 4.5m), three distances of crop from tree row

(D1 – 1.0m, D2 – 2.0m and D3 – 3.0m) and two directions of crop from tree row (S1 – north aspect of tree row and S2 – south aspect of tree row). *G. optiva* has been planted at 8mx2.5m along east-west direction.During experiment plantation was 6 yrs old. Net sown area of both the crops (wheat and soybean) was same i.e. 9400 sq.m The package of practices were followed as recommended by the state department of agriculture, Himachal Pradesh for raising *Rabi* (winter) and *Kharif* (summer) crops (*Rabi* – wheat and *Kharif*- soybean). Likewise, grain yield per hectare and straw yield per ha were recorded.

Branchwood and leaf biomass of *G. optiva* was recorded in October. The branches were lopped completely and separated from leaves and their individual fresh weight was recorded in the field. Branch and leaf samples were dried at 85° to calculate dry weight. Leaf and branchwood biomass was expressed in kg per plant.

The cost of cultivation of different field crop was worked out on the basis of net cropped area. The yield of different field crop and fodder tree was converted into gross returns in rupees per hectare, based on prevailing localmarket prices. Net return in both the season was calculated by deducting the total cost from gross returns. The data obtained from the present investigation were subjected to statistical analysis and analysed for proper interpretation.

RESULTS AND DISCUSSION

Grewia optiva – Wheat (*Triticum aestivum*) Combination: Wheat Yield

The grain as well as straw yields showed significant effect due to interaction between pollarding heights (P) x crop distance (D) x crop direction (S) (Table 1). Among the interactions the highest grain and straw yield were registered at P3D3S1 (15.03) and P2D3S2 (20.61), respectively. The lowest grain and straw yield were recorded at P3D1S1 (5.57) and P2D1S1 (8.63) respectively.

Khan and Aslam (1974) observed yield reduction in crops in tree- crop intercropping system. The depression was highest near the tree line and decreased with increasing distance. Yamaoh *et al.* (1988) and Dugma *et al.* (1988), Khybri *et al.* (1992) in wheat- *Grewia*, wheat – *Morus* and wheat – *Eucalyptus* intercropping systems observed 39 per cent yield reduction up 1m, 33 per cent from 2m, 25 per cent from 2 to 3m and 12 per cent from 3 to 5 m from tree row. The crop raised in the southern aspect of the tree row registered significant increase of 9.36 per cent in grains and 23.23 in straw as compared to that raised in northern aspect.

G. optiva- Soybean Combination: Soybean Yield.

The grain as well as straw yield tended to depreciation with increase in pollarding height, yet the variation was recorded to be statistically non-significant. The yield (both grain and straw) in response to distance as well as direction of crop showed a significant effect, wherein it enhanced remarkably with increase in crop distance and was seen to be higher in southern aspect compared to northern (Table 2).

The grain yield improved by 16.55 and 9.86 per cent whereas, straw yield increased by 26.9 and 7.96 per cent from D1 to D2 and D2 to D3, respectively. The crop raised in southern aspect yielded out more than in northern aspect by 15.2 per cent in grain yield and 16.39 per cent in straw yield (Table 3). Sheikh and Haq (1978) and Kumar (1996) have also reported better performance of crop on southern than in northern aspect.The interaction effects of pollarding height, distance of crop from tree rows revealed non-significant variation on yield of the crop.

The gain of N, P and K in soil can be attributed to inclusion of legume as crop, residual effect of N, P and K applied at the time of wheat and partially, presence of tree

Table 1. Interaction of pollarding height x crop distance x crop direction on grain and straw yield(q/ha) of wheat (P x D x S)

Pollarding Height	Crop distance											
	D1				D2				D3			
	Crop direction				Crop direction				Crop direction			
	S1		S2		S1		S2		S2		S2	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
P1	9.42	12.90	12.17	15.81	10.98	17.03	12.06	19.35	10.92	17.00	12.08	18.62
P2	9.27	8.63	10.92	12.14	9.69	10.45	11.05	13.26	8.75	11.04	10.25	20.61
P3	5.57	12.30	9.78	13.30	7.86	12.27	9.05	13.86	15.03	11.51	7.16	12.43

Effect	Grain		Straw	
	SE (diff.)	CD (p=0.05)	SE (diff.)	CD (p=0.05)
PxDxS	0.06	1.22	0.97	1.9

Table 2. Effect of distance of crop from tree row on yield of soybean (q/ha)

Crop distance	Yield q ha^{-1}	
	Grain	Straw
D1 (1m)	18.79	28.10
D2 (2m)	21.90	35.66
D3 (3m)	24.06	38.50
SE (diff)	1.46	2.93
CD (p=0.05)	2.99	5.96

Table 3: Effect of direction of crop from tree row on yield of soybean

Crop direction	Yield (qtl/ha)	
	Grain	Straw
S1 (North aspect)	20.06	31.60
S2 (South aspect)	21.11	36.18
SE (diff.)	1.19	2.39
CD 0.005	2.43	4.86

component in the system (Table 4). The results are in line with Nair (1984) and Kang and Juo (1986) who reported efficient cycling under tree based systems than many other systems. Kumar (1996) also reported that higher net gain of available N, P and K in soil in *Morus*- soybean than *Morus* – wheat combination due to more release of nutrients and cycling by *Morus* – soybean combination than Morus- wheat.

Effect of Pollarding Height on Biomass (leaf and branches) Production of *Grewia optiva*

Analysis of the data in Table 5 reveals that leaf biomass enhanced with the increase in pollarding height, yet the difference between P_2 and P_3 remained statistically non-significant. There was a gain of 67.66 % from P_1 to P_2 and P_3 to P_2.

The overall results shows that Leaf and branch biomass were influenced significantly due to pollarding height. The data for branch wood biomass (Table 5) shows that P_2 (pollarding at 3m*)* recorded the maximum biomass followed by P_3 and P_1(pollarding at 4.5 and 1.5m respectively) . It is increased by 32.41 per cent from P_1 to P_2 and declined by 11.93 per cent with increase in pollarding height from P_2 to P_3.

From the present studies, it can be concluded that that the yield of both wheat and soybean responded negatively to increasing pollarding heights from 1.5m to 4.5m and positively to increasing distance of crop from tree rows (1m to 3m). Besides both the crops performed better on southern aspects as compared to the northern. Leaf and branch biomass were influenced significantly due to pollarding height and were found to be recorded maximum at P_2 followed by P_3, however P_2 and P_3 were at par. This shows that pollarding at 3m is relatively better height for pollarding to form more sprouts and their growth.

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Table 4: Amount of available N, P and K in soil before sowing and after harvest as well as their gain/depletion of associated crops viz., wheat and soybean

Events	Wheat			Soybean		
	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
Before sowing of crop	387.1	30.96	304.2	377.4	27.06	299.5
After harvest of crop	377.4	27.06	299.5	388.9	31.04	310.1
Gain (-) / Depletion (+)	-	-	-	+	+	+

Table 5. Effect of pollarding height on leaf and branchwood biomass production of *Grewia optiva*

Pollarding height	Leaf biomass (kg per tree)	Branchwood biomass (kg per tree)	Total biomass (kg per tree)
P_1	3.37	13.42	16.78
P_2	5.73	17.77	23.50
P_3	5.65	15.65	21.30
SE (diff.)	0.56	1.78	2.06
CD (p=0.05	1.25	3.96	5.03

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Tree Growth, Organic Carbon and Nutrient Content of Soil under Various Multipurpose Tree Species

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Abstract: The effect of pure stands of seven tree species was studied on soil organic carbon (OC) and macronutrient (N, P and K) content of soil in Punjab. Tree plantations of 13-year-old *Eucalyptus tereticornis* (eucalyptus), *Azadirachta indica* (neem), *Melia azedarach* (dek), *Dalbergia sissoo* (shisham), *Albizia lebbeck* (siris), *Leucaena leucocephala* (subabul) and *Acacia nilotica* (kikar) spaced at 6 x 3 m and adjoining open (control) area were selected for this study. Depthwise (0-15, 15-30, 30-45 and 45-60 cm) soil samples were taken randomly from each plantation as well as control and analysed for soil OC and available macronutrients (N, P and K). After 13 years of growth, eucalyptus, subabul and siris recorded higher diameter at breast height and height than the other tree species. The effects of litterfall addition were significantly higher in the surface layer (0-15 cm) than the lower soil depths. The soil OC and nutrient content decreased with increase in depth irrespective of the tree species. In the surface soil depth, the OC increased by 90.4% under siris followed by kikar (84.6%), shisham (82.2%) and subabul (80.9%) over control (8.53 Mg/ha). The OC content in the 0-60 cm soil profile under the tree species varied from 30.0 Mg/ha under eucalyptus to 39.2 Mg/ha under kikar. The available nitrogen was higher under leguminous tree species subabul, siris, shisham and kikar (N: 167.6, 162.2, 158.6 and 155.9 kg/ha, respectively in surface layer) than the other tree species and control (120.1 kg/ha).

***Key Words*:** Available nutrients, Growth parameters, Organic carbon, Soil depths

There is a major role of trees in meeting the basic needs of the people and maintaining the ecological balance. Because of increasing demand of timber for wood based industries and dwindling supplies from forest areas, the poor quality sites are required to be brought under tree cover. Trees have the capacity to grow under stressful environment conditions where crops cannot be grown successfully. There lies a lot of opportunities to increase productive potential of poor quality lands by planting trees, which will help to sequester carbon in the woody biomass in addition to increasing the soil organic carbon status and amelioration of sites. Therefore, the afforestation programmes should bring more and more wastelands, degraded lands and other unusable lands under tree plantations.

Trees offer a significant potential to sequester substantial quantities of atmospheric carbon, thus, forming an important option for mitigating change in climate. Deforestation is thought to be a source of 1.6 Pg C yr^{-1} but the land not undergoing deforestation has large mitigation opportunity to stabilize greenhouse gases in the atmosphere (2 to 4 Pg C yr^{-1}) (Scholes and Noble, 2001). Carbon is stored in the foliage, stem, root system and soil under the trees.Forest soil is one of the main sinks of carbon on earth. In India, the maximum soil organic carbon under different forest species in 30 cm soil depth has been estimated in Arunachal Pradesh (1702.08 million tonnes), whereas, Punjab ranks on the lower side (9.42 million tonnes) (Jha *et al*., 2003). The planting of trees on poor quality sites (highly alkaline) have lead to production of wood and their amelioration through the build of organic matter and the recycling of nutrients (Gill *et al*., 1987; Singh *et al*., 1997). The effects of organic matter accumulation are higher on surface than subsurface horizons. The quantity and quality of litter produced by trees depend on the species, age of trees and spacing (Mohsin *et al*., 1996; Singh and Sharma, 2007). Rate of decomposition of litter is directly related to the soil moisture availability, soil micro-organisms and physico-chemical properties.

Generally higher soil organic carbon and nutrient content under the trees have been observed than the adjacent open sites in different states of the country under different tree species such as *Acacia auriculiformis, Eucalyptus tereticornis, Casuarina equisetifolia, Leucaena leucocephala, Acacia nilotica, Bauhinia variegata, Albizia lebbeck, Acacia catechu* and *Dalbergia sissoo* (Gupta *et al.,* 1991; Mathew *et al*., 1997; Kumar *et al*., 1998). However, such studies are lacking in Punjab. The present study was therefore conducted to study the effect of pure stands of different tree species on sequestration of carbon and nutrient content in soils of Punjab.

MATERIAL AND METHODS

The study was carried out at Regional Station (RS) of Punjab Agricultural University (PAU) at Bathinda, located in the Indo-Gangetic alluvial plains in the south-western region of Punjab at 30° 14" N latitude and 74° 57" E longitude. The climate of site is mainly characterized by a very hot summer, a short rainy season and a very cold winter; it is arid with high variation between summer and winter temperatures. Summer season starts in March and continues till June, the summer temperature can be as high as 47°C. Winter season starts from November and extends till February and winter temperature is as low as 0°C. The weather is generally dry, but is humid from mid-May to the end of August. Rainfall is primarily from the south-west monsoons and is concentrated in the period July to mid-September. The average rainfall in the area is about 410 mm.

Tree plantations of 13 years old *Eucalyptus tereticornis* (eucalyptus), *Azadirachta indica* (neem), *Melia azedarach* (dek), *Dalbergia sissoo* (shisham), *Albizia lebbeck* (siris), *Leucaena leucocephala* (subabul) and *Acacia nilotica* (kikar) spaced at 6 x 3 m were investigated. The adjoining open area without trees was taken as control site for comparison of properties. These species were planted during July 1995 in monsoon season and gap filling was done during July 1996 in almost all the species. The plants were irrigated during summers of first year and second year and thereafter no irrigation or other management practices were applied to the plantation. Growth parameters (tree height and DBH) of twenty five trees of each species were measured in the month of August 2008.

Depthwise (0-15, 0-60 cm) soil samples were taken randomly from six points in each replications in each tree species as well as from control. The samples were air dried and ground to pass through a 2 mm sieve. The samples were analysed for soil organic carbon OC and available macronutrients (N, P and K)by following standard methods. The data of different species were subjected to statistical analysis using ANOVA technique in split plot design (SPD) by taking tree species (including control) in main plots and soil depths in sub plots. Mean separation was done with the least significant difference test at 5% level of significance.

RESULTS AND DISCUSSION

The growth parameters of trees recorded after 13 years of planting varied considerably (Table 1). Among the seven tree species, DBH (cm) was heighest in eucalyptus (26.05) followed by siris (25.03) and subabul (21.91). Shisham and kikar attained the lowest DBH growth (18.63 and 20.12, respectively). Similarly, eucalyptus attained the heighest (23.6m) height followed by subabul (15.0m) and siris (14.7m) after 13 years of planting. Among the different tree species, the species ranking was eucalyptus>siris> subabul>neem>dek>kikar>shisham for DBH and eucalyptus>subabul>siris>kikar>neem> shisham>dek for height. The variation in growth characteristics of the tree species might be due to different genetic makeup and thus their variable growth potential as the environmental conditions were similar for all the species in the study.

Table 1. Growth parameters of tree species after 13 years.

Tree species	DBH (cm)	Height (m)
Eucalyptus tereticornis	26.05±5.6	23.6±2.8
Azadirachta indica	21.21±4.8	11.3±1.1
Melia azedarach	20.96±3.9	10.0±1.5
Dalbergia sissoo	18.63±3.4	10.8±1.3
Albizia lebbeck	25.03±7.7	14.7±1.5
Leucaena leucocephala	21.91±3.8	15.0±0.9
Acacia nilotica	20.12±3.8	12.4±1.6

The soil organic carbon (OC) content decreased with increase in depth irrespective of the tree species. The effects of litterfall addition were highly pronounced in the surface layer (0-15 cm). In the surface soil depth, the highest increase in OC status was under siris followed by kikar, shisham and subabul over control (8.53 Mg ha^{-1}), whereas under eucalyptus, the increase over control was the lowest (Table 2). The total sequestration of organic carbon in the 0-60 cm soil profile under the tree species varied from 30.0 Mg ha^{-1} (33.7% in surface layer) under eucalyptus to 39.2 Mg ha^{-1} (40.2% in surface layer) under kikar and this content was significantly higher than OC in control treatment (27.1 Mg ha^{-1}) (Table 2). In a span of 13 years, the carbon sequestration in 0-60 cm profile by trees varied from 2.9 Mg ha^{-1} under eucalyptus to 12.2 Mg ha^{-1} in kikar over the control.

Available N content under tree species was higher than the nearby site without trees (control) in all the soil depths. Amongst the various tree species, the N content was the highest under subabul followed by siris and the lowest content was present in eucalyptus followed by control in surface soil depth. The N content in 0-60 cm soil profile was higher by 56.4 per cent under subabul, 55.8 per cent in siris and 53.9 per cent in shisham over control (310 kg/ha) (Table 2). The increase was the lowest under eucalyptus (22.6%). As a whole, the N content was higher under the leguminous tree species (subabul, siris, shisham and kikar) than other species when compared to control. Among the tree species the available P content was higher by 60.1 per cent under siris followed by 57.0 per cent under kikar and the lowest increase was observed under eucalyptus (23.9%) over control (20.0 kg/ha) in the surface soil depth. The P content in 0-60 cm soil depth revealed significantly higher values under kikar, subabul, shisham and siris (99.3, 95.7, 92.3 and 89.8 kg ha^{-1}, respectively) as compared to other tree species and control (Table 2). The available K

Table 2. Soil OC and nutrients (0-15 and 0-60 cm soil depths) under different tree species after 13 years of plantation

Tree species	Organic carbon ($Mg\ ha^{-1}$)		Available nutrients ($kg\ ha^{-1}$)					
			N		P		K	
	0-15	0-60	0-15	0-60	0-15	0-60	0-15	0-60
Eucalyptus tereticornis	10.10	30.0	124	380	24.8	79.2	543	1869
Azadiracta indica	11.72	33.6	133	392	27.2	80.6	572	1915
Melia azedarach	12.81	33.4	140	406	25.1	78.8	566	1915
Dalbergia sissoo	15.54	38.9	159	477	29.5	92.3	588	1950
Albizia lebbeck	16.24	39.1	162	483	32.0	89.8	593	1959
Leucaena leucocephala	15.43	38.5	168	485	29.7	95.7	599	1967
Acacia nilotica	15.74	39.2	156	456	31.4	99.3	585	1945
Control	8.53	27.1	102	310	20.0	68.6	505	1796
CD (P=0.05)	2.01	2.48	13.3	29.3	3.72	6.66	26.8	50.2

content was very high in control as well as under different tree species than other nutrients; however, the available K content under trees was significantly higher than control. In the surface soil depth, the available K content was the highest under subabul and siris and the lowest content was under eucalypt. But this was significantly higher than control. Similarly, the increase in K content in all the soil depths (0-60 cm) varied by 4.06 (eucalyptus) to 9.52 per cent (subabul) over control (1796 kg ha^{-1}).

Soil under trees is a major store house of organic carbon in comparison to other land use systems because of continuous addition of litterfall by trees.The higher build-up of organic carbon on surface layers of soils under the various tree species may be attributed to the regular accumulation of litterfall of tree species on soil surface and fine roots turnover throughout the increasing age of trees. The subsequent decomposition of litterfall and its incorporation into the soil with time might have helped in raising the organic matter status of soil. Differential behaviour of the tree species in raising organic carbon content may be ascribed to the addition of variable amount of litterfall and fine roots and varying rates of decomposition of organic matter added through these tree species. Higher build up in organic carbon status under kikar, siris, shisham and subabul may be due to the deciduous nature of these species which shed whole of its leaves in winter season whereas eucalyptus is an evergreen tree species. In addition to that, eucalyptus has thick and leathery leaves and high polyphenol content, thus, its incorporation into the soil may not be as quick as of above leguminous tree species. Higher build-up of available nutrients (N, P and K) on surface layers under tree species is attributed to accumulation and decomposition of litterfall on the soil surface as well as its incorporation in the soil surface layers. It leads to mineralization of organic N and P from the litter and its release into the soil. Higher availability of K at surface layers under trees is attributed to liberation of K by decomposition process of litterfall as well as solubilization of insoluble forms of K present in soil due to organic decomposition products. Contractor and Badanur (1996); Mathew *et al.* (1997) and Kumar *et al.* (1998) observed that availability of N, P and K was higher on surface layers than subsurface horizons under different tree species and it decreased gradually with depth. Ohta (1990) observed an enhanced capacity of inorganic N and P supply even in young tree plantations in spite of the decrease of the total N content compared with the grassland soil in 0-5 and 5-10 cm soil layers. This was associated with the addition of fresh organic matter rich in readily mineralizable N, which leads to the increased activity of soil fauna at the same time. The differences in available nutrient content under different tree species might be due to variation in nutrient concentration of litter, total litter production and varying rates of mineralization in these species. The leguminous species at this site (shisham, siris, subabul and kikar) had higher N content in the soil under these tree species as compared to non-leguminous (eucalyptus, dek) tree species. The P and K content under these species was also higher than the other. Their leaves decompose at a faster rate than eucalypt and have higher N content than eucalypt. Gill *et al.* (1987) and Patel and Singh (2000) reported lower N content under eucalyptus as compared to other species.

The poor quality sites can be used for wood production by planting trees because the demand of wood and wood products is increasing and their supplies are decreasing. In addition, trees ameliorate these sites and mitigate the climate change through sequestration of carbon in the soil-biomass system. The addition of litterfall and roots of the tree species improve the soil organic carbon and nutrient status, thus improving the site properties which can be utilized further for production of crops after harvesting of trees.

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Terminalia arjuna – A Fast Growing Forest Species and a Source of Livelihood to Vana Samrakshana Samithi Members

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Abstract: Studies confirm that out of 10 forest flora raised under Telugu Ganga compensatory afforestation scheme in Nellore district of Andhra Pradesh, *Pterocarpus santalinus*, *Emblica officinalis,* and *Terminalia arjuna* attained the maximum plant height (m) as 8.21, 7.54 and 6.75 after six years of plantation, respectively. *T. arjuna* topped the list of species studied in attaining girth at breast height (GBH) (35 cm). One hectare economic block plantation of arjuna raised at the expense of Rs. 17,575/- can be exploited for 450 dfls rearing of tasar silkworm after 4 years of gestation period. Silkworm rearing is an eco-friendly activity that consumes 11.25 MT leaf biomass out of total production 14.50MT/ha and ejects 5.63 MT of litter, which replenishes nutrients and improve edaphic conditions of soil. Under Telugu Ganga afforestation programme the forest department has raised different species of forest plantation to the extent of 6930 ha and T. arjuna was predominant as monoculture and mixed plantation. The plantations are maintained by 100 Vana Samrakshana Samithis (VSS). Trial rearing of tasar silkworm *A. mylitta* D. on *T. arjuna* plantations revealed that 12800 to 14500 cocoons are produced/ha/season and the income per Vana Samrakshana Samithi member ranges between Rs 2500 to Rs 3000/- in a period of one month. On site training and technology dissemination with sound extension backup will double the income of VSS members through tasar culture.

Key Words: *Terminalia arjuna*, *T. tomentosa*, Tasar silkworm, VSS, Technology, GBH

The government of Andhra Pradesh and Tamilnadu jointly constructed one irrigation project called Telugu Ganga Irrigation Project with a view to provide 15 TMC of drinking water to Chennai city besides irrigating about 5.75 lakhs ha in drought effected districts of Rayalaseema. During the course of construction of reservoirs and canals about 3921.40 ha reserve forest area in Nellore district is diverted and government has transferred 9758 ha of non-forest area for compensatory afforestation. During the period from 1990-95 the forest department has planted around 49 tree species which included some of the primary and secondary tasar food plants such as *Terminalia arjuna, T. elata, T. bellerica, Syzygium cuminii,* etc. to the extent of 6930 ha. In most of the plantations, species are planted in intimate mixtures. During 2005-06, Regional Tasar Research Station (RTRS), Warangal with a view to provide additional income to VSS members conducted studies on tasar rearing on trial basis.

Indian Tasar silk industry has two major components viz., tropical and temperature tasar. Tasar culture activities as whole is grouped into sectors – pre and post cocoon sectors. The precocoon sector mainly involves the tasar silk worm rearing on foliage of *T. arjuna* (arjun), *T. tomentosa* (asan) and *Shorea robusta* (sal) to produce cocoons. Culturing of Tasar silkworm commercial races, Daba and Sukinda, is mainly done by 1.28 lakh tribal families all over India. More than 0.03 lakh families are benefited with average net income of Rs. 2,950/- and gainful employment of 30 man days (per season) in Andhra Pradesh (Yadav *et al*., 1998). During 2006-07, Andhra Pradesh stood fifth among traditional states in tasar raw silk production by recording 15.50 MT against total country production 350 MT.

The plantations of tasar host flora, arjun and asan are mainly raised through seeds and to a limited extent through vegetative propagation i.e. air layering, cuttings, saplings etc. Natural regeneration of this flora is difficult as bark and seed of this species are being utilized as medicines. Further due to hard pericarp, germination is slow (25-35%) and erratic in case of asan and arjun under natural conditions. Artificial regeneration are carried out through standardized nursery techniques, which can improve the quick and uniform germination to the tune of 80-90 per cent (Sinha *et al*., 2007).

Basically Tasar silkworm rearing has been practiced in natural forest areas dating back to decades. But due to tremendous pressure on land and shrinking of forest area, the green wealth of arjun and asan is vanished gradually near the dwellings of arboringalls. Even tasar silk growers hardly found any forest patch with enough plant density for profitable tasar silkworm rearing. Further they face many hardships in rearing on forest patches with scanty and unmanageable heights of tasar host flora. It is on this back drop the concept of raising economic plantation has come into picture. Raising of block plantation with asan and arjun is carried through nurseries. The present study was conducted to study the rate of success of seed germination and establishment of species and the relative growth leaf and branches biomass production of *Terminalia* spp. in Warangal and Nellore districts.

MATERIAL AND METHODS

The experiments were conducted at nursery of Regional Tasar Research Station, Warangal in Andhra Pradesh. The climate is semi arid and monosoonic. The mean maximum and minimum daily temperature of the study month (June-July, 2006) were 33.5° and 23.5° C respectively. The average rainfall was recorded 900mm during the investigation. Arjun and asan seeds were collected from four districts during April month. 50 bigger size trees of each species were selected from each district. Seed parameters namely seed weight, length, diameter, wing width, germination, period for germination and survival were recorded. The seed samples of each species collected location wise were stored at the onset of monsoon (June-July). The seed samples of arjun and asan soaked in water for duration of 96 and 48 hrs, respectively and after soaking, the seeds were heaped sample wise under tree shade. The heaps were covered with wet gunny cloth and watered till germination. The germinated seeds were sorted out daily and sown individually at a depth of 3-4 cm in polybags of 25 cm x 11 cm filled with rooting media (FYM:Soil:Sand 3:2:1). Watering was carried out regularly once in a day. Observations on seedling survival (%) were recorded 120 days after germination.

One hundred trees of each species were taken for recording observations on plant height (m), crown diameter (cm), collar diameter (cm), diameter at breast height – DBH (cm), per cent survival at the age of 5th, 6th and 7th year of transplantation. After 7 years planting in 4x4' and 6'x6' plots, 10 trees of each species were harvested for total biomass production consisting of dry yield of branches and foliage. Foliage and branches biomass (kg/tree) harvested was converted into per hectare production.

RESULTS AND DISCUSSION

Observation on seed morphology of arjun and asan were presented in Table 1. Seeds of arjuna were 2.75-4.89 cm long with 5-8 narrow wings, which were 0.55-1.32 cm broad. Seed weight was 2.05-3.27 gm. Asan seed length, wing width and weight was measured as 3.60-6.63cm, 1.25-1.95cm and 1.75-2.40 gms, respectively. Seed germination initiated on 12th day of soaking and lasted for 30.00 days with mean period of 17.00 days.

The overall germination per cent in arjun seeds varied from 39.36-85.60 per cent with an average of 67.66 per cent (Table 1). Maximum arjun seed germination (85.60%) and seedling survival (89.90%) were recorded from seed sample weighed for 3.27 gms. Almost similar trends were also observed in asan. In case of asan, the germination per cent was comparatively low 30.75-60.75 per cent with an average of 43.51 per cent. Asan seedling survivability too recorded very low 24.50-76.30 per cent with mean of 47.53 per cent.

The data on growth indices viz. plant height, DBH, collar and crown (canopy) diameter of asan and arjun recorded on 5th, 6th and 7th year of establishment are given in Table 2. A maximum plant height was recorded in arjun (4.08m) followed by asan (3.62m) at the age of 7th year. An steep

Table 1. Details of seed parameters of *Terminalia* spp. collected from different locations

Tree species	Location (District)	Seed weight (gm)	Seed length (cm)	Seed diameter (cm)	Wing width (cm)	Seed germination (%)	Period for germination (days)	Survival (%)
Terminalia arjuna (arjun)	Chinnoor (Adilabad distt.)	2.05	4.00	6.38	0.65	76.92	27.50	78.90
	Mahadevpur (Karimnagar dist.)	3.27	4.89	7.41	1.32	85.60	12.00	89.90
	Jakaram (Warangal dist.)	2.15	2.76	6.48	0.59	39.36	30.00	47.00
	Rapur (Nellore dist)	2.91	4.10	6.85	0.55	68.75	14.00	90.00
Mean		2.56	3.94	6.78	0.78	67.66	20.87	76.50
Terminalia tomentosa (asan)	Chinnoor (Adilabad dist.)	1.95	6.63	7.17	1.36	60.75	13.00	76.30
	Mahadevpur (Karimnagar dist)	2.35	3.60	9.18	1.95	42.35	15.00	58.99
	Jakaram (Warangal dist)	1.75	4.75	10.60	1.25	30.75	19.00	30.15
	Rapur (Nellore Dist.)	2.40	6.10	8.15	1.63	40-00	21.00	24.50
Mean		2.08	5.27	8.18	1.55	43.51	17.00	47.53

Table 2. Relative growth performance of *Terminalia* spp. in Warangal district

Growth parameter	Arjun			Asan		
	Fifth year	Sixth year	Seventh year	Fifth year	Sixth year	Seventh year
Plant height (cm)	290 (121-383)	325.19 (177-400)	408.95 (219-516)	264.38 (90-327)	308.00 (191-386)	362.66 (133-433)
DBH (cm)	4.00 (2.31-5.90)	5.59 (3.00-7.70)	7.96 (2.80-13.00)	5.73 (4.80-7.00)	6.85 (6.00-9.85)	8.10 (6.75-9.50)
Collar diameter(cm)	09.38 (8.10-10.65)	8.43 (7.60-9.10)	9.44 (5.66-9.83)	09.22 (7.80-10.30)	8.76 (4.51-12.00)	11.43 (5.81-12.00)
Crown diameter(cm)	49.36 (20.00-90.70)	63.22 (33.70-101.00)	79.57 (66.15-112.10)	53.00 (22.17-87.00)	57.86 (38.16-79.66)	67.46 (49.29-101.76)
Survival (%)	93.45	89.00	87.73	67.77	65.75	65.77

* Figures in parenthesis indicate range

rise in plant height was observed in arjuna plantation. Collar diameter was recorded as in case of asan (11.43 cm) and arjun 9.44 cm at 7 years age of plantation. Canopy (crown) spread was maximum in case of arjun (79.57 cm) with a range of 66.15-112.00 cm. Natural tendency of arjun caused more canopy spread than asan. Diameter at breast height (DBH) is not much varied among species studied.

Survival percentage recorded at 7 years age of plantation was substantially high (87.73%) in arjun and than in asan (65.77%). Similar observation of survival percentage were recorded in plantations of 5th and 6th years age. Poor survival of asan was mainly due to inherent genetical characters and abiotic stress.

Data on biomass production (leaf and branches) presented in Table 3 revealed that the total biomass production was obtained more in arjun and asan plantation at 4x4' spacing, when compared to 6x6' plantation. This may be due to availability of more no. of plants in one ha at 4x4' spacing. Hence raising of block plantation at 4x4' is more economical in terms of leaf production for tasar silkworm rearing. Wider spacing was found uneconomical as leaf yield per unit area is greatly reduced due to accommodation of less no. of plants. However, asan at 6x6' spacing reported ideal for economic plantation. Ojha and Pandey (2004) observed that arjun and asan foliage is highly palatable feed to tasar silkworm races. It is estimated that 39-61 per cent of biomass intake is ejected as litter by Daba and Sukinda tasar eco-races, the highest of 61 per cent in case of arjun and lowest of 39 per cent in sal. 300 dfls of tasar silkworm rearing would consume 11.25 MT of leaf biomass, eject 5.63 MT of litter and in turn produce 15,000 cocoons weighing 240 kgs.

Arjuna plantation in 138 ha can effectively be utilized for 62,100 dfls of tasar silkworm rearing with anticipated cocoon production of 24.850 lakhs in one season in Nellore district. The total tasar raw silk production can be anticipated around 2.55 MT per season. It is advised to take every alternate crop in a hectare providing gap for regeneration of leaf.

Participatory Training Through Trial Tasar Rearing

Regional Tasar Research Station, Warangal had conducted trial rearing with 2650 dfls by involving 16 VSS members as stake holders. Besides forest officials were also made well versed with recent techniques of tasar silk worm rearing during 2005-06, 2006-07 and 2007-08 in Nellore district (Table 4). Integrated package of rearing technology (IPR) evolved by CTR&TI, Ranchi had been disseminated in field i.e., spray of 1.5 per cent urea solution of foliage for quality leaf improvement, spray of sodium hypochlorite (0.01%) on worms to prevent spread of disease and spray of leaf surface microbe solution for viral and bacterial disease of silkworm.

Tasar cocoon yield per 100 dfl rearing was recorded in the range of 2650-4267 with an average of 3030. Each member fetched net income of Rs 3350-00 with range of Rs 2550/- to Rs. 4389/-. The B:C ratio has been arrived at 7.50 to 8.75 net income was estimated higher (Rs 4389/-)

Table 3. Details of biomass production/ha in arjun and asan plantations (7th year)

Biomass	Arjun				Asan			
	4x4'		6x6'		4x4'		6x6'	
	Kg/tree	MT ha^{-1}	Kg/tree	MT ha^{-1}	Kg/tree	MT ha^{-1}	Kg/tree	MT ha^{-1}
Leaf	2.80	19.00	3.00	9.15	2.40	16.75	3.56	10.75
Branches	5.75	38.66	9.00	27.22	7.50	49.75	11.75	35.55
Total	8.55	57.60	12.00	36.30	9.90	66.50	15.32	46.30

Table 4. Tasar silkworm rearing and economical performance in Nellore district, AP

Year	VSS members covered	Dfl(s) reared (Nos.)	Effective rate of rearing	Cocoons harvested (Nos.)	Cocoon yield/100 dfl	Total (Rs.) gross income	Income per 100 dfls (Rs.)
2005-06	03	300	46.00	12,80	4267	9890	3000
2006-07	03	350	51.00	14,50	4145	10150	2850
2007-08	10	2000	39.75	53,00	2650	48790	4389
Total	16	2650	—	80,30	3030	68830	3350

even though the cocoon yield recorded lower. The reason may be due to higher prices offered by bidders for quality of cocoons. Silkworm rearing with IPR technology may improve cocoon yield up to 10-15 dfl over the yield of traditional rearing, which in turn fetches more income of Rs 2,300/- per season. Employment generated was 52 man days in case of 200 dfl rearing from one ha area. An investment of about Rs 200/- can bring a return of about Rs. 1750/- with in 35 days of silkworm rearing in natural forest (Anonymous, 2005), whereas, silkworm rearing with 450 dfls in economic block plantation can fetch Rs 12,425/- to Rs. 14,950/- per ha.

It is on this back drop, the tasar silk rearing can be undertaken since it proved profitable and source of gainful employment in Nellore district.

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Screening and Selection of VAM Fungi for Fast Growing Fuel Wood Trees

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Abstract: The consumption of fuel wood is very high in India, but the production of fuel wood has not been able to keep pace with requirements, the prices of fuel wood during last 40 years have shown an abnormally high increase. Because of the escalating prices of petroleum products and the rising demands, a stage has reached where fuel woods can be economically farmed with inputs of selected species and varieties of plants and biofertilizers. Programmes of reclamation of wastelands are in progress but success is low due to various reasons. Vesicular arbuscular mycorrhizae enable the plants to grow and survive better under stress conditions. Selection of efficient VAM fungi can help in enhancing the 'P' supply as well as other micronutrients. A pot experiment was designed to screen and select the suitable VAM inoculants for fuel wood trees i.e., *Acacia arabica, Cassia fistula* and *Leucaena leucocephala* for which seedlings were raised in sterilized soil inoculated with 11 different VAM fungi belonging to *Acaulospora, Glomus* and *Sclerocystis*. After 150 days of growth three consecutive best inoculants were selected for each plant on the basis of their better effect on plant height, dry biomass and root colonization as compared to control.

Key Words: Fuel wood, VAM fungi, Biofertilizers, Wasteland, Reclamation, Dry biomass

Approximately 2.4 billion people currently use wood and other forms of biomass for cooking and heating. The demand for fuel wood is leading to deforestation, which will speed up global warming. Although this crisis seems to be uncontrollable but there are number of ways to control and stop fuel crisis. One of the methods is to make more fuel wood available by planting fast growing fuel wood trees. Tree species with high coppicing ability are very useful as they keep producing new wood every time they are cut. If planned carefully and wisely plantation of trees in waste lands provide a variety of products that may be used by farmers or sold (Nandeshwar *et al.,* 2006). The initial step for reclamation of waste lands is to identify the suitable plant species, which can grow on such land (Das *et al.*, 2007). The reclamation of waste land faces problems as microbial deficiency creates problems in establishments of the plants. The use of biofertilizers for reclamation leads to achieve the fertility of barren dumps in very short time (Dubey *et al.,* 2006). VAM fungi benefits growth of plants specifically for the nutrient supply for the roots of the colonizing plants (Marschner and Dell, 1994; Smith and Read, 1997). VAM are much more wide spread and can form association with most herbaceous and many woody species (Neeraj, 1982). Mycorrhizal strains and host species interact to determine the amount of infection and the level of colonization. Strains giving good growth responses with one plant species are generally effective with others but differ in potentiality and tolerance to stresses. Therefore, inoculation with a suitable VAM fungal strain to improve the growth and survival of seedlings in aforestation programmes is very essential (Reena and Bagyaraj, 1990; Jamalluddin *et al.*, 2001). The role of VAM fungi in improving the quality and survival of plant seedlings after plantation has been well recognized (Kaushik *et al.,* 1992; Khan and Uniyal, 1999). Bearing all this in mind, the present study was undertaken to determine the effect of VAM fungi on the growth performance of three multipurpose fast growing fuel woods trees, *Acacia catechu, Cassia fistula* and *Leucaena leucocephala*.

MATERIAL AND METHODS

A pot experiment was done under sterilized soil condition to evaluate the effect of VAM fungi, which was pure cultured and mass multiplied in lab for screening its effect on fast growing fuel wood trees i.e., *Acacia catechu, Cassia fistula* and *Leucaena leucocephala* in nursery conditions. Polybags of 2kg capacity were used for the study and filled with sterilized black cotton soil : compost: sand mix (8:1:1) autoclaved at 15 lbs, 121^0C, 3 h. Each VAM inoculants (175–200 spores $100gm^{-1}$ soil) were added by placing it just 3 cm below the seed sowing level. The uninoculated control set was also treated in the same way without any inoculums. The mature and dried seeds of similar weight of the three host species were surface sterilized with $HgCl_2$ (0.01%) and 5 seeds/pot were sown in each of 10 replicates. After germination, single seedlings were maintained for better performance. Plants at the age of 150 days of growth were harvested and observations were recorded for shoot height, dry biomass, VAM infection, per cent root colonization and spore count. Simple biological norms were considered for studying the Plant height. Dry weight of plant samples was determined after drying it at 60^{0}C up to the level of constancy. VAM infection was assessed by Root Clearing & Staining Technique (Phillips and Hayman, 1970) and per cent root colonization was determined by Kormanik and Mc Graw Side Method (1982). VAM spores were isolated by 'Wet Sieving and Decantation Technique" (Gerdermann and Nicholas, 1963) and estimation was done by method of Gaur and Adholeya (1994). Data observed were and analysed statistically.

To determine the effect of these inoculants as isolated from respective trees following inoculants were used for three hosts:

1. ***Acacia catechu*** - *Acaulospora dilatata, Acaulospora laevis, Glomus aggregatum, Glomus fassiculatum and Sclerocystis microcarpus.*
2. **Cassia fistula** – *Glomus macrocarpus, Glomus mosseae, Acaulospora laevis, Acaulospora longula and Glomus hoi.*
3. ***Leucaena leucocephala***- *Glomus macrocarpus, Glomus mosseae, Glomus geosporum and Sclerocystis sinuosa*

RESULTS AND DISCUSSION

Three genera of VAM fungi, i.e. *Acaulospora, Glomus & Sclerocystis* isolated and purified from the rhizosphere of *Acacia catechu, Cassia fistula and Leucaena leucocephala* were screened for growth parameters in the respective host plants.

The success of VAM inoculation was exhibited by the presence of vesicular-arbuscular structures within the root system in all the host plants experimented, though a visible difference was found in their root colonization pattern. Increase in VAM spore numbers was found in accordance to percent root colonization in all the three host plants as shown in Table 1, 2 and 3. The results of the response of *A. catechu* inoculated with 5 different VAM fungi is shown in Table 1. It is evident from the table that the *Glomus aggregatum* showed a maximum significant increase in height (74.00 ± 4.16) as compared to uninoculated control, Dry biomass of shoot was enhanced maximally over control when inoculated with *G. aggregatum* (15.19±1.62) followed by *A. laevis* and *G. fassiculatum,* respectively. The effect of VAM inoculantion after 150 days on *C. fistula* is shown in Table 2. *A. laevis* showed a maximum significant increase in height (57.00±2.64) and shoot dry mass (19.33±1.50) as compared to the other VAM fungi and uninoculated control, *G. macrocarpum* and *G. hoi* also showed increase in plant

Table 1. Effect of VAM fungi on per cent root colonization, spore count, growth and biomass in *Acacia catechu*

S.No.	VAM fungi	% Root colonization	Spore count per 100g soil	Shoot height (cm)	Dry shoot biomass (gm)
1	Uninoculated control	00	00	53.50 ± 4.18[b]	11.66 ± 0.43[b]
2	*Acaulospora dilatata*	74	121	63.10± 3.46[ab]	13.11 ± 1.62[ab]
3	*Acaulospora laevis*	84	167	68.20± 1.48[ab]	14.48 ± 0.43[ab]
4	*Glomus aggregatum,*	93	185	74.00± 4.16[a]	15.19 ±1.62[a]
5	*Glomus fassiculatum*	80	172	65.40± 2.02[ab]	13.54 ± 1.01[ab]
6	*Sclerocystis microcorpus*	62	97	59.70± 2.14[b]	12.71 ± 0.64[b]

(Values without common letters differs significantly at P= 0.01, Duncan;s Multiple Range Test)

Table 2. Effect of VAM fungi on per cent root colonization, spore count, growth and biomass in *Cassia fistula*

S.No.	VAM fungi	% Root colonization	Spore count per 100g soil	Shoot height (cm)	Dry shoot biomass (gm)
1	Uninoculated control	00	00	39.33 ± 1.31[c]	10.66 ± 1.15[c]
2	*Acaulospora laevis*	97	154	57.00± 2.64[a]	19.33 ± 1.52[a]
3	*Acaulospora longula*	69	109	46.19±1.82[abc]	13.12 ± 1.00[abc]
4	*Glomus macrocarpum*	81	182	53.48± 1.15[ab]	15.33 ±3.51[ab]
5	*Glomus mosseae*	67	87	47.36±0.67[abc]	14.00 ± 3.46[abc]
6	*Glomus hoi*	73	106	51.33± 1.73[bc]	16.33 ± 3.78[bc]

(Values without common letters differs significantly at P= 0.01, Duncan;s Multiple Range Test)

Table 3: Effect of VAM fungi on per cent root colonization, spore count, growth and biomass in *Leucaena leucocephala*

S.No.	VAM Fungi	% Root colonization	Spore Count per 100g soil	Shoot height (cm)	Dry shoot biomass (gm)
1	Uninoculated control	00	00	46.70 ± 3.12[b]	13.70 ± 2.03[b]
2	*Glomus geosporum*	58	91	52.10± 4.18[b]	15.73 ± 0.02[b]
3	*Glomus macrocarpum*	98	187	60.30± 4.16[b]	17.85 ± 0.53[a]
4	*Glomus mosseae*	63	116	54.50± 1.48[ab]	16.37 ±0.20[ab]
5	*Sclerocystis sinuosa*	72	132	55.40± 3.46[ab]	17.61 ± 3.46[ab]

(Values without common letters differs significantly at P= 0.01; Duncan's Multiple Range Test)

height and shoot dry biomass respectively over control. Result of 4 VAM inoculants on *L. leucocephala* are shown in Table 3. It showed a maximum signifant increase in shoot height (60.30±4.16) and shoot dry mass (17.55±0.53) as compared to control followed by *S. sinuosa* and *G. mosseae*. Present findings are also in according with earlier reports suggesting the importance of VAM fungi in producing quality seedlings positive growth effect and nutrient uptake by plants in different soils (Abdel-Hanej and Abdel-Monsief, 2006; Al Zalzaleh *et al.*, 2009). Very little is known of the competitive ability of the strains because they are hard to identify & cannot be grown in culture. At the moment, competitive strains are selected empirically on the basis of plant growth response to inoculations. If the plants responds the strain is considered competitive & is selected (Reena and Bagyaraj, 1990 and Jamaluddin *et al.*, 2006). It has also been reported in the study that the different VAM fungi increases growth of plants to different extent.

All the inoculations have a significant marked effect on the growth of *Acacia catechu, Cassia fistula* and *Leucaena leucocephala* seedlings compared to the control uninoculated in which a very small growth effect was observed. On the basis of plant height and dry biomass *G. aggregatum, A. laevis, G. macrocarpum* were selected as the best VAM fungi for the inoculation of *Acacia catechu, C. fistula* and *L. leucocephala* respectively. It is evident from results that *Glomus* strains have given better performance in all the three trees species. Since this experiment was done at nursery level, selection of three VAM inoculants would be of immense imporatance for the development of biofertilizer package for the fuel wood tree species in future.

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Enhancement of Leaf and Shoot Growth in *Dalbergia sissoo* Seedlings by Application of VAM, *Rhizobium* and Inorganic Fertilizers

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Abstract: Studies were conducted to determine the influence of inorganic and biofertilizers on seedling growth in *Dalbergia sissoo*. Significantly higher number of leaves and internodal length were achieved in dual inoculated plants as compared to single inoculation with VAM or *Rhizobium* or uninoculated control. Number of leaves and internodal length significantly increased with application of 30kg N ha^{-1}. However, higher doses of nitrogen proved detrimental to the vegetative growth. Nitrogen x phosphorus, nitrogen x biofertilizers, phosphorus x biofertilizers and nitrogen x phosphorus x biofertilizers interactions also increased number of leaves and internodal length significantly. Among all treatment combinations, maximum growth was achieved with dual inoculation (VAM+ *Rhizobium*) combined with application of 30 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1}.

Key Words: *Dalbergia sissoo*, Biofertilizers, VAM, *Rhizobium*

Dalbergia sissoo (shisham), is one of the most important commercial tree species in Indian sub-continent and known for high valued timber. Due to massive exploitation in the past decades and large scale mortality in the recent past of shisham, its supplies have dwindled to great extent. To counter the threat to its survival, intensive efforts are required to afforest large areas under this tree species. Production and supply of high quality planting stock on a sustainable basis is an essential requirement for the successful implementation of afforestation programmes. Supply of mineral nutrition to the seedlings in the nurseries has an important role for enhancing growth rate and achieving plantable size in the shortest possible time. Excessive use of inorganic fertilizers results not only in soil pollution but also soil deterioration. Biofertilizers have been reported to meet the nutrients demand of plants and play a synergistic role with inorganic fertilizers. *Rhizobium* is helpful in fixing atmospheric nitrogen and vesicular arbiscular mycorrhiza (VAM) absorbs phosphorus from the soil. This paper describes the individual and combined effect of VAM, Rhizobium and inorganic fertilizers on growth of this important species.

MATERIAL AND METHODS

The present experiment was carried out in polythene bags of 30x25 cm size. Uniform quantity of 3.25 kg of sieved soil was filled in each polythene bag. Soil of pH 7.3 of the study site was analyzed for important physico-chemical characteristics. The soil was silty loam in texture with electrical conductivity of 0.55 mmhos/cm and 0.48 per cent organic carbon. The treatments consisted of three levels of nitrogen (N_0 -No application of nitrogen; N_1- 30 kg N ha^{-1} and N_2- 60 kg N ha^{-1}), three levels of phosphorus (P_0- No application of phosphorus; P_1- 75 kg P_2O_5 ha^{-1}; P_2-150 kg and P_2O_5 ha^{-1}) and four levels of biofertilizers (B_o -No application of biofertilizers; B_1-VAM; B_2 - *Rhizobium;* B_3 - Dual application i.e. VAM +*Rhizobium*). Experiment was laid out in split plot design with three replications. Nitrogen X phosphorus levels (nine combinations) were taken as main plot treatments and four levels of biofertilizers were taken as sub- plot treatments.

Nitrogen was applied in the form of urea in three splits, first as basal dose, before filling of polybags and remaining two doses were applied after one and two months of completion of seed germination. A total of 94.5 mg and 188.9 mg urea per polybag was applied under the nitrogen level of 30 kg N ha^{-1} and 60 kg N ha^{-1}, respectively after preparing the aqueous solution by dissolving the desired quantity of urea in water. The full dose of phosphorus was applied as basal dose before filling of polybags in the form of single super phosphate. A total of 690 mg and 1380 mg single super phosphate per polybag was added for 75 kg P_2O_5 ha^{-1} and 150 kg P_2O_5 ha^{-1}, respectively.

Rhizobium culture (*Bradyrhizobium* spp cowpea) was obtained from the Department of Microbiology, Punjab Agricultural University, Ludhiana. The seeds were inoculated with *Rhizobium* culture and dried in shade for few minutes before sowing to avoid stickiness. Inoculation with vesicular arbuscular mycorrhiza (VAM) fungi was done by placing the soil based inoculum containing 60 spores/polybag of soil at 2-3 cm depth. Healthy pods of *Dalbergia sissoo* were collected from a phenotypically superior single tree. Pods were dried and broken into single seed segments. The seed segments were soaked in water for 24 hours before sowing and two seeds were sown in each polythene bag. Irrigation, weeding and hoeing were applied as and when required. The data on number of leaves per plant and intermodal length were recorded five months after sowing of seeds. Estimation of VAM spores in soil was made following the method suggested by Gaur and Adholeya (1994). The data generated from the present investigation were analyzed statistically as per the procedure suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Mean performance of plants for number of leaves and internodal length as influenced by nitrogen, phosphorus and biofertilizers application and their interactions is presented in Table 1 and 2, respectively. Perusal of data revealed significant differences among different doses of nitrogen, phosphorus and biofertilizers for number of leaves per plant and intermodal length. Among different biofertilizer levels, dual inoculation of *Rhizobium* and VAM recorded significantly higher number of leaves (80.94) per plant and intermodal length (4.33cm) as compared to VAM and *Rhizobium* alone and uninoculated control. Single inoculation of VAM and *Rhizobium* also resulted in significantly higher number of leaves and intermodal length over control (49.0). VAM was found to be superior over *Rhizobium* in increasing the average number of leaves whereas for intermodal length, rhizobium proved to be more efficacious. Sengupta and Chaudhary (1995) also recorded higher number of leaflets in *Sesbania grandiflora* inoculated with *Rhizobium* and VAM, alone or in combination, in comparison with control. Inoculation of VAM resulted in higher number of leaves as compared to uninoculated control in *Dalbergia latifolia* (Sumana and Bagyaraj 1998). Data also depicted that nitrogen and phosphorus application, singly or in combination had significant influence in increasing the number of leaves. Number of leaves (77.22) and intermodal length (3.65cm) were significantly higher in plants with application of 30 kg N ha^{-1} as compared to those with no nitrogen application. The increase in number of leaves is due to increased nitrogen availability as it is a constituent of protein, component of protoplasm and also increase the chlorophyll contents in leaves. All these factors contributed to cell multiplication, cell enlargement and differentiation, which has resulted into better photosynthesis and ultimately in respective growth. The results are supported by Deol and

Table 1. Effect of biofertilizers application on number of leaves of *Dalbergia sissoo* at different nitrogen and phosphorus levels

N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Biofertilizers: Control	VAM	*Rhizobium*	VAM + *Rhizobium*	Overall mean
0	0	34.64	38.64	36.10	40.54	37.48
	75	50.54	61.16	56.91	68.71	59.33
	150	39.52	67.33	45.27	68.78	55.22
Mean		41.56	55.71	46.09	59.34	50.67
30	0	52.21	57.90	60.44	62.78	58.33
	75	59.46	99.00	78.61	117.20	88.56
	150	59.47	90.13	80.23	106.44	84.09
Mean		57.04	82.34	73.09	95.47	77.22
60	0	41.75	45.72	75.62	77.25	60.08
	75	58.84	87.84	79.45	107.04	83.29
	150	44.58	66.04	51.80	79.90	60.58
Mean		48.39	66.53	68.95	88.06	67.97
Overall mean		49.00	68.19	63.03	80.94	
P x B –	0	42.87	47.42	57.39	60.19	51.96
	75	56.28	82.67	71.66	97.65	77.00
	150	47.86	74.50	59.10	85.04	66.86

CD for N	= 0.66	B	= 0.73
P	= 0.66	N x B	= 1.26
N x P	= 1.14	P x B	= 1.26
		N x P x B	= 2.18

Table 2. Effect of biofertilizers application on internodal length (cm) of *Dalbergia sissoo* at different nitrogen and phosphorus levels

N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Biofertilizers				Overall mean
		Control	VAM	*Rhizobium*	VAM + *Rhizobium*	
0	0	2.78	2.95	2.87	3.07	2.91
	75	2.88	3.33	3.27	4.09	3.39
	150	2.59	2.69	2.99	4.27	3.14
Mean		2.75	2.99	3.04	3.81	**3.15**
30	0	3.01	3.56	3.83	4.26	3.66
	75	3.03	3.24	3.71	4.98	3.74
	150	2.98	3.24	3.24	4.78	3.54
Mean		3.00	3.34	3.59	4.67	**3.65**
60	0	2.09	3.11	3.16	4.35	3.17
	75	2.60	2.92	2.90	4.16	3.14
	150	2.54	2.90	2.80	4.00	3.06
Mean		2.41	2.97	2.95	4.17	**3.13**
Overall mean	2.71	3.10	3.19	4.22		
P x B =	0	2.63	3.21	3.29	3.89	**3.25**
	75	2.84	3.16	3.29	4.41	**3.42**
	150	2.70	2.94	3.01	4.68	**3.33**

CD for	N	= 0.05	B	= 0.06
	P	= 0.05	N x B	= 0.10
	N x P	= 0.09	P x B	= 0.10
			N x P x B	= 0.16

Khosla (1983) who found significant increase in internodal length with application of 60 kg N ha^{-1} in *Populus ciliata.* Higher doses of nitrogen (60 kg N ha^{-1}) decreased intermodal length(3.13cm). Application of 75 P_2O_5 kg ha^{-1} significantly increased the number of leaves (77.00) and intermodal length (3.42cm) as compared to 150 kg P_2O_5 ha^{-1} and control. Significant interaction was observed between nitrogen and phosphorus in increasing the number of leaves. The interaction effect between nitrogen x biofertilizer and phosphorus x biofertilizer were also significant. Aguiar *et al* (2004) reported enhanced number of leaves in *Prosopis* spp. with application of 50 kg P_2O_5 ha^{-1} along with VAM inoculation as compared to control. Nitrogen x phosphorus x biofertilizer interaction showed significant effect in enhancing the number of leaves and intermodal length. Dual inoculation of *Rhizobium* + VAM combined with application of 30 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1} produced significantly higher number of leaves (117.20) and intermodal length (4.98cm).

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Study of Reforestation of Mine Wastelands using Indigenous VAM Fungi through Nursery Technology for *Acacia nilotica*

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Abstract: VAM fungi and nursery technology have a great deal to contribute in improving the productivity and profitability of stress lands. The importance of VAM fungi in regeneration of different types of mining sites has been studied and positive results have been reported. An approach has been made to evaluate the growth of plants by application of indigenous VAM fungi for mine wastelands (Bauxite) of Mainpat, Sarguja District,C.G. A pot experiment was designed to screen and select the suitable VAM fungi for reclamation of mine wastelands with fast growing fuel wood tree, *Acacia nilotica.* Soil of mine wastelands was sterilized and inoculated with 11 different VAM fungi belonging to genus *Acaulospora, Glomus, Sclerocystis* in triplicates and seedlings of *Acacia nilotica* were raised in them. After 150 days of growth period, 2 consecutive best VAM fungi were selected on basis of growth parameters, dry biomass, and root colonization as compared to control (i.e., without VAM fungi). Thus, the use of these indigenous fungi in nursery to raise the seedlings of *Acacia nilotica* for reforestration of mine wastelands may ensure successful reclamation of mine areas.

Key Words: *Acacia nilotica*, VAM fungi, Mine wastelands, Nursery, Reforestration, Biomass

The exploration and exploitation of mineral wealth brings in complete destruction of forest and formation of new wastelands in the form of barren dumps of mine overburdens resulting in ecological disturbances and hazards. Open cast mining destroys microbial communities, disrupts ecosystems, cannot support biomass development. In India, gradual increase in such landscapes due to intensive mining activity endangers the forest productivity (Saxena and Chatterji, 1988a, 1988b). 20.16 per cent of total geographical area of India is occupied by the degraded lands (Kiran *et al.,* 2009). The revegetation of the mine wastelands of the country is not achieving success due to various factors, such as high rate of mortality and slow growth of planted species, nutrient deficiency, low moisture retention and lack of biological activities (Dubey *et al.,* 2006). The use of bio-fertilizers for reclamation leads to achieve the fertility of barren dumps in a very short time. There are several evidences that the disturbed sites may be revegetated when the seedlings be pre-inoculated with microbial inoculants (Williams *et al.,* 1974; Daft and Hacskaylo, 1976; Adholeya *et al.,* 1997). Besides rhizobia, endomycorrhizae improve the quality of seedlings in tree nurseries (Kormanic, 1980). Data from earlier studies show that when root systems are tailored in nursery with VAM fungi prior to planting, tree survival and growth improves significantly (Behl, 1990; Verma *et al.,* 1994). Role of mycorrhiza in re-establishment of vegetation in the coal mines spoil has been well emphasized by several workers (Daft and Hacskaylo, 1977; Jasper *et al*., 1988; Johnson and McGraw,1988). Similarly, use of VAM fungi in reclamation of iron and chromite mine wastes have given positive response (Mishra, 1992). VAM fungi have received less attention and poorly explored, but may be helpful in the development of low cost nursery technology to rehabilitate the wastelands and increase productivity.

Acacia nilotica (L.) commonly known as babul, kikar has been recognized as a multipurpose tree. It is relatively fast growing species of wastelands, drought resistant multipurpose legume with the ability of nitrogen fixation (Bowen, 1973). *A. nilotica* form symbiotic associations with naturally occurring soil fungi called VAM (Kaushik & Mandal, 2005). Though not host specific, recent studies have indicated host preferences of mycorrhizal fungi, thus suggesting the need for selecting efficient VA mycorrhizal fungi for a particular host (Baig and Gupta, 1998). Keeping all these factors in mind, present study was done to explore the possibility of application of indigenous VAM fungi in association with *A. nilotica* for reclamation of Bauxite mine wastelands around Mainpat area.

MATERIAL AND METHODS

To evaluate the growth of *Acacia nilotica* for reforestration of mine wastelands of Mainpat, Sarguja District, (C.G.) by application of indigenous VAM fungi a pot experiment was set using the soil surrounding mine wasteland. Indigenous VAM fungi were isolated by " Wet Sieving & Decantation Technique" (Gerdemann and Nicolson, 1963) purified and maintained following the methods of Menge and Timmer (1982). Morphological characterization and Identification of VAM spores was done following INVAM Guidelines. 11 different indigenous VAM fungi belonging to genus *Acaulospora, Glomus and Sclerocystis* were used for evaluation. The soil surrounding mines area was collected in bags, pH was recorded at the site as well as when brought to laboratory. Soil was sterilized by fumigating with 4 per cent formalin for 48 h. After fumigation, soil was kept under open air to remove excess fumes of formalin, saturated with water before the addition of inoculants and seed sowing. Each VAM inoculants (spore load 200-250 spores/100g soil) was added in each pot separately just 2" below the seed sowing level, two seeds were sown and covered with soil. In control sets, no inoculums was added. Only three replications were prepared and daily watering was done as per the requirement of host plants. After 30 days observations were recorded for mycorrhizal colonization. Final observations were recorded after 150 days on seedling shoot length, root length, shoot fresh and dry weight and per cent root colonization, spore count and 'P' content of seedlings. VAM infection was assessed by Root Clearing and Staining technique (Phillips and Hayman, 1970) and percent root colonization was determined by Kormanik & McGraw Slide Method, 1982. Estimation of VAMF spores done by method of Gaur and Adholeya (1994). 'P' content was determined by Vanadomolybdate phosphoric yellow colour method (Jackson, 1973). Data were compared with the control and analyzed statistically by the analysis of variance.

RESULTS AND DISCUSSION

Soil of the mines wasteland collected for experimentations showed a pH ranging between 5.2-5.9. Colour of the soil was Red and soil 'P' content was 0.63 ppm available P (extracted with 0.002 N H_2SO_4). Three genera of VAM fungi, i.e. *Acaulospora, Glomus* and *Sclerocystis* have been isolated from the rhizosphere of forest plants of Mainpat area from five different sites. *Glomus* sp.(6) were present in abundance followed by *Acaulospora* (3) & *Sclerocystis* (2). The VAM fungi present were identified as *A. dilatata, A. laevis, A. longula, G.* aggregatum, *G. fasciculatum, G. geosporum, G. hoi, G. macrocarpum* , *G. mosseae, S. microcarpus* and *S. sinuosa.* Altogether, 11 VAM fungi were found to be infective after 30 days as both vesicles and arbuscles had been observed in roots showing positive response for host plant *A. nilotica.* The effect of different inoculants after 150 days on host plant *Acacia nilotica* is shown in Table 1, 2 and 3. The highest per cent root VAM colonization and spore count was observed in *Glomus macrocarpum* (93, 132%), followed by *G. fasciculatum* (87, 116) (Table 1). A wide range of root colonization (55-93%) showed generalized and high level of susceptibility in *A. nilotica* for VAM symbionts. Estimation and analysis of 'P' content in plant tissues have shown increased level with mycorrhization as compared to uninoculated control. The maximum P content in shoots and root tissues was obtained in plants inoculated with *G. macrocarpum* (7.27 & 7.67 μg^{-1}) followed by *A. laevis* (5.52 & 7.32 μg^{-1}) as compared to control and other inoculants (Table-3). It is evident from the results that all the inoculations had a higher P content of shoots and roots than the control. P content of roots was higher than that of shoots in all inoculated seedlings of *A. nilotica.* It was revealed that *G. macrocarpum* showed a maximum significant increase in shoot height(44.00cm) and root length (29.33cm) as compared to control and other inoculants followed by *A. laevis* (42.00cm & 27.00cm). The maximum fresh and dry shoot biomass was recorded in plants inoculated with *G. macrocarpum* (28.28 and 24.10 g) followed by *A. laevis* (27.71 and 23.96 g) as compared to control and other inoculants in which all the above mentioned parameters were low (Table 2).

Table 1. Effect of VAM inoculants on per cent root colonization, spore count and per cent in *Acacia nilotica*

S.No.	VAM fungi	Per cent Root colonization	Spore count/ 100g soil
1.	*Acaulospora dilatata*	62	92
2.	*Acaulospora laevis*	82	108
3.	*Acaulospora longula*	55	55
4.	*Glomus aggregatum*	70	97
5.	*Glomus fasciculatum*	87	116
6.	*Glomus geosporum*	71	62
7.	*Glomus hoi*	55	85
8.	*Glomus macrocarpum*	93	132
9.	*Glomus mosseae*	75	89
10.	*Sclerocystis microcarpus*	80	102
11.	*Sclerocystis sinuosa*	65	96
12	Control	0	0

There are many reports that suggest the importance of VAM fungi in successful reclamation of mine wastelands (Daft and Hacskaylo,1976, 1977; Mishra, 1992; Adholeya *et al.*,1997). Reports on the positive effect and nutrient uptake by plants through VAM in both forestation and agricultural crops are well documented (Rani *et al.*,1999; Gill and Singh, 2002). In the present study, the better growth responses were seen in host plant *A. nilotica* when inoculated with different indigenous VAM inoculants. Results revealed that different VAM fungi differed in the extent to which they increased growth, biomass and 'P' uptake, thus indicating the need for selecting efficient VAM fungi for *A. nilotica* which

Table 2. Effect of VAM inoculants on growth response and biomass in *Acacia nilotica*

S.No.	VAM fungi	Root length (cm)	Shoot height (cm)	Fresh shoot biomass (g)	Dry shoot biomass (g)
1.	Uninoculated control	10.66±1.15[d]	24.66 ± 6.02[de]	20.14 ± 4.33[defg]	16.39 ± 1.57[bc]
2.	*Acaulospora dilatata*	20.66±3.21[abc]	32.00 ± 5.00[abcde]	21.14 ± 4.01 [cdef]	18.25 ± 5.16 [b]
3.	*Acaulospora laevis*	27.00±6.24[a]	42.00 ± 3.00[ab]	27.71 ± 2.69 [a]	23.96 ± 2.81 [a]
4.	*Acaulospora longula*	17.33±1.52[bcd]	31.33 ± 3.98[bcde]	21.00 ± 4.47 [cdef]	18.25 ± 1.96 [b]
5.	*Glomus aggregatum*	21.33±4.93[abc]	34.00 ± 9.54[abcde]	22.28 ± 3.35 [bcde]	18.96 ± 1.11 [ab]
6.	*Glomus fasciculatum*	25.33±3.51[ab]	38.33 ± 5.50[abc]	26.14 ± 1.57 [ab]	19.67 ± 1.11 [ab]
7.	*Glomus geosporum*	22.66±3.05[abc]	34.33 ± 3.50[abcde]	22.42 ± 2.14 [bcde]	19.10 ± 5.81 [ab]
8.	*Glomus hoi*	16.33±3.78[cd]	25.85 ± 3.41[cde]	20.28 ± 1.11 [defg]	17.10 ± 7.86 [bc]
9.	*Glomus macrocarpum*	29.33±1.52[a]	44.00 ± 3.60[a]	28.28 ± 5.82 [a]	24.10 ± 3.28 [a]
10.	*Glomus mosseae*	23.00±1.00[abc]	36.00 ± 2.64[abcd]	23.14 ± 2.03 [bcd]	19.25 ± 2.16 [ab]
11.	*Sclerocystis microcarpus*	24.00±3.46[abc]	36.33 ± 8.00[abcd]	24.57 ± 3.77 [abc]	19.39 ± 7.26 [ab]
12.	*Sclerocystis sinuosa*	21.00±4.35[abc]	32.33 ± 3.50[abcde]	21.14 ± 2.73 [defg]	18.67 ± 9.50 [ab]

(Values without common letters differ significantly at P=0.01, Duncan's Multiple Range Test).

Table 3. Effect of VAM inoculants on the 'P' content of *Acacia nilotica.*

S.No.	VAM fungi	'P' content in Roots ($\mu g\ g^{-1}$ tissue)	'P' content in Shoots ($\mu g\ g^{-1}$ tissue)
1.	Uninoculated control	5.01 ± 0.06[gh]	2.19 ± 0.03 [gh]
2.	*Acaulospora dilatata*	5.87 ± 0.06[ef]	3.20 ± 0.00 [ef]
3.	*Acaulospora laevis*	7.32 ± 0.06[ab]	5.52 ± 0.27 [b]
4.	*Acaulospora longula*	5.61 ± 0.06[fg]	2.47 ± 0.03 [gh]
5.	*Glomus aggregatum*	6.21 ± 0.06[de]	3.80 ± 0.03 [de]
6.	*Glomus fasciculatum*	7.28 ± 0.00[ab]	5.40 ± 0.02 [c]
7.	*Glomus geosporum*	6.25 ± 0.00[de]	4.01 ± 0.00 [d]
8.	*Glomus hoi*	5.57 ± 0.00[fg]	2.41 ± 0.00 [gh]
9.	*Glomus macrocarpum*	7.67 ± 0.06[a]	7.27 ± 0.04 [a]
10.	*Glomus mosseae*	6.47 ± 0.06[cd]	4.26 ± 0.08 [c]
11.	*Sclerocystis microcarpus*	6.94 ± 0.00[bc]	5.37 ± 0.10 [b]
12.	*Sclerocystis sinuosa*	6.08 ± 0.00[def]	3.66 ± 0.59[de]

(Values without common letters differ significantly at P=0.01, Duncan's Multiple Range Test).

are in accordance with many workers (Rani *et al*, 1999, Jamaluddin *et al.*, 2001; Kaushik and Mandal, 2005). The increased rate of P uptake and inflow in roots has been regarded as the major contribution of VAM infection (Mosse, 1973). Inoculated seedlings with the entire test VAM fungi increased the P content of roots and shoots as compared to the control in this study and similar results were also reported (Kumar *et al.,* 2002).

All the 11 indigenous VAM fungi tested showed positive mycorrhization for host plant *A. nilotica.* All the inoculation treatment have a marked effect on the growth, biomass and 'P' content of *A. nilotica* seedlings as compared to the control. Based on these parameters, the best two VAM inoculants *G. macrocarpum* and *A. laevis* were selected for nursery development of *A. nilotica* for reclamation of Mainpat mines wasteland. The above study reveals that inoculation of VAM fungi enable the plant species to become more stress tolerant by ensuring continuous supplies of nutrients during their early stages of growth. Therefore, reclamation with VAM fungi through nursery technology seems to be cost-effective and promising for revegetating the mines wasteland, however field trial is awaited for financial and technical support.

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Application of Analytical Hierarchy Process for Land Use Allocation

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Abstract:This study was conducted to develop a framework for participatory and improved land use decision-making in Besitang Watershed, Langkat, North Sumatra, Indonesia. It aimed to determine the best land use allocation using AHP. Socio-economic information and physical data were derived from interviews and field survey. Collective opinion was derived from the workshop with stakeholders. Alternative for forestry in Besitang Watershed based on integrated approach has very high suitability (63%). Agriculture use has high (63%) to very high (37%) suitability. Settlement area has low (23%) to moderate (77%) suitability. Fishery use has low (47%), moderate (18%), and high (35%) suitability. Industry has very low suitability in all decision zones. Based on allocation for multiple-use, Besitang Watershed has very high potential suitability for forestry (63%) and agriculture (37%) land uses. The most significant contributions of this study in facilitating land use decision-making were: as a tool for land use allocation and policy formulation, as well as for scientific investigations. This approach provides participatory involvement of stakeholders in land use allocation. This approach is efficient and reliable land use allocation for watershed management, since it involves the physical components as well as participation of stakeholders to ensure sustainability.

Key Words*:* Land use allocation, AHP, Besitang watershed

The increasing human population, the more consequent accelerating demands and intensity of human activities on the land have various degrees of impact on all of the material and natural resources in the world. Human population pressures have accelerated the increases of land value and the diversity of land use. Land is becoming scarce so that the more fragile upland areas are looked upon as the last frontier for the expansion of agriculture and other land uses. As a result, numerous problems have now been threatening the ecological stability of much upland (Cruz, 1990).

At the moment, there is a trend to make use of the land for the economic interests, which could increase the income. One of the favourite and higheconomic-value plants in this area is oil palm. Another problem in Besitang Watershed that seems to be a major one is land conversion to oil palm plantation and fish pond in the mangrove forests by the surrounding community have decreased the size of the available area. According to Ekanayake and Dayawansa (2003), land as resource cannot be measured by the surface area alone; hence the types of soil which is critical for productivity, underlying geology, topography, hydrology and plants/animal population also have to be considered. These attributes limit the extent of land available for various purposes. The growing population, industrialization and misuse and overexploitation of land resources have in fact increased the demand for land.

Changes in the use of land occurring at various spatial levels and periods can have either beneficial or detrimental effects. The latter is the main concern of decision-makers because of its effect on the population and the environment. The goal of managing land use and its change is to develop the land resources in ways that capitalize on the local potential and suitability, avoid negative impacts and respond to present and future societal demand within the limits of the carrying capacity of the natural environment (FAO, 1995). Decision support system has been identified as a critical component to identify and solve problems, provide information and current scientific knowledge in watershed management decision making process.

Based on the Besitang Watershed's condition, some thoughts on good steps or actions are needed to overcome these problems. Rehabilitation of watersheds is also needed so that it can support and enhance other environmental functions. At present, researches on land use and land use planning have been carried out in the area but these have not fully looked into the driving forces of land use as influenced by renovation policies. There is a need of an approach that can involve the participation of stakeholders so that land use management planning can be effectively and efficiently done in accordance with Republic of Indonesia Law Number 26 (2007) about Spatial Management. The research about land use allocation with stakeholder participation and collaboration that is crucial for successful and sustainable watershed management has never been conducted previously in the area. For this reason, it is essential that research in this area be conducted. Therefore, This study generally aimed to develop a framework of participatory and improved land use decision-making in Besitang Watershed, Langkat, North Sumatra, Indonesia. Specifically, the study aimed to determine the current and potential land use suitability in the area with stakeholder participation and to develop a spatial participatory land use allocation for the area.

MATERIAL AND METHODS

The study was conducted in the Besitang Watershed, from April to August 2008. Administratively, the study area lies in the Langkat Regency, North Sumatra Province, Indonesia. It consists of five sub-districts, namely: Besitang, Barandan Barat, Padang Tualang, Pangkalan Susu and Sei Lepan.

Besitang Watershed has an area of 100,035 ha excluding the islands. In the border of Malaka Strait in the East, there are islands that have an area of 5,089 ha. Geographically, it is located between 97° 50' 00" to 98° 20' 00" east longitude and 03° 45' 00" to 04° 15' 20" north latitude. It is bordered by the Province of Nangroe Aceh Darussalam in the North, Sei Lepan Watershed in the South, Malaka Strait in the East, and the Province of Nangroe Aceh Darussalam in the West.

Collective Opinion Information

Information for collective opinion was gathered from primary data (interviews during field survey and during the workshop). The workshop was conducted to determine land use suitability allocation based on public opinion from stakeholder using AHP. The study largely relied on the use of questionnaire and key stakeholder (local officers, extension workers, teachers, researchers, and people) who knew the study sites well at provincial, regional, sub-regional, and village level. Key stakeholders provided qualitative in-depth information about physical and socio-economic conditions of the study area. Secondary data were collected from offices, which are related to the study.

Potential Land Use Suitability Classification and Land Use Allocation

The collective opinion was used based on AHP as a tool and used expert choice as software. The AHP utilizes the system approach to decision making. The recommended procedure to solve a problem using the AHP method based on the AHP principles is as follow:

Structuring the problem into a hierarchy. In this study, generating the integrated measure (the first step in the AHP) was to define the hierarchy, each representing a level in the system. Three identified levels of hierarchy in the area are shown in Fig. 1.

Comparing the hierarchy elements on a pairwise base. Based on the hierarchy levels, then the questionnaire was developed and the respondents were filled during the workshop. Preference is denoted by a vector of weights following and AHP scale of relative importance ranging from 1 to 9 (Saaty, 1980). The pairwise comparison matrix (PCM) is a reciprocal matrix in which elements under its main diagonal are inverses of the upper elements. If there are "n" elements to be compared, which form an n x n PCM, then there was n(n-1)/2 pairwise comparisons in a PCM. In this study, there were four elements for objectives and five elements for alternatives to be compared, then there were six pairwise comparisons for objective and ten pairwise comparisons for alternatives in a PCM.

In this study, in order to make informed and valid assessments, the area was divided into zone with relatively

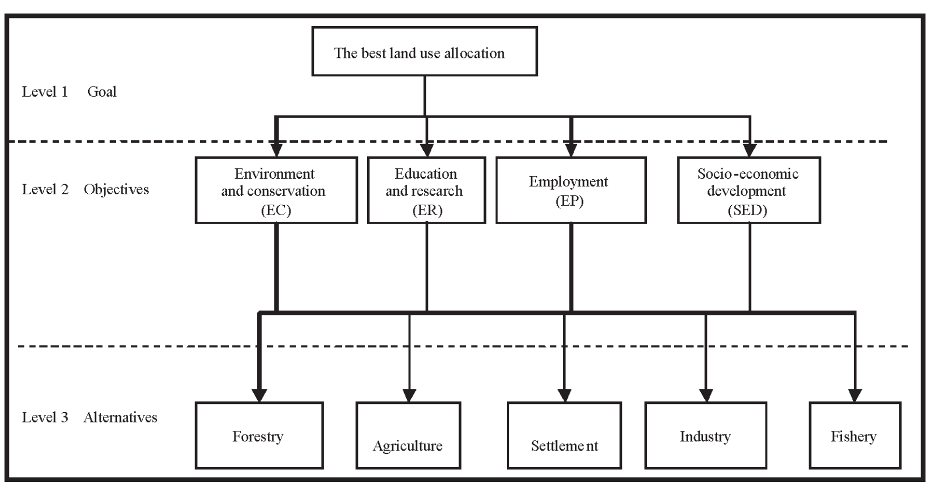

Fig. 1. Hierarchical levels for decision-making in AHP model

homogenous characteristics. The analysis was preceded by conducting a pairwise comparison of the objectives. Each decision maker was asked independently to establish the relationship among the objectives using the ratio scale of measurement. For each decision maker, therefore, a square objectives matrix was generated, then, the matrices were normalized. This was processed in Expert Choice Program. Central to AHP is a measure of consistency in human judgments. According to Malczewski (1999), if consistency ratio (CR) is less than 0.1, there is a reasonable level of consistency in the pair-wise comparisons. If CR is more than or equal 0.1, the values of the ratio are inconsistent. In the latter case, the original value in the pair wise comparison matrix should be revised. Consistency measurement was done by using Expert Choice Program.

Aggregating all priority vectors. The final step was to aggregate the priority (weight) vectors of each level obtained in the second step, to produce overall weights. This was processed in Expert Choice Program.

The land use allocation was derived from the results of the potential land use suitability based on integrated approach. In this study, land use allocation was adopted from Bantayan (2006). The classification procedure puts the alternatives in classes signifying the degree of suitability of a particular alternative to the land units. The land use suitability classification in this study was categorized as: very high suitability (S1), high suitability (S2), moderate (S3), low suitability (S4), and very low suitability (S5). These were expressed as relative weight of alternatives by decision zone. Based on these priorities, the degrees of preference for the major land use groups can be expressed as degrees of land use suitability for each decision zone.

In this study, land use allocation used two kinds of land use allocation that was adopted from Bantayan (2006), namely: allocation for single use and allocation for multiple-use. Land use allocation for single use, the process of allocation depends on whether or not the results of the land use suitability classification are regarded in absolute terms. A process of exclusion is implemented where only the alternative that receives the highest suitability is chosen for allocation and the rest are excluded in regard to the land units in question. Land use allocation for multiple-use, an alternative approach is to recognise the gradation in the suitability classification. It can be accomplished by concurrent and continuous use of several natural resource products obtainable on a particular land unit requiring the production of several goods and services from the same area.

RESULTS AND DISCUSSION

Land system is based on Regional Physical Planning Programme for Transmigration survey in 1980 and still being used. Basic concept of land system is to divide the landscape into areas meaningful for development planning. The land concept is based on ecological principles and presumes closely interdependent links between rock types, hydroclimatology, land form, soils and organism. The same land system is recognized wherever the same combination of such ecological or environmental factors occurs. A land system therefore, is not unique to one locality only, but considers all areas having the same environmental properties. Furthermore, because a land system consists always of the same combination of rocks, soil and topography, it has the same potential, and limitation, wherever it occurs.

In Besitang Watershed, there are eight land systems. Majority land system in Besitang Watershed is Teweh (50%), followed by Maput (16%), Bukit Pandan (13%), Kajapah (13%), Mantalat (3%), Kahayan (2%), and Pendreh (3.%). Only 0.02% is Air Hitam Kanan. The land system is used as a basis to determine decision zone (DZ) in this study. Decision Zone 1 is located in Bukit Pandan and Air Hitam Kanan Land Systems, Decision Zone 2 is located in Pendreh Land System, Decision Zones 3, 5, and 10 are located in Maput Land System, Decision Zones 4, 6, and 11 are located in Teweh Land System, Decision Zones 7 and 8 are located in Mantalat Land System, Decision Zone 9 is located in Kahayan Land System, and Decision Zone 12 is located in Kajapah Land System. Based on the explanation above, look that the decision zones areas were different from each others and have broad scale. Hence, for detailed information and assessment (planning), need to rearrange the area of decision zone by stakeholder participation considering the interaction among land uses (ecological interaction).

Potential Land Use Suitability Classification and Land Use Allocation

Primary data were collected from interviews during field survey and during the workshop. Secondary data were collected from offices, which are related to the study. Data and thematic layers needed as supporting data and as guide for stakeholders to fill the questionnaire during the workshop.

A workshop with the stakeholders was conducted for AHP on July 31, 2008 in University of Sumatera Utara, Medan, North Sumatra, Indonesia. The participant is the stakeholder from provincial level, regional level, sub-regional level, and village level. The participants came from different occupations and institutions. Before conducting the workshop, interviewed with some stakeholders that were selected from 100 respondents during gathered data for socio-economic was done to determine several choices for objectives and alternatives. Then, the stakeholders were invited in the workshop as an expert in the area. The group agreed with four of objectives and five of alternatives for potential land use allocation in Besitang Watershed, during the workshop. The objectives were: i) Environment and conservation, ii) Education and research, iii) Employment, iv) Socio-economic development and the alternatives were: i) Forestry, ii) Agriculture, iii) Settlement, iv) Industry, and v) Fishery. Supporting data such as: socio-economic, soil erosion, land classification, and secondary data (Langkat administrative map, watershed boundary map, land system map, soil depth, and soil erosion map) were shown to respondents during the workshop.

Based on interviews with stakeholders and discussion during the workshop, there were some reasons why they choose the objectives and alternatives. The reason for choosing the environment and conservation is because in this area there are protected areas. As mentioned earlier, it has the main function of sustaining the biodiversity ecosystem services, cultural heritage, and geologic monument among others for sustainable development. Besides, there are buffer areas between the Leuser Ecosystem (KEL) and the Gunung Leuser National Park (TNGL) and Besitang Watershed as one of the Priority II watersheds in Indonesia (it means that it is in a moderately to severely damaged class). Hence, the areas need special management to maintain the watersheds ecosystem. In relation to land use changes assessment, this area has the large portion of forest change from 1990 to 2006. Decrease of forest area will affect the environment in this area. As we know that forest is a system that has some functions, such as: nutrient cycles, water or hydrologic cycles, succession and forest regeneration, wildlife-habitat interactions, photosynthesis,etc. If any one of these systems breaks down, the forest will not function as it should. According to Perschel *et al*. (2007), forest has an important role in mitigating climate change by naturally taking carbon out of the atmosphere. Forest preservation maintains carbon storage and forest management that increases carbon sequestration can augment forests' natural carbon storage capacity in working forest. In addition, based on estimates of soil erosion and analysis of land capability and suitability, conservation is needed to reduce soil erosion to ensure sustainability in this area.

This area has very good potential for research and education activities because in this area there is natural reserve forest. The area was also a potential to employment especially in agriculture because in this area there are big areas for agriculture and plantation. Also, majority of the people are involved in farming, therefore,socio-economic development is important to achieve human welfare in this area.

In terms of potential land use suitability in Besitang Watershed, the area was classified by five alternative land uses, namely:

i) **Forestry.** The area that is suitable for forestry and will be used for forestry activities, such as: protected forest, nature reserve, limited production forest, and production forest.
ii) **Agriculture.** The area that is suitable for agriculture and will be used for agriculture activities area, such as: plantation, dry land agriculture, and wetland agriculture.
iii) **Settlement.** The area that is suitable for settlement and will be used for settlement area. This area has the main agricultural activities including the management of natural resources with the order of the area as a function of the rural settlement, services, government services, social services, and economic activities.
iv) **Industry**. The area that is suitable for industry and will be used for industrial activities, such as: agriculture and fishery based industry activity.
v) **Fishery.** The area that is suitable for fishery and will be used for fishery activities area, such as: fish pond, prawn pond, salting, etc.

The reason for choosing forestry as one of the alternatives for potential land use allocation in this area because of Republic of Indonesia Law Number 26 (2007) about Spatial Management (Chapter 17) that minimum 30 per cent of watershed area must be covered by forest area. The reason for choosing agriculture as one of the alternatives for potential land use allocation in this area is because majority of the people are involved in farming. The reason for choosing the settlement as one of the alternatives for potential land use allocation in this area is because in Besitang Watershed there are 30 villages and they live in their watershed for a long time. Moreover, as mentioned earlier, in this area the main agricultural activities include the management of natural resources with the order of the area as a function of the rural settlement, services, government services, social services and economic activities. The reason for choosing the industry as one of the alternatives for potential land use allocation in this area is because ofease of accessibility. This area connects two provinces (NAD and North Sumatra) and there are road accesses from the land even from the sea. The reason for choosing the fishery as one of the alternatives for potential land use allocation in this area is because of the location of Besitang Watershed especially in low stream sub-watershed bordered by sea and river.

In this study, the workshop was conducted only because of time and budget constraints. Some stakeholders brought their laptop during the workshop, so they could fill the AHP questionnaire in Expert Choice Program and the consistency could directly be determined. The stakeholders who did not bring the laptop filled the questionnaire manually. Hence, test of consistency was conducted after the workshop was finished. In the end, sixteen sets of data were generated from stakeholders in the workshop.

The 16 sets of data were generated from the workshop processed using Expert Choice Program to determine priority of objective for each stakeholder. Furthermore, mixed aggregation of objective used geometric average was derived to represent group judgment. Based on mixed aggregation, the priority objective for all decision zones using mixed aggregation was determined (Table 1). These values are used to establish the priority of alternative for all decision zones (Table 2). The values show high for the priorities in view of environment and conservation in this area, followed by education and research, employment, and social-economic development.

Based on the result, the first objective in DZ 1 to 9 and DZ 12 was environment and conservation, followed by education and research, employment, and socio-economic development. It means that to achieve the best land use allocation in Besitang Watershed (DZ 1 to 9 and DZ 12), the first priority of objective should be environment and conservation. For DZ 10, the first priority objective to achieve the best land use was education and research, followed by environment and conservation, employment, and socio-economic development. For DZ 11, the first priority objective to achieve the best land use was employment, followed by education and research, socio-economic development, and environment/conservation.

The priority of alternative for each stakeholder was processing using Expert Choice Program in integrated approach. Mixed aggregation of alternative used geometric average. Furthermore, the priority of alternative for all decision zones using mixed aggregation was determined (Table 2).

Based on these priorities, the degrees of preference for alternative potential land use in this area can be expressed as degrees of land use suitability for each decision zone. This study is in agreement with Bantayan (1996). The land use suitability classification in this study was categories as following: very high suitability (S1), high suitability (S2), moderate (S3), low suitability (S4), and very low suitability (S5). Moreover, the relative weight of the alternatives (forestry, agriculture, settlement, industry, and

Table 1. Priority of objective for all decision zones using mixed aggregation

Objective	Decision zone											
	1	2	3	4	5	6	7	8	9	10	11	12
Environment and conservation	0.590	0.566	0.581	0.575	0.581	0.486	0.399	0.383	0.293	0.286	0.184	0.434
Education and research	0.262	0.275	0.270	0.271	0.274	0.268	0.243	0.233	0.257	0.296	0.271	0.272
Employment	0.087	0.095	0.085	0.089	0.086	0.147	0.217	0.218	0.245	0.225	0.292	0.161
Socio-economic development	0.061	0.065	0.064	0.065	0.059	0.099	0.140	0.165	0.205	0.193	0.253	0.132
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2. Priority of alternative for all decision zones using mixed aggregation

Potential land use	Decision zone											
	1	2	3	4	5	6	7	8	9	10	11	12
Forestry	0.622	0.615	0.613	0.613	0.606	0.528	0.393	0.326	0.246	0.203	0.188	0.345
Agriculture	0.126	0.130	0.129	0.135	0.131	0.187	0.244	0.262	0.253	0.258	0.270	0.215
Settlement	0.085	0.086	0.089	0.085	0.090	0.105	0.126	0.138	0.160	0.182	0.189	0.139
Industry	0.077	0.081	0.080	0.078	0.082	0.086	0.104	0.117	0.126	0.148	0.157	0.107
Fishery	0.089	0.088	0.089	0.089	0.091	0.094	0.132	0.157	0.214	0.208	0.196	0.194
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Land suitability classification per decision zone based on priority of alternative for integrated approach

Potential Land Use	Decision Zone											
	1	2	3	4	5	6	7	8	9	10	11	12
Forestry	S1	S1	S1	S1	S1	S1	S1	S1	S2	S3	S4	S1
Agriculture	S2	S2	S2	S2	S2	S2	S2	S2	S1	S1	S1	S2
Settlement	S3	S3	S3	S3	S3	S3	S4	S4	S4	S4	S3	S4
Industry	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
Fishery	S4	S4	S4	S4	S4	S4	S3	S3	S3	S2	S2	S3

fishery) as shown in Table 3, then is transformed to show the suitability in the context of integrated approach (Fig. 2).

Based on Table 3, alternative for forestry indicated with the very high suitability (62,814 ha) except for DZ 9 (2,250 ha) (high), DZ 10 (4,757 ha) (moderate), and DZ 11 (30,214 ha) (low). Majority for agriculture is high suitability (63%) and for DZ 9, 10, and 11 is very high suitability (37,220 ha). Settlement is moderate suitability (76,873 ha) in DZ 1 to 6 and DZ 11 and low suitability (23,162 ha) in DZ 7 to 10 and DZ 12. Fishery is high suitability (34,970 ha) in DZ 10 and 11, moderate suitability (18,405 ha) in DZ 7, 8, 9, and 12 and low suitability (46,659 ha) in DZ 1 to 6. In this area, industry indicated with the very low suitability in all decision zones (100,035 ha).

Land allocation in this area is based on Table 3 using the single use concept that was adopted from Bantayan (2006). The decision zone that receives the highest suitability shall be allocated to the land systems in that particular decision zone. Hence, based on the potential land use suitability classification as is shown in Table 3, the majority land allocation in Besitang Watershed is allocated to the forestry (63%) potential land use (DZ 1 to 8 and DZ 12) followed by agriculture (37%) potential land use (DZ 9, 10, and 11). Another concept of land use allocation is based on allocation for multiple-use. As explained earlier, an alternative approach is to recognise the gradation in the suitability classification. Such an approach follows the multiple-use concept for land use allocation.

According to Bantayan (2006), the objective of multiple-use management is to manage the natural resources in a manner that maximises the benefits which can be derived. Land use allocation for multiple-uses can be accomplished by concurrent and continuous use of several natural resource products obtainable on a particular land unit requiring the production of several goods and services from the same area. As shown in Table 3, Besitang Watershed has very high potential suitability for forestry (63%) and agriculture (37%) land uses.

As alternative for forestry, potential land use suitability classification in Besitang Watershed based on integrated approach indicated that most areas have very high suitability. Majority of agriculture area has high to very high suitability. Settlement area has low to moderate suitability. Fishery area has low to high suitability. In this area, industry has

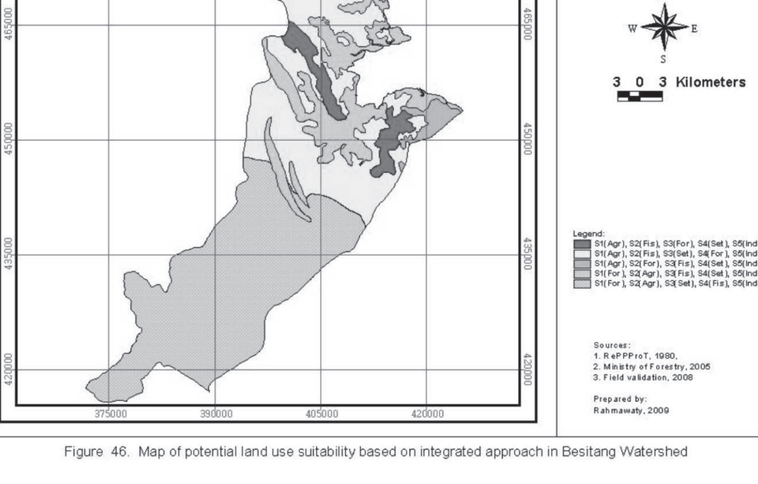

Figure 46. Map of potential land use suitability based on integrated approach in Besitang Watershed

Fig 2: Map of potential land use suitability based on integrated approach in Besitang Watershed very low suitability in all decision zones. Land allocation in Besitang Watershed using the single use concept indicated that the majority of land is allocated to the forestry potential land use followed by agriculture potential land use. Based on allocation for multiple-use, Besitang Watershed has high potential suitability for forestry and agriculture land use.

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Community Forestry: The Centre for Biodiversity Conservation

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Abstract: Nepal has an extremely high level of biological diversity at the landscape, ecosystem, and species levels, especially in relation to its small land area. Community Forestry in Nepal has been successful to fulfill twin goals, conserving the biodiversity on one hand and socio-economic upliftment on other hand. It was found that community forestry has rehabilitated the degraded forest, increased the number of plants, birds as well as animals and helped in soil conservation which proves that biodiversity has been conserved through community managed forests. It was noticed that local forest users were eager to increase biodiversity in the forest. Regular monitoring was important to know the status of forest.

***Key Words*:** Biodiversity, Community forestry, Peoples' participation, Monitoring

Biological diversity or biodiversity (the variety of life on earth) Includes all organisms, species, and populations; the genetic variation among these; and all their complex assemblages of communities and ecosystems. The components of biodiversity are ecosystem, species and genetic variation (http://en.wikipedia.org/wiki/Biodiversity). Nepal has an extremely high level of biological diversity at the landscape, ecosystem, and species levels, especially in relation to its small land area. This diversity is the result of Nepal's unique geographic position and altitudinal and climatic variations. Nepal's location in the central portion of the Himalayas places it in the transitional zone between the eastern and western Himalayas. It incorporates the Palearctic and the Indo-Malayan bio-geographical regions and the major floristic provinces of Asia (the Sino-Japanese, Indian, western and central Asiatic, Southeast Asiatic, and African Indian desert) creating a unique and rich terrestrial biodiversity. Nepal is a mosaic of various forest types intermixed with agricultural land, pastures, high mountains, and alpine plateaus, creating a range of landscapes. Ecologically linked to neighboring countries through shared ecosystems, habitats, and rivers, Nepal contains internationally important populations of large mammals that are rare or extinct elsewhere in the world. Community Forestry in Nepal has been successful to fulfill twin goals, conserving the biodiversity on one hand and socio-economic upliftment on other hand.

Community Forestry (CF) is a part of national forest handed over to user group under specific rules and regulations for its conservation, development and utilization for collective benefits (Anon., 1993). The community forestry is a social process in which user groups share mutually recognized claims to specify their user rights to the management, development and utilization of forest. Nepal is recognized as one of the world's leaders in community forestry. Approximately 1.23 million ha of forests are managed by 14,431 community forest user groups (CFUGs); these schemes benefit 1.66 million households, about 40 per cent of all the country's households (MoFSC, 2009). A basic principle in community forestry is the need for a location-specific approach to forest management, and incorporation of local values and knowledge systems. Originally, community forestry focused on the basic forest-related needs of local communities. Forest biodiversity is critical to the livelihoods of the people living around forests. Some indigenous communities, such as the Raute in western Nepal, are totally dependent on a variety of forest products for their livelihoods. Other indigenous communities, such as the Chepang in central Nepal, recently started to practices agriculture, but still depend on forests for many products. Even in communities that engage in agriculture, many people collect a variety of food, fodder and timber and non-timber forest products (NTFPs). Participatory forestry is being increasingly considered as a chief strategy of conservation, management and sustainable use of forest biodiversity. The present study aimed to access the biodiversity conservation through community forestry.

MATERIAL AND METHODS

The study was carried out in a Bhangara community forest of Kaski district (Table 1). The district lies in western development region, mid hills of Nepal having altitudinal variation from 58 meters to 7939 meters. It covers an area of 2,017 sq km in between 27°6' to 28°36' northern latitude and 83°40' to 84°12' eastern longitude. It is centrally located being Lamjung and Tanahun in the east, Parbhat in the

Table 1. Flora and fauna of Bhangara community

Characteristics	Bhangara Community CFUG Lekhanath.
Total households	218
Forest area	235.33 ha.
Main floral species	Sch*ima wallichii, Castonopsis indica, Shorea robusta, Albizzia, Oroxylon indicum. Ficus cunia, Pennisetum purpureum, Ficus religiosa*
Major fauna species	Common Leopard (*Panthera paradus*), Rhesus monkey (*Macaca mulatta*), Tree-striped palm squirrel (*Funambulus palmarum*), Funambulus palmarum (*Canis aureus*). Pheasant (*Lophura leucomelana*), Crested serpent eagle (*Spilornis cheela*), etc.

west, Manang and Lamjung in the north and Tanahun and Syanjha in the south. It experiences humid subtropical to warm temperate climate. Administratively, Rupa lake basin falls in 4 different VDCs and Lekhnath Municipality. At the western part of Rupa lake lies Bangara Community. A total of 49749 people reside in the basin areas. The major occupation is subsistence agriculture (Oli, 1996). Rupa is a small advancing eutrophic lake with marshes and paddy field along its shores. Lake covers an area of 115 ha in its watersheds basin is 30 km^2 and has humid upper tropical and lower subtropical climate. The mean annual temperature is 19.30^{o}C and precipitation is 3157 mm. Rupa is recognized for eight main vegetation types with 379 genera and 128 families that comprise 128 tree species and 85 herbs and shrubs containing 25 endangered, 13 threatened, 5 rare and 2 vulnerable species of wetlands plants.

The following methodologies were used to gather information in the study.

Semi-structured questionnaire survey was conducted among the users of the forests. The questionnaire was about the forest management, silvicultural activities and importance of biodiversity in community forest. Sampling Intensity of questionnaire survey was 30 per cent.

Participatory social and resource maps were prepared to collect the information on the distribution and condition of forest resources. Focus group discussion was conducted to obtain the information on forest management and silvicultural activities carried out, varying perceptions towards management and biodiversity conservation issues. The discussions were concentrated mainly in the male, female and ethnic users. A survey was conducted with the key informants like teachers and users' group committee executives to collect the information on the forest management and biodiversity conservation practices in the forests.

Different published and unpublished documents, review of operational plan and constitution journals, library of forestry campus and department of forest, organizations working on biodiversity and community forestry, internet browsing, etc. were used to collect data. Data were edited, coded and analyzed using MS-Excel Data.

RESULTS AND DISCUSSION

The community forestry has been practiced to preserve biodiversity since time immemorial and they are home to many plants, birds and animals. The species richness can be seen and the degraded lands have been covered with green forest.

Forest Management Operations

The Community Forest User Groups were predominantly applying selective felling, singling, thinning, pruning, lopping, and weeding/cleaning operations followed by plantations, soil conservation work and leaf litter collection. These forest management operations were carried out depending upon the nature, kind and conditions of the forests. The application of such activities may promote uniformity in species composition, spacing and canopy development.

Knowledge of Forest User Group about Biodiversity

It is clear from Fig.1 that 88 per cent of respondents had knowledge about biodiversity conservation but still 12 per cent of the respondents do not have knowledge about biodiversity conservation.

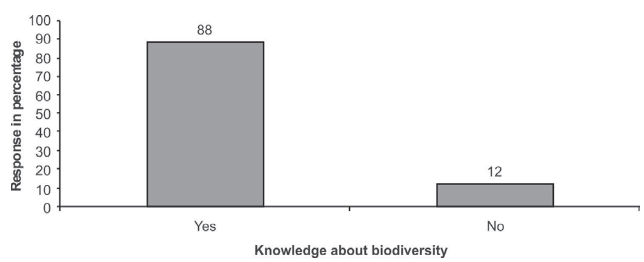

Fig. 1. Perception of Forest user group about biodiversity

Local People Response to Biodiversitty Conservation through Community Forestry

Fig. 2 reveals that 90 per cent of respondent responded that they have experienced increase in biodiversity in their community forest due to the increase in forest cover and the water source has increased in Rupa lake, which has increased birds and animals in their community forest. According to 5 per cent of respondents, biodiversity is decreasing and 5 per cent of the respondent reported that they don't know about increasing or decreasing status of biodiversity.

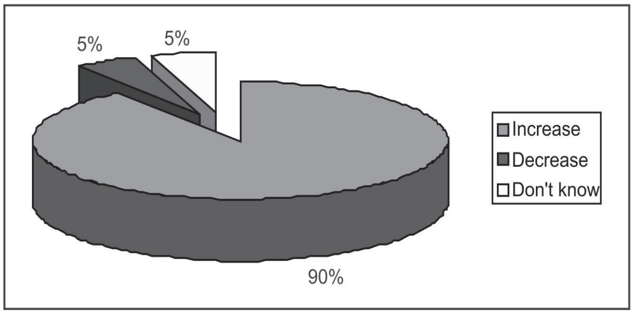

Fig. 2. Response of local peoples to biodiversity conservation through community forestry

Best Practices for Biodiversity Conservation

The study revealed that CFUGs are increasingly adopting measures for biodiversity conservation in the community forestry. Few major initiatives observed particularly in Bangara Community Forest were:

1. Allocation of biodiversity conservation area,
2. Species conservation,
3. Plantation and Silvicutural (Forest management) practices,
4. Forest guard,
5. Reward and penalties,
6. Awareness Program (School and community) and Lake conservation,
7. Training on CBR (Community Based Biodiversity Registration).

The Bangara Community Forestry was found rich in biodiversity due to the presence of dense forests and lake. Forest User groups are actively participating in biodiversity conservation. Eighty per cent of respondents have good knowledge about biodiversity conservation and according to 90% of respondents biodiversity is increasing in their community forest. Appropriate mechanism to compensate forest user groups is necessary for sustainable conservation of Biodiversity.

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Community Forest as a Vehicle for Poverty Reduction, Good Governance and Gender Equity

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Abstract: Nepal has increasingly gained world-wide recognition in participatory forest management and natural resource management, primarily through "Community Forestry" (CF) program which has a well-documented history over 30 years. The local people have been involved in the management, protection and utilization of forests. Community Forestry program has been successful to meet the twined goals of forest conservation on the one hand and socioeconomic transformation through poverty reduction, participation, good governance and gender equity and power devolution. The main objective of community forestry was to meet the basic forest products required by the communities through active participation in forest development and management, but later on it was expanded to include the mobilization and empowerment of the members of community forest user groups in the development of their local communities too. The data was collected using PRA tools like household survey, key informants interview, internet and library. The data was edited, coded and fed in to analyze using MS-Excel and SPSS. The result depicted that many Income Generating Activities (IGA) like goat rearing, non-timber forest products cultivation, leasing forest etc are conducted in the community forestry as a means of poverty reduction tool. Today a lot of community forests are even led and managed by women only. Out of three main positions in a user committee, at least one should be woman. Woman participation in meetings and decision making is highly increased. CF lead by women group is more successful. The CF has transparency of the decisions, equitable access and control of the services and resources, accountability/ownership of the users, active participation of the users, good and effective management and communication, equitable representation of the man and women of the different level in the committee, collective decision making and implementation, and rational and wise mobilization of the resources. Now-a-days, the community forestry has been a playground for the local users where they can protect, manage and utilize the forest products, increase participation of people and stakeholders, ensuring benefits to the local users, and regard forestry as a potential vehicle for poverty reduction, good governance and gender equity.

Key Words: Community forestry, Good governance, Gender equity, Nepal

The saying that "Green Forests are the Wealth of Nation" has been successful only after the forest of Nepal has been handed to the local people as Community Forestry. The important role that forests play in rural livelihoods, especially of the poor, is generally well recognized. In the late 1970s, in countries such as India, Nepal and the Philippines, it was generally perceived that widespread deforestation had led to environmental degradation, and that governments acting alone were not able to reverse the trends. So the concept of community forestry arose into force, where the management and utilization of the degraded forest and bare land was done nationally. "Community forestry is a village-level forestry activity, decided on collectively and implemented on communal land, where local populations participate in the planning, establishing, managing and harvesting of forest crops, and so receive a major proportion of the socio-economic and ecological benefits from the forest." (http://www.rainforestinfo.org.au/good_wood/comm_fy.htm). According to the Forest Act 1993, Community Forestry (CF) is a part of national forest handed over to user groups under specific rules and regulations for its conservation, development and utilization for collective benefits. The Forest Act of 1993 and Forest Regulation of 1995 provide a clear regulation of the CF and the process of handing over forest to the local communities by forming user groups, the so called Community Forest User Groups (CFUGs). Also the Forest Act of 1993 and the Forest Regulation of 1995 have entirely revised the Forest Act of 1961 and its first amendment of 1978 in line with MPFS of 1989. The CFUGs are "independent, autonomous and self-perpetuating institutions", responsible for both the management of community forests and the conduction of community development activities. CFUGs have the legal right to claim support services from the Divisional Forest Officer, and are also free to collaborate with other organizations.

Community Forestry has been accorded the highest priority in forestry sector in Nepal. It is a participatory approach that has been in practice for more than three decades and is being implemented throughout the country. The CF has resulted in rural farmers gaining increased access to forest resources, together with improvements in biodiversity and landscape values. CF has proved to be an effective tool for managing and conserving forests where local people are dependent on the forests for their daily sustenance but at the same time it has also been observed that in many cases poorest users, who depend relatively more on the forest for their livelihoods, have limited participation and inclusion in the whole process of CF. It has been proved that communities are able to protect, manage and utilize the forest resources in a sustainable manner. However, the contribution of CF towards supporting the poorest, most vulnerable and marginalized members of society has been limited (Kandel and Subedi, 2004), but still the important role that forests played in rural livelihoods, especially of the poor, is generally well recognized. The Fourth National Workshop on Community Forestry in 2004 focused on emerging issues related to poverty reduction. Poverty reduction is a major concern at global level and is explicitly spelled out in the Millennium Development Goals (MDGs) of the United Nations. Community forestry is considered to have caused social and cultural change, improved the livelihood of the locals and is believed to have potential for poverty reduction. The present investigation aims to study whether community forestry has played the role of good governance, gender equity and helped in reducing poverty.

MATERIAL AND METHODS

The primary data were collected by reconnaissance survey, face-to-face interview or household survey, focus group discussion, key informants survey and direct observation. Different journals and bulletins, projects, I/NGOs working in community forestry, China Agricultural University and Beijing Forestry University libraries, Internet search, e-forums & e-consultations were consulted to gather secondary data. Data were edited, coded & fed into and analyzed using MS-Excel. The data are shown in table and bar graph for simplicity.

RESULTS AND DISCUSSION

Community forestry is directed from decentralization to devolution, it has major contribution in socio-economic, environmental and ecological aspects with the practice of good governance that supports directly to the poverty reduction and economic development of the nation. Community forestry has become a means to increase natural, social, human, financial, and to some extent the physical capital of community forest users. National Planning Commission has emphasized on poverty reduction as a sole objective in 10th five year plan. Development of CF improves environment in rural level and create employment opportunity for poor group by developing occupation based on timber and non-timber forest products (NTFPs). CFUG based enterprises provide income and employment for community members, and in many cases jobs are prioritized for members of poorer households (Dev *et al*., 2003), who are typically more vulnerable to food shortages by nature of their socio-economic status. Even the leasehold program is included in the community forestry where the poorest of the poor household or disadvantaged groups (DAGs) can easily get the land free of cost and cultivate cash crops, non timber forest products and others as their need and improve their livelihood. With the revolving fund of community forestry, the users can rear goats, grow vegetables and other cash crops in their own land too to earn their living. Perception of users toward community forestry, its uses and management is given in Table 1 and Fig 1.

According to Pokharel and Niraula (2004), CF in Nepal offers many examples of good governance such as decentralized decision-making, participatory management of resources, and equitable sharing of benefits. Government, nongovernmental and private sector agencies at service delivery level have become more accountable to the forest users. More than 80 per cent of the Nepalese people depend on forest resources to support their livelihood. Good governance is, therefore, crucial for providing equitable access to and benefits from forest resources to all people including the poor and the marginalized. With participation from various sections of society, there will be better community forest management and reduced conflicts. Well functioning of CFUGs will eventually lead to sustainability of community forestry. Participation from different segments of society, particularly women, poor and dalits is ensured to reflect their concerns and raise ownership feeling in the community forestry management process. It was seen that the government staffs, committee members and user groups have commitment and accountability as per the assigned tasks/responsibilities. Auditing, sharing in yearly general assembly, income transaction record keeping, meeting minutes reflect the transparency. Active participation in management, planning, decision making process, monitoring and evaluation was seen in the community forestry.

The Master Plan for the Forestry Sector,1989, has adopted to balance the interests of both men and women. It is therefore emphasized that there should be equal access of men and women in decision making processes. Recognizing the importance of women's participation in community forestry, forestry policy has focuses on enhancing the wider participation of women in decision making and benefit sharing. Now-a-days, out of three main positions in a committee, (chairperson, secretary and treasurer) at least one should be woman. The woman has twin works of reproduction and taking care of the house. The community forestry is the only forestry activity activities in Nepal where both male and female are brought under

Table 1. Perception of users (%) towards community forestry, its uses, management, committee members.

S. No.	Questions	Poor			Medium			Rich		
		Yes	No	Don't Know	Yes	No	Don't Know	Yes	No	Don't Know
1.	Is CF beneficial for you?	83	15	2	91	7	2	96	3	1
2.	Do you take part in CF activities?	79	21	0	91	9	0	85	15	0
3.	Do you think that there is transparency in fund mobilization?	88	10	2	95	5	0	97	3	0
4.	Do you think that there is equity in forest products distribution?	77	13	10	87	7	6	89	10	1
5.	Do you think that woman and poor are included in decision making process?	82	6	12	93	3	4	95	3	2
6.	Do you think that CF improves livelihood and thus help to reduce poverty?	90	6	4	88	7	5	92	8	0

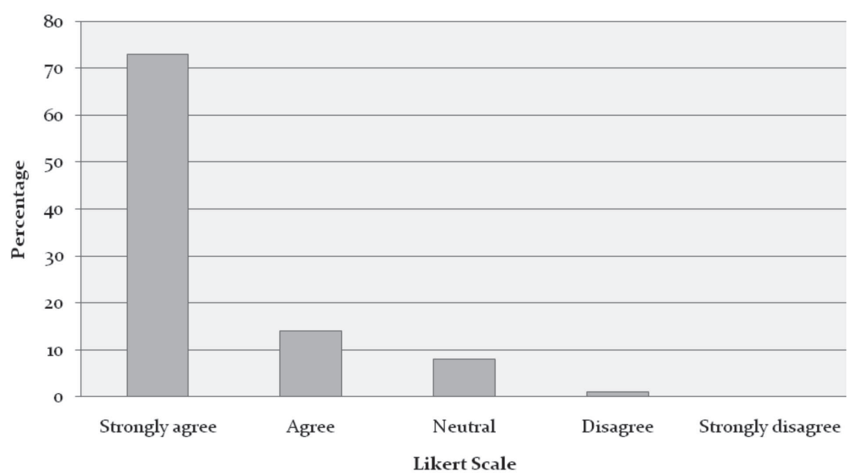

Fig. 1. CF helps in povert reduction, good governance and gender equity.

one umbrella to work together. About 10-15% of the community forestry in Nepal are managed solely by women only. It was seen that community forest led by women only was more successful and earned more revenue as compared to led by men only. Women are increasingly participating in user groups meetings and women members in the local bodies have contributed further to enhancement of community forestry.

The critical role of Community Forestry in particular and forestry in general in fostering social and economic development in Nepal's rural areas has already drawn some attention. The Community Forestry has been a cook-book solution for conserving the forest of mid-hills of Nepal. Community Forestry has not only helped to conserve biodiversity and improve the environment and mitigate the global warming but it has really become a boon for the users, especially the poor. The socio-economic upliftment and conservation of natural resources is achieved if people become aware of their roles and responsibilities. CF is not just a special technology rather a process of socio-economic change that requires a continuous participation of the community in planning, implementing and problem solving (Kayastha, 1991). But in some places, the poor are often restricted to using forest and tree resources only to help mitigate poverty while the local elites and outsiders are able to harness the same resources, either legitimately or illegally, in order to accumulate wealth. So this should be controlled by increasing the level of awareness, participation of women and disadvantaged groups. The CFs have been practicing decision making processes and leadership, and function equitably in cost and benefit sharing mechanism. CFUGs have identified disadvantaged households and are supporting household level livelihoods plans for their disadvantaged members to uplift their livelihood. A good management of NTFPs have great potential for contributing to the national poverty alleviation programs and also maintaining the diversity of the forest ecosystem under community forest management. The forest should be managed both scientifically and technically as well as socially benefitted. Further researches on different aspects of forestry like technical, social, etc. should be conducted for the benefit of the forest and the users too. The suggestions and recommendations made by researchers, technicians and forestry personnel should be checked and implemented by the government and forest department. Above all, everything is good if we use it wisely and sustainably but if we misuse it, the diamond will also be valueless. Therefore, to protect environment and uplift users and make them active the community forestry has really played an important role and to make it sustainably is the role of us Nepalese people.

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Nature and Extent of Damage Inflicted by Gastropods to Saplings of Some Ornamental Plants in Plant Nurseries at Ludhiana (Punjab)

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Abstract: Slugs and snails are common in almost every ecosystem and particularly in nurseries with ideal habitats. Three commercial plant nurseries were surveyed for Gastropod (slugs and snails) infestation and damage inflicted by them to various ornamental plant saplings. Two snail species *viz., Macrochlamys indica* GA and *Macrochlamys (Euaustenia) cassida* Hutton and one slug species i.e., *Filicaulis (Eleutherocaulis) alte* (Ferrusac) with two biotypes *viz*., brown colour with black spots and caterpillar like excavated irregular holes within the leaves and on the margins. Maximum mean per cent plants attacked by gastropods were 81 in *Dracaena green* and money plant (*Pothos*), 58 in *Dracaena mixed*, 74 in *Dracaena brown,* 76 in *Dieffenbachia*, 71 in Song of India (*Pleomle reflexa),* 55 in bougainvillea (*Bougainvillea sp.)*, 57 in selum (*Phyllodendron var. selum)*, 61 in ribbon grass *(Phalaris),* 44 in poinsettia *(Pulcherrima euphorbia),* during April and 72 in *Dracaena brown*, 75 in *Dracaena mixed*, 80 in *Dieffenbachia,* 36 in money plant (*Pothos*), 31 in ribbon grass *(Phalaris)* during September. Control measures are essential during these months to minimize damage inflicted by these gastropods.

Key Words: Plant nurseries, Gastropods, *Filicaulis alte, Macrochlamys indica*

Slugs and snails (gastropods) are widely distributed throughout the world and occasionally become serious pests. In India, about 9 species of snails and 14 species of slugs have been reported to cause damage to ornamental plants, vegetables and horticultural crops and orchids, *viz.* rice, coffee, tea, tobacco, potato, sugarcane, cosmos, chrysanthemum, lady finger, beans and fruits (Jagtap, 2000), yet scanty attention has been paid towards studying the extent of damage by these pests in the country.

Commercial nurseries are serving the farming community by providing planting material of wide range of crops like vegetables, fruits, flowers, ornamental and plantation crops. These crops are important source of farm income and fits well in crop diversification (Anonymous, 2003). Slugs and snails are common in almost every ecosystem and particularly in nurseries where ideal habitats are available. Plant damage normally occurs after dark when moisture levels are higher and temperatures are lower. During the day, slugs and snails usually hide in a moist dark place unless there is ample shade and high levels of moisture.

Preliminary studies conducted by Kaur and Kaur (2003) indicated that black/brown slug with mid-dorsal streak, *Filicaulis alte* (Ferrusac) inflicted three types of damage to seedlings/saplings of vegetables and flower plants in laboratory feeding tests viz. leaves eaten from the margins, consumption of whole upper portion of seedling and stem girdling with resultant wilting of plants causing damage to sponge gourd (53%), coriander (69%), cabbage (75%), cauliflower (20%), brinjal (51%), spinach (48%) and to flower seedlings *viz.,* zinnia (58%), portulaca (59%), balsam (69%) and marigold (97%). Same type of damage was inflicted by the other biotype of *F. alte* i.e., the brown slug with black spots but to somewhat less extent *viz.* sponge gourd (47%), coriander (34%), cabbage (56%), brinjal (22%), spinach (33%), cauliflower (20%) and to flower seedlings *viz.* zinnia (41%), portulaca (32%), balsam (33%) and marigold (73%) (Kaur, 2007) indicating it's less destructive nature as compared to black/brown slug with mid-dorsal streak. *Laevicaulis alte* has been found infesting neem seedlings in forest nurseries of Rajasthan and Gujarat (Kumar *et al.,*1998).

During survey of three plant nurseries at Ludhiana, two snail species *viz. Macrochlamys indica* and *Macrochlamys cassida* (Euaustenia) and one slug species i.e., *F. alte* (Ferrusac) with two biotypes viz. brown colour with black spots and caterpillar like were noticed. Out of these gastropods, snail *M. indica* and slug biotype brown colour with black spots were predominant in all the three plant nurseries. So far no damage assessment has been done in plant nurseries in Punjab. Hence, present studies were undertaken to study the nature and extent of damage inflicted to ornamental plant saplings in three commercial plant nurseries at Ludhiana, so that the effective timings for gastropod control in plant nurseries can be determined.

MATERIAL AND METHODS

Three commercial plant nurseries *viz.* Bengal nursery and Suman nursery, Pakhowal Road and Carewell nurseries and flowers, New Rajguru nagar, Ferozepur road at Ludhiana were surveyed to study the nature and extent of damage inflicted by gastropods to ornamental plants saplings. Three replicates (each 10 m^2) size for each ornamental plant type were undertaken. Plants were observed carefully for gastropod damage at three weeks interval in each nursery. Total plants in rows along with damaged ones were counted in each replicate. Mean per cent damage to various ornamental plant saplings by gastropods was arc sine or angular transformed into degrees.

RESULTS AND DISCUSSION

Results of assessment of damage inflicted by gastropods to ornamental plant saplings in three commercial plant nurseries are presented in Table 1, 2 and 3, respectively. Gastropods carved irregular holes within the leaves or on the margins of the plant saplings from March to October as animals were in hibernation from mid November to February.

Dracaena

Three varieties of dracaena were found in Suman nursery *viz.* brown, green and mixed but only two varieties *viz.* brown and green were found in Bengal nursery and Carewell nurseries and flowers. The gastropods carved irregular holes in the interior portion of leaves of all varieties of *Dracaena* saplings.

Dracaena brown. Mean per cent infested plants by gastropods were above 71.6 per cent in the month of April in Bengal nursery and Care well nurseries and flowers. Damage declined afterwards to 44-49 per cent in July (Table 1 and 2). However damage again increased to 72.3 per cent in Care well nurseries and flowers (Table 2) and 59.3 per cent in Bengal nursery in September (Table 1), which declined to about 41-49 per cent up to October. However, in Suman nursery 35 per cent plants were found damaged in March. Extent of damage increased again and was maximum in May (60%). It declined afterwards to 28.3 per cent in August. 56.6 per cent plants were damaged in September (Table 3). Maximum damage was observed in Care well nurseries and flowers i.e., 73.6 per cent in April (Table2).Overall damage was less in Suman nursery as compared to other nurseries. This might be due to less density of gastropods.

Dracaena green*.* Gastropods in Bengal nursery infested maximum plants (81.3%) in April. Mean per cent damage declined afterwards to 46 per cent in June which again increased to 52 per cent in July and declined to 35.33 per cent in August. Damage again increased to 49.33 per cent in September. However, mean per cent damage declined afterwards and was 20 per cent in November (Table 1).

In Carewell nurseries and flowers, gastropods infested mean per cent plants were 63.33 per cent in April. In May, damage declined to 47.6 per cent, however, it increased afterwards and was maximum (67.3%) in July. No damage was noticed in August. However, gastropods damaged 56.6 per cent in September and damage reduced to 41 per cent

Table 1. Mean per cent damage inflicted by Gastropods to some ornamental plants per 10 m^2 per replicate at Bengal nursery, Pakhowal road, Ludhiana

Ornamental Plants	Per cent plants with damage/row/replicate (Mean ± SE)							
	14-April	5-May	16-June	7-July	18-August	8-September	21-October	10-November
Dracaena	81.3 ±1.33	56.6±6.39	46±2.08	52±5.5	35.33±2.18	49.33±3.18	45.33±3.18	20±2.64
(Green)	(64.2)	(48.7)	(46.1)	(46.1)	(36.3)	(41.6)	(42.1)	(26.6)
Dracaena	71.6 ±2.60	54.3±5.23	53.3±1.86	49.3±3.18	50.67±2.03	59.33±4.98	49±2.89	-
(Brown)	(57.8)	(47.3)	(46.7)	(44.4)	(48.7)	(50.2)	(44.4)	
Croton	19±2.64	16±2.30	16± 4.04	-	-	-	-	-
	(25.8)	(23.6)	(23.6)					
Song of India	71.3±3.28	11.6±3.75	11.33±6.74	-	-	5 ± 4.04	-	-
(*Pleomele reflexa*)	(57.4)	(19.9)	(19.4)	(12.9)				
Bougainvillea	54.6±3.52	-	-	-	15±2.54	3.66±2.03	-	-
(*Bougainvillea sp.*)	(47.6)	(22.8)	(10)					
Money plant	80.6±5.45	-	-	32.3±0.88	43.3±2.03	36.6± 5.04	29.3±5.84	-
(*Pothos*)	(63.8)			(34.4)	(41.0)	(37.2)	(32.6)	
Salem	56.6±5.45	7.33±1.76	6±3.21	-	-	6.33 ±2.96	-	-
(*Phyllodendron var.selum*)	(48.7)	(15.3)	(14.2)			(14.2)		

* Figures within parenthesis are angular transformation of per cent to degrees.

Table 2. Mean per cent damage inflicted by Gastropods to some ornamental plants per 10 m^2 per replicate at Care well nurseries and flowers, New Rajguru nagar, Ferozepur road, Ludhiana

Ornamental Plants	Per cent plants with damage/row/replicate (Mean ± SE)						
	28-April	19-May	30-June	21-July	11-August	22-September	13-October
Dracaena	73.6 ±2.03	65.3±3.48	60	43.6±5.36	-	72.3±3.52	41±6.81
(Brown)	(59.0)	(53.7)	(50.8)	(41.3)		(58.1)	(39.8)
Dracaena	63.3 ±2.33	47.6±8.23	20±2.64	67.3±11.7	-	56.6±8.82	41±6.81
(Green)	(52.5)	(43.6)	(26.6)	(48.7)	(54.9)	(39.8)	
Dieffenbachia	76 ±3.21	56± 7	70	61±4.04	61.3±8.64	54.6± 8.25	36.6 ±7.21
	(60.7)	(48.7)	(56.8)	(51.4)	(51.4)	(47.6)	(37.2)
Bougainvillea	-	7 ±1.732	26.6±8.82	19.3±4.10	-	16.3±4.10	16±7.80
(*Bougainvillea sp.)*	(13.9)	(31.0)	(25.8)	(23.6)	(23.6)		
Money plant	53.3± 8.82	-	-	30±8.39	-	-	22.3±5.90
(*Pothos)*	(46.7)	(33.2)	(28.0)				
Ribbon grass	61.3±1.45	63.3±1.76	54.33±2.33	-	31±4.04	-	14.33 ±3.38
(Opheopogon	(51.4)	(52.5)	(47.3)	(33.8)	(22.0)		
jaburan variegated)							

* Figures within parenthesis are angular transformation of per cent to degrees.

in October (Table 2). Mean percent plants damaged by gastropods in Suman nursery were 20 per cent in March. Damage increased afterwards and was maximum (48%) in May but declined to 42.6 per cent in June. In July, damage was 47 per cent, which declined afterwards to 22.6 per cent in October (Table 3). More damage was observed in Bengal nursery i.e., 81.3 per cent in April as compared to Care well nurseries and flowers. This might be due to more density of brown slug with black spots in Bengal nursery, which preferred *Dracaena green* variety.

Dracaena mixed. In Suman nursery gastropods damaged 24.3 per cent plants in March. Damage increased to 58.3 per cent in April, which declined afterwards to 41 per cent in June. However, damage increased afterwards and was maximum (75%) in September. It declined to 30 per cent in October (Table 3).

These studies revealed that for protection of Dracaena brown and green varieties from gastropod control measures should be adopted in months of April and September and for Dracaena mixed in September.

Poinsettia *(Pulcherrima euphorbia)*

In Suman nursery, 27.7 per cent damage was seen in March that increased to 44.2 per cent in April and May. Damage was seen in the form of leaves eaten from the margins and also holes within them. No damage was seen in June and July and about 24 per cent damage was noticed in August. No damage was seen afterwards (Table 3). Gastropod damage control measures should be adopted in April-May.

Croton *(Codiaeum variegatum pictum)*

Gastropods mainly ate margins of leaves. 13.7 per cent damage was noticed in Suman nursery in the month of March that increased to 33.3 per cent in April, which again decreased to 23.6 per cent in May and more afterwards (Table 3). However, little damage i.e., 16-19 per cent was seen in the months of April to June and none afterwards in Bengal nursery (Table 1). Hence gastropods should be controlled in April.

Bougainvillea (*Bougainvillea sp.)*

Damage was in the form of holes in leaves. Mean per cent damage was 38.8 per cent in the month of April that declined to 10.3 per cent in May in Suman nursery (Table 3) and no damage was observed afterwards. However, 54.6 per cent damage was observed in April in Bengal nursery (Table 1). No damage was seen from May to July and October onwards. Little infestation was seen in August-September. So plants should be protected from gastropods in April.

Dieffenbachia

In Dieffenbachia, gastropods excavated holes within leaves and margins were also eaten. In Care well nurseries and flowers, maximum damage (76%) was seen in the month of April that declined to 56 per cent in May and again increased to 70 per cent in June. There was decline in plant infestation afterwards to 54.6 per cent in September. Only 36.6 per cent damage was seen in October (Table 2). In Suman nursery, about 27 per cent damage was seen that increased to 54 per cent in May. Damage declined afterwards and was 39 per cent in August that again increased to 80 per cent in September. 42 per cent damage was seen in October (Table 3). Gastropod control measures should be adopted during April to July and September.

Ribbon grass *(Phalaris)*

Margins of leaves were eaten leading to the gradual destruction of the whole plant. About 61 – 63 per cent damage was observed in April-May that declined to 54.33 per cent in June and 31 per cent in August. Little damage (14.33%) was seen in October in Care well nurseries and flowers (Table 2).

Money plant (*Pothos*)

Damage in money plant was in the form of irregular holes in leaves and margins of leaves were also eaten. In Bengal nursery, 80.6 per cent leaves were eaten in April. Damage was 32.3 per cent in July that increased to 43.3 per cent in August and again declined afterwards (Table 1). In Care well nurseries and flowers, 53.3 per cent damage was seen in April that declined to 30 per cent in July. Little damage (22.3%) was recorded in October. No damage was seen in May and June in both nurseries (Table 2). Hence, gastropods should be controlled in April to protect money plant. More damage was observed in Bengal nursery as compared to Care well nurseries and flowers. This might be due to more population of slugs in Bengal nursery which preferred money plant leaves more.

Song of India (*Pleomele reflexa)*

Irregular holes in leaves were noticed. 71.3 per cent saplings were damaged in Bengal nursery in April but damage declined to 11 per cent in May and June. No damage was noticed in July and August. However little damage was noticed in September (Table 1). Gastropods should be controlled in April to protect Song of India

Salem (*Philodendron var. Salem*)

Irregular holes were noticed in Bengal nursery, 56.6% plants were damaged in April, however, little damage was noticed afterwards. Leaves were destroyed heavily (Table 1). Gastropods should be controlled during month of April.

Begonia *(Begonia nemperthneuse)*

Thirty six per cent damage was seen in Suman nursery in April only (Table 3). However, no damage was observed in case of saplings of plants like Areca palm (*Chrysaledocarpus lutescens*), Christmas tree (*Picea abies*), Yucca palm and Narangi *(Citrus reticulata).* This might be due to their hardy leaves or alkaloid components within them. Mean percent infestation of some plant type by

Table 3. Mean per cent damage inflicted by Gastropods to some ornamental plants per 10 m^2 per replicate at Suman nursery, Pakhowal road, Ludhiana

Ornamental Plants	Percent plants with damage/row/replicate (Mean ± SE)							
	31-March	14-April	5-May	16-June	7-July	18-August	8-September	21October
Dracaena (Green)	20±2.89 (26.6)	44.4±10 (41.6)	48±2.88 (43.9)	42.6±2.60 (40.7)	47±3.79 (43.3)	43±2.64 (41.0)	44±2.07 (41.6)	22.6±1.45 (28.4)
Dracaena (Brown)	35±2.88 (36.3)	55.5±10 (48.1)	60±2.08 (50.8)	54.6±3.48 (47.6)	52.3±3.18 (46.1)	28.33±2.60 (31.9)	56.6± 8.45 (48.7)	-
Dracaena (Mixed)	24.3 ±8.17 (22.4)	58.3±7.35 (49.6)	56.6±4.98 (48.7)	41±2.08 (39.8)	44.3±5.45 (41.6)	50±3.46 (45.0)	75 (60.0)	30±1.73 (33.2)
Croton	13.7±0.87 (22.6)	33.3±4.79 (35.4)	23.6± 2.03 (29.0)	-	-	-	-	-
Bougainvillea (*Bougainvillea sp.)*	- (38.4)	38.8±5.56 (18.4)	10.3±0.87	-	-	-	-	-
Poinsettia *(Euphorbia Pulcherrima)*	27.7±4.18 (31.6)	44.2±2.90 (41.8)	44±2.31 (41.6)	-	-	24±1.53 (29.3)	-	-
Begonia *(Begonia nemperthneuse)*	-	36.1±7.35 (36.9)	-	-	-	-	-	-
Dieffenbachia	21.7 ±2.4 (26.7)	44.4± 10 (41.6)	54±7.50 (47.3)	42.6±2.60 (40.7)	47.3±1.76 (43.3)	39± 7.5 (38.6)	80 (63.4)	42.6±2.60 (40.7)

* Figures within parenthesis are angular transformation of per cent to degrees.

gastropods varied in different plant nurseries which might be due to differences in shady conditions and slug population. Similarly earlier studies reported that black or brown slug biotype (Kaur and Kaur, 2003) and brown with black spots biotype (Kaur, 2007) of slug *F.alte* showed no feeding response towards seedlings of Kochnia, Coleus, Kalanga and Sadabahar in feeding tests under labortary conditions. During these studies mainly damage was in the form of holes within leaves or on margins in various ornamental plant saplings. According to Jagtap *et al.* (1990a & b) the damage inflicted may either be in the form of severe defoliation or destruction of young plants. Raut and Ghosh (1984) reported that pestiferous gastropods fed on small leaves, made holes in mature leaves, fed on leaf margins, rasped the lower surface of thick leaves and bored mine like holes and tunnels in tubers, roots and bulbs. Liu *et al.* (1997) found that slugs mainly damage the leaves, flowers and roots of the orchid plants.

These results, thus pointed out that brown slug with black spots biotype, *F.alte* and snail*, M.indica* had a high potential to cause heavy damage to saplings of ornamental plants and thus more emphasis should be laid on saving the plant saplings from these pestiferous gastropods in commercial nurseries during months of April and September.

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Clostera resitura (Walker) Larval Behaviour on Poplar (*Populus deltoides*) Clones

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Abstract: The relative natural resistance/ susceptibility of 13 *Populus deltoids* clones (USA, India and Australian origin) was evaluated against its potential defoliators, *Clostera restitura* by single choice test at Forest Protection Laboratory, Department of Forestry and Natural Resources. The evaluation was carried out on the basis of actual leaf area consumed by the defoliator larvae. Eight clones, WSL22, WSL32, WSL39, PL5, S7C15, Udai, PL4 and PL2 were found resistant and the remained five, 65/27, PL3, Karanti, PL7 and PL1 was susceptible to the defoliator. Biological parameters did not vary significantly among the clones indicating equal suitability and no adverse effect of clones on the larva and pupal period and their survival.

Key Words: Biological parameters, Defoliator, *Populus*, Resistance

Poplar is an important farm forestry tree species of India with an estimated 30 million trees covering 0.06 million ha (average density of 500 trees ha^{-1}) in North Western India (Chandra, 2001) with productivity of 30 m^3 ha^{-1} per annum (Dogra, 1999). Poplar gives 1.125 million m^3 of industrial wood annually amounting to five per cent of the country's total domestic wood requirement (Chandra, 2001). Wide spread acceptability of poplar as an agroforestry tree in north western India is primarily attributed to its short rotation (as compared to other trees) and winter deciduous nature (Newman, 1997). Prolonged leafless period (3-4 months) makes poplar ideal for compatibility with intercrops (Newman, 1997). However, the quality of the wood often gets deteriorated due to insect pests attack. Both indigenous as well as exotic species of poplar are attacked by about 143 species of insect pests in north western India and about 65 species alone were found to infest *P. deltoides* (Singh *et al.,* 2004). Among the defoliators, *Clostera cupreata* (Butler), *Clostera restitura* (Walker) and *Clostera fulgurita* (Walker) often cause large scale defoliation of poplars and are well established on *P. deltoides* in north western India. Large scale defoliation of *P. deltoides* by *Clostera* sp. has been reported from plantations (>1100 ha) in the central Tarai region of northern India during 1980's (Jha *et al.,* 1991). Sohi *et al.* (1987) reported epidemic defoliation of poplar by *C. restitura* in the Satluj river bed areas of Punjab. Simulated defoliation studies have established that defoliation (>70 %) decreases the total biomass of poplar by about 33 per cent (Reinchenbacker *et al.,* 1996). Severe and repeated defoliation of young plants (2-3 year old) of poplar by defoliators result in their mortality (Singh and Singh, 1986). Complete loss of leaves, particularly in the growing season, is generally the most damaging as it renders the plant weak and exposes it to attack by other insects and diseases. Among different methods of insect control, resistant/tolerant varieties have played an important role in checking the population build up of insect pests. Resistance to the pests varies among clones, hybrids, cultivars and species of the *Populus.* Screening of resistant clones are highly desirable so that, clones showing poor performance can be rejected at nursery stage and the tolerant material would be maintained pest free by using standard management practices. Keeping these points in view, the studies were undertaken to identify of relatively resistant and susceptible clones based on leaf consumption and to study biological parameters of *C. restitura* on the identified resistant clones.

MATERIAL AND METHODS

Relative natural resistance or susceptibility of 13 poplar clones, viz, WSL 22, WSL 32, WSL 39, PL1, PL2, PL3, PL4, PL5, PL7, S7C 15, Udai, 65/27 and Karanti was evaluated against defoliator, *Clostera restitura* by single choice test on the basis of feeding potential, i.e. amount of food consumed by the insect under laboratory conditions. The experiment was carried out at Department of Forestry & Natural Resources, Punjab Agricultural University, Ludhiana. A culture of *C. restitura* was maintained in the laboratory for the experiments. The larvae of defoliator were collected from the different poplar plantations and kept in glass jars covered with muslin containing tender host leaves. The food was changed daily until pupation to maintain the culture of *C. restitura*. The pupae obtained from these jars were transferred to other glass jars having moist sponge sheet at the bottom. The males and females that emerged on the same day were paired and released into split cage for mating and egg laying. Newly hatched larvae of uniform age were used for the present study. Foliage of various clones was assessed by releasing third instar larva in a petri dish on a pre-measured leaf taken from the middle portion of 8-month-old plant of each clone for maintaining homogeneity within it. After 24 h of feeding, the leaf was again measured by leaf area meter and replaced with a new pre-measured leaf of the same clone. The study was continued till the formation of pupae by all the larvae. The experiment was replicated 4 times with each clone. The data was subjected to computer analysis to calculate mean leaf area consumed by the larvae per day for each clone, weightage percentage of resistance and susceptibility. Weightage percentage of resistance (WPR) and weightage percentage of susceptibility awere calculated by applying the below given formula (Ahmed, 1993):

$$\text{Weightage \% of Resistance (WPR)} = \frac{100 \times [\{\text{Max. leaf area fed - leaf area fed of concerned clone}\}]}{(\text{Max. leaf area fed-Min. leaf area fed})}$$

Weightage % of susceptibility (WPS) = 100 – WPR of concerned clone

Resistant and susceptible clones of poplar were grouped into six categories by taking the value of the mean leaf area of each clone consumed by the larvae of *C. restitura*.

R1 = Most resistant = $x < (\overline{X} \text{ -SD})$

R2 = Resistant = $(\overline{X} \text{ SD}) < x < (\overline{X} \text{ -SD/2})$

R3 = Moderately resistant = $(\overline{X} \text{ -SD/2}) < x < \overline{X}$

S1 = Most susceptible = $x > (\overline{X} \text{ +SD})$

S2 = Susceptible = $(\overline{X} \text{ +SD}) > x > (\overline{X} \text{ +SD/2})$

S3 = Moderately susceptible = $(\overline{X}) > x > (\overline{X} \text{ +SD/2})$

x = Mean leaf area consumed by larvae for each clone per day

$\overline{X}$ = Overall mean of leaf area consumed by larvae for all clone per day.

SD = Standard deviation.

In another experiment, comparative development of poplar defoliator *C. resitura* was studied on resistant clones G 48, WSL 22 and S7C15 from the first experiment in insect proof screen house made of galvanized wire-netting at Entomological Research farm, Punjab Agricultural University, Ludhiana. The different biological parameters studied were duration of different larval instars, total larval period, larval survival, pupal period and pupal survival of *C. restitura*. Twenty newly hatched larvae were taken from reared culture. There were five larvae in each of the four replications for a clone. Larvae were kept individually in separate plastic vitals containing leaves of different clones of poplar. The number of larval instars was recorded on sample of 20 larvae. The time, when the larvae stopped their activity and feeding, was considered to be near moult and appearance of exuva and head capsule confirmed the entrance of the larva into next stage. Larval period was considered from the time of hatching till it stopped feeding to enter pupal stage. The numbers of larvae which successfully completed larval stage and entered pupal stage were counted and survival percentage was worked out. The stage when pupae were formed to the emergence of adults was taken as pupal period. The number of pupae from which the adults emerged was counted and survival percentage was worked out. The experiment was carried out in completely randomized design (CRD).

RESULTS AND DISCUSSION

Relative Resistance/ Susceptibility of Poplar Clones against *C. restitura*

Mean leaf area of different clones consumed by the larvae is arranged in descending order of magnitude in Table 1, and made the basis for calculating insect resistance in each clone. The maximum and minimum leaf area consumed by the poplar defoliator per day were 22.13 and 11.58 cm^2, respectively with over all mean of 17.08 cm^2 and standard deviation (SD) of 2.67. Clones were categorized into six groups, R1, R2 and R3 as resistant and S1, S2 and S3 as susceptible groups. Out 13 clones, 8 were found resistant and remaining 5 were recorded to be susceptible.

Poplar clone WSL 22 was found to be most resistant (R1) against C. *restitura* as only 11.58 cm^2 of leaf area was consumed by the larvae and hence its weightage percentage of resistance (WPR) was calculated as 100 per cent. Three clones viz. S7C15, PL5 and Udai were adjudged as resistant (R2). The average leaf consumption per day on these clones were 14.71, 14.95 and 15.01 cm^2 having 70.33, 68.05 and 67.48 per cent WPR, respectively. Four clones, WSL 32, WSL 39, PL4 and PL2 were categorized as moderately resistant (R3) having 50.23, 49.09, 48.34 and 45.30 per cent WPR and 16.83, 16.95,17.03 and 17.35 cm^2 leaf area consumed, respectively.

Poplar clones 65/27 and PL 3 were found to be the most susceptible (S1) clones for the attack of *C. restitura* as 22.13 and 20.50 cm^2 foliage was consumed by the larvae having 100 and 94.02 per cent weightage per cent of susceptibility (WPS), respectively. Three clones, i.e. Karanti,

Table 1. Relative resistance / susceptibility (weightage %) of poplar clones against poplar defoliator, *Clostera restitura* measured along with mean leaf area fed (cm^2)

Clones	Mean leaf area fed (cm^2)	WPR / WPS	Resistance category
Most Resistant Clones			
WSL 22	11.58	100.0	R1
Resistant Clones			
S7C15	14.71	70.33	R2
PL5	14.95	68.05	R2
Udai	15.01	67.48	R2
Moderately Resistant Clones			
WSL 32	16.83	50.23	R3
WSL 39	16.95	49.09	R3
PL4	17.03	48.34	R3
PL2	17.35	45.30	R3
Most Susceptible Clones			
65/27	22.13	100.0	S1
PL3	21.50	94.02	S1
Moderately Susceptible Clones			
Karanti	18.28	63.50	S3
PL1	18.00	60.85	S3
PL7	17.84	59.33	S3

'X =17.08 Standard Deviation =2.67

WPR - Weightage percentage of resistance

WPS - Weightage percentage of susceptibility

PL7 and PL1 were categorized as moderately susceptible (S3) clones. The leaf area fed by these clones was 18.28, 17.84 and 17.54 cm^2 having 63.50, 60.85 and 59.33 per cent WPS, respectively. Similar results with same set of clones were recorded by Singh (2004). The overall categorization was same although the order of clones *w.r.t.* resistance/ susceptibility category varied slightly in case of *C. fulgurita.*

Tyagi and Khan (1993) conducted this type of study to screen one hundred sixty clones of poplar for their relative resistance to *Pygaera cupreata* Butler and on the basis of maximum and minimum infestation the clones were categorized from resistant to susceptible as EL-clones > D-clones > G-clones > other clones > ST- clones. Ahmad (1993) evaluated 109 nine clones of *P. deltoides* for their relative resistance against its prime defoliator, *C. cupreata*. Clone 67 of USA was found to be the most resistant clone with the weightage percentage of resistant as 100. All the clones were categorized into six homogeneous groups of 13, 26, 19, 24, 14, and 13 in different categories i.e. R1, R2, R3, S1, S2, and S3, respectively. Singh (2000) studied the relative susceptibility and resistance of 80 clones to *C. cupreata* larvae. Clone 110120 of Tennessee was the most resistant where as Oklahoma clone 104 was most susceptible to this pest. Amongst the most resistant clones, WSL-4, WSL-12 and WSL- 18 were found to be superior, in terms of growth increment as compared to the standard and most widely planted clones in the northern India (G-3 and G-48). Singh and Pandey (2000) screened 40 clones of *P. deltoides* on the basis of feeing potential of second instar newly moulted larvae of *C. cupreata*. Clone G-48 followed by clones S_4C_2, 113413, 3567 and S13C14, respectively, were ranked as most resistant clone. S_7C_8 followed by clone 113324, S_7C_1, 82-33-1, ST-124, D-75 and 82-26-5 were found to be most the susceptible. Singh (2002) tested 39 poplar clones for their relative natural resistance against the defoliator *C. cupreata* and results revealed that Clone 14-15-6-1 (Mississippi) was the most resistant and clone 77-26-7-1 the most susceptible. Singh and Pandey (2002) evaluated relative natural resistance/susceptibility of 45 *P. deltoides* clones against its potential insect defoliator, *C. cupreata*, in Northern India. Seven American clones (D-171 > 82-42-5 > 3167 > 3324 > S7C13 > D-273 > S7C4) lying amongst the first 12 clones at the resistant end were identified as promising clones based on their superior growth performance and survival in the field plantations.

Comparative Development of *C. restitura*

Based on categorization of clones according to Ahmad (1993), clones WSL 22, S7C15 and PL5 were relatively more resistant to *C. restitura*. To ascertain the effect of clones on biological parameters, one generation of *C. restitura* was

Table 2. Duration of larval instars of *C. restitura* on different poplar clones

Clones	*Mean duration of different larval instars (days)				
	I	I	III	V	IV
PL5	3.06±0.06	2.06±0.06	3.13±0.31	2.88±0.41	4.50±0.20
WSL 22	2.50±0.29	2.29±0.17	2.58±0.14	2.92±0.42	4.04±0.27
S7C15	2.67±0.24	2.25±0.25	2.46±0.21	4.00±0.41	4071±0.17
CD (p= 0.05)	NS	NS	NS	NS	NS

* Mean± SE of 20 Observations

studied on relative resistant clones (WSL 22, S7C15 and PL 5).

Duration of larval instars. Duration of larval instars did not differ significantly when *C. restitura* was reared on three different clones of poplar, i.e. G48, WSL 22 and S7C15 (Table 2). The duration of first, second, third, fourth and fifth larval instar was 3.06±0.06, 2.06±0.06, 3.13±0.31, 2.88±0.41 and 4.50±0.20 days on PL5; 2.50±0.29, 2.29±0.17, 2.58±0.17, 2.92±0.42 and 4.04±0.27 days on WSL 22; and 2.67±0.24, 2.25±0.25, 2.46±0.21, 4.00±0.41 and 4.71±0.17 days on S7C15, respectively.

Larval period and survival. The total larval period on PL5, WSL 22 and S7C15 was 15.63±0.46, 14.33±0.51 and 16.08±0.49 days, respectively. However there were no significant differences among the three clones. The survival of larvae of defoliator was 50.0, 45.0 and 40.0 per cent when reared on PL5, WSL 22 and S7C15 clones, respectively with non-significant differences between the three (Table 3).

Pupal period and survival. The differences in pupal period among different clones of poplar were non-significant (Table 3). The duration of pupal period was 8.40±0.18 days on PL5, 9.33±0.51 days on WSL; and 22 9.75±0.75 days on S7C15.The survival of the pupae did not differ significantly among different poplar clones (Table 3). It was observed to be 75.0, 87.5 and 87.5 per cent on PL5, WSL 22 and S7C15 clones, respectively.

The results of present investigation were in conformity with the findings of earlier workers. Mann (1982) studied various biological parameters of *C. restitura* and reported the incubation period, larval period, pre-pupal period and total life cycle was 5-6, 38-55, 3-4 and 46-55 days, respectively. Sohi *et al.* (1987) reported incubation period, larval period, pupal period and total life cycle of *C. restitura*, 5-7, 25-30, 4-7 and 30-45 days, respectively. Sangha *et al.* (2005) studied the biology of *C. restitura* and reported the larval, pupal and total life cycle of the insect varied from 11.5-25.9, 5.7-8.5 and 22-30 days, respectively.

Damage index given by Ahmad (1993) help in categorization of the clones based on standard deviations and mean of the leaf consumed by the larvae during 24 h. In present study the clones were categorised into five different categories. Study of one generation of *C. restitura* on WSL 22, S7C15 and PL5 (relative resistant clones) revealed non significant differences among biological parameters. This indicated that there should be other better method/ technique for evaluating resistance/susceptibility.

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Table 3. Total larval period, pupal period of *C. restitura* and their per cent survival on different poplar clones

Clones	Larval duration (days)		Pupal period (days)	
	Mean ±SE*	Survival (%)	Mean±SE*	Survival (%)
PL5	15.63±0.46	50.00 (44.98)	8.40±0.18	75.00 (67.47)
WSL 22	14.33±0.51	45.00 (42.10)	9.33±0.51	87.50 (78.72)
S7C15	16.08±0.49	40.00 (38.93)	9.75±0.75	87.50 (78.72)
CD (p= 0.05)	NS	NS	NS	NS

* Mans± SE of 20 observation; figures in parentheses are arc sine values

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Short Rotation Forestry in Jammu and Kashmir: Options and Opportunities

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The state of Jammu and Kashmir is located in the North-Western corner of India, stretching between 32°-17' N to 37°- 05' N latitude and 72°- 31'E to 80°- 20' E longitude. The mountainous region is characterized by diverse ecosystem with respect to relief and agro-climatic situations. The state occupies total geographical area of 22.223 m ha, half of which is under the illegal occupation of Pakistan and China. The region comprises of diverse natural vegetation ranging from lush green conifers on gentle slopes of high altitudes, scrub jungles in the foot hills to deciduous flora on southern slopes of Shiwaliks and Pir Panjal ranges. The total forest cover in the state is 2.023 m ha (Anon., 2009) accounting to 19.95 per cent, which is far below the National Forest Policy recommendations. The three distinct agro-climatic regions namely, sub-tropics of Jammu, temperate of Kashmir Valley and cold arid region of Ladakh have witnessed exponential growth in human and livestock population, rapid industrialization and a spurt in developmental activities. These have resulted in loss of forest area accompanied by an overall degradation of forest crop and forest soils.

Per capita forest cover has also witnessed a sharp decline from 0.85 ha in 1947 to 0.20 ha in 2009 due to rapid population growth. Total growing stock in the region is estimated to be 132.92 million m^3 with an average annual yield of 1.65 m^3 contributed mainly by coniferous species occupying 31.8 per cent of the total forest cover (Anon., 2009). Pre-dominant species include deodar (*Cedrus deodara*), kail (*Pinus wallichiana*), fir (*Abies pindrow*) and chirpine (*Pinus roxburghii*) (Table 1).

Forests of the region are managed primarily for timber production besides sustaining many forest based industries like resin/turpentine, wooden works, silk, leather tanning, etc. The destructive causes to damage the forests are illicit felling, encroachments, unauthorized grazing and forest fires. To overcome these problems massive plantations have been raised on the pattern of Joint Forest

Table 1. Major forest types of Jammu and Kashmir

S. No.	Forest type	Area covered in sq km (% of total area)	Dominant species
1.	Sub-Tropiocal Dry Deciduous Forests	807 (4)	Found in lower reaches of Shiwaliks of Jammu region. Important species include *Acacia catechu*, *Dalbergia sissoo*, *Acacia modesta*, *Albizia* spp., *Salmalia malabarica*, *Eucalyptus* spp., *Dendrocalamus strictus,* etc.
2.	Sub-Tropiocal Pine Forests	2732 (14)	Located in upper reaches of Shiwaliks and outer Himalayas and include species like *Pinus roxburghii*, *Albizia* spp., *Dalbergia sissoo*, *Olea cuspitata* and other broad leaved as associates.
3.	Himalayan Moist Temperate Forests	8914(44)	This type of forests are found in Chenab valley and common associates are *Cedrus deodara, Pinus wallichiana, Picea smithiana, Pinus gerardiana, Abies pindrow*, *Juglans regia*, *Acer* spp., *Populus ciliata*, *Prunus padus* and other broad leaved species like *Aesculus indica*, *Fraxinus floribunda*, *Quercus* spp., etc.
4.	Himalayan Dry Temperate Forests	1378 (7)	This include the main forests of Kashmir Valley with tree species like *Cedrus deodara, Pinus wallichiana, Picea smithiana, Pinus gerardiana, Abies pindrow*, *Juglans regia*, *Acer* spp., *Prunus* spp., *Aesculus indica* and a typical under growth of *Parrotia jacquementiana.*
5.	Alpine Forests	5716 (28)	These forests are situated well above the main temperate zone. Common species are high level fir and kail, Junipers, *Quercus* spp., *Populus ciliata, Betula* spp., *Salix* spp., *Rhododendron* and wide variety of wild flowers and grasses.

Source: Anon. (2009)

Management (JFM) by sharing its harvests among the people. Production of timber from the forests to the tune of 72.207 thousand m^3 has been realized during 2008-09 with revenue of 1,18.55 million. Total fire wood out turn during 2008-09 was 99,98 tones by the forest department. Although, commercial felling of green trees has been discontinued, mortality of trees due to natural causes is unavoidable such as continuous and unrestricted grazing, deficit regeneration, forest fires, invasive weeds, un-regulated tourist movement, lack of timely and appropriate silvicultural operations. As a result, more than 40 per cent of forests in the state have moved to the category of open forests.

Why Short Rotation Forestry (SRF)

Failure of the natural forests to regenerate, sustaining the farmlands, forests and industries, meeting bio-energy needs, conservation of biodiversity as well as natural landscape and environmental mitigation, integration of short rotation species seems to be the only viable option under the present scenario. The traditional species of the region including confers like *Cedrus deodara, Pinus roxburghii, Abies pindrow, Picea smithiana* and broad leaved like *Quercus* spp. having rotation of more than 75 years and felling restrictions imposed in conventional forests, fail to meet the regional requirements. Thus, Short Rotation Forestry (SRF) aiming at the intensive culture of fast growing hardwoods at close spacing for a rotation period of 10-30 years for energy or small timber is ecologically acceptable.

Short Rotation Forestry (SRF) is the only fastest silvicultural practice to reforest vast areas of barren forest lands, deforested mountains, salty grounds, enhance farm income, from subsidence farming and also to mitigate adverse influence of global climatic change (Christersson and Verma, 2005). SRF offers better energy returns than conventional forestry and coppice crops. Ravindranath et al. (2001) predicted that to meet the biomass demands by 2015, 3.63 mha area has to be covered under SRF with 0.12 m ha annually.

Choice of species. Choice of the species is the key component in meeting the requirements of SRF. Species should be native, naturalized and exotic as well. The indigenous tree species suitable under SRF in different agro-climatic situations of Jammu and Kashmir (India) are summarised in Table 2.

Table 2. Indigenous tree species under SRF

Zone	Species
Sub-tropical zone	*Albizia lebbeck, A. procera, Azadirachta indica, Morus alba, Eucalyptus* spp., *Leucaena leucocephala, Populus deltoides, Acrocarpus fraxinifolius, Melia azedarach, Bombax ceiba*, Bamboo, etc.
Temperate and cold arid zones	*Populus ciliata, Salix* spp., *Robinia pseudoacacia, Alnus neplensis, Ulmus wallichiana,* etc.

Area available for undertaking SRF. Under the prevailing situations, the land areas to be put under SRF be identified. Area under rehabilitation of degraded forests under various programmes in the state is 3,664 ha. The state also possesses 6.529 m ha as the cultural non-forest area, which can be put to judicious use under the concept of short rotation management. Agricultural lands including farmer arable and pasture lands, marginal lands with low opportunity costs for high yields to establish biomass based energy systems such as slopes, marginal and degraded ones, and integration of SRF with traditional cereal and fruit crops or grazing lands in different agro-ecological situations are potential areas of concern and importance for SRF.

Future Strategies to Extend Area under SRF and Productivity

- Facilitation of local communities and big farmers to take up SRF which in turn will generate employment and reduce the pressure of import of wood /wood products.
- Institutional funding to promote farmer-industry relationship in production forestry, the long gestation activity.
- Leasing of degraded forest lands and non-forested wastelands to co-operative societies, corporate houses and interested individuals can promote the SRF**.**
- Availability of quality planting material of species selected for promotion under SRF.
- Development of SRF based farm forestry models for different regions.
- Arrangement of credit facilities for these interventions and developing organized market with policy planning at the state level.
- Setting up of a separate mission to manage Short Rotation Forestry (SRF) as a viable renewable energy source, etc.

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Growth Performance of Different Multipurpose Tree Species under Riverain Soils of Punjab

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In the developing countries like India, traditionally, trees occupy a place of paramount importance in meeting the basic needs of timber, fodder, energy, etc. Major portion of wood now produced in the country comes from tree plantations established outside the conventional forest areas. Plantation boom in the country occurred in 1979 after the establishment of Forest Development Corporations (FDCs) in the states and launching of Social Forestry Projects with the help of external donors. India's achievements in raising tree plantations in term of area have been impressive and figures second in the world after China (Anon. 2001). Till 1997-98, the total area of tree plantations under different schemes was 28.28 m ha. Of this, some 3.54 m ha were raised before 1980; 13.51 m ha during 1980s and the rest during the 1990s (Bansil, 2002). The current rate of planting is about 1.2 m ha.

The existing recorded forest cover in India occupies about 69.09 million ha, which is 21.02 per cent of the total geographical area of the country (FSI, 2009). In addition, the tree cover of the country has been estimated as 92,769 km^2 (2.82 per cent of the country's geographical area). Therefore, there is need to extend tree plantations on non-forestry lands, which include in its fold, environmental goods and services like carbon sequestration, replacement of fossil fuels, bio-diversity conservation, soil and water conservation and eco-tourism in addition to conventional forestry products in which the participants share the economic values. There are number of multipurpose tree species existing throughout the tropical and sub-tropical parts of India. But the paucity of information on their natural variability, adaptability and growth performance in different agro-climatic zones of Punjab have restricted their optimum utilization. The present study was therefore proposed to assess the performance of some selected indigenous and fast growing exotic tree species and to select the promising ones for massive afforestation programme.

The field experiment was established at Agroforestry Research Farm, Ladhowal (Ludhiana) during August, 2003. To evaluate the performance of 18 tree species. Ladhowal is located at 30°56'N Latitude and 75°52'E Longitude at a mean height of 247 m above mean sea level. The soil of the experimental area is sandy loam in texture. The pH of soils ranges from 7.7 to 8.2 and electrical conductivity between 0.16 to 0.21 dSm^{-1}. In general, the experimental site comes under Zone VI (Flood plain zone) of agro-climatic zones of Punjab, the climate typically shows three distinct seasons viz.; a hot dry summer (March-June), a warm rainy season (July-October) and a cool dry winter (November-February). The average annual rainfall is 750 mm and of this 80 per cent occurs during the rainy season i.e., July-September.

The experiment was laid out in the completely randomized design with 18 tree species i.e. *Acacia auriculiformis, A. catechu*, *A. nilotica, A. auriculiformis* prov. *springvalle, Acrocarpus fraxinifolius, Albizia lebbeck, Anthocephalus cadamba, Bombax ceiba, Eucalyptus tereticornis, Gmelina arborea, Holoptelia integrifolia, Leucaena leucocephala, Madhuca indica, Melia azedarach, Morus alba, Pongamia pinnata, Syzigium cuminii* and *Terminalia arjuna* in 4 replications at spacing of 6 m x 3 m. Biometric observations namely per cent survival, height (cm), collar diameter (cm) and crown spread (east-west and north-south directions) were recorded for different species in each replication during January 2005 (at the age of 2.5 years). The growth data were analyzed statistically to test the differences in growth at 5 per cent level of significance.

Results pertaining to the survival and growth performance of different multipurpose tree species are presented in Table 1. Cent per cent survival was recorded in *Acacia catechu, A. nilotica, M. azedarach, P. pinnata, S. cuminii* and *T. arjuna* followed by 97.50 per cent survival in *A. auriculiformis, A. auriculiformis* prov. *springvalle* and *Gmelina arborea*. *Albizia lebbeck, Anthocephalus cadamba* and *Morus alba* had significantly lower survival rate i.e., 90.00 per cent to *Acacia catechu, A. nilotica, Holoptelia integrifolia, Pongamia pinnata, Syzigium cuminii* and *Terminalia arjuna*. Minimum survival (72.50%) was recorded in *Eucalyptus tereticornis.* The variation in survival percentage of the species can be ascribed to the genetic behaviour of the species on riverain soil.

Plant height varied from 66.67 cm to 281.49 cm and three species, *Acacia catechu, Eucalyptus tereticornis* and *Terminalia arjuna* exhibited better growth than other species, whereas, *Madhuca indica, Bombax ceiba, Albizia lebbeck* and *Holoptelia integrifolia* performed poorly. Fast growth is one of the important attributes of a successful species, which ensures higher photosynthesis rate and least competitions with weeds. This is also silviculturally important attribute, which extends the time interval between planting and successive first weeding operation in a stand. The fast growth of *Acacia catechu* can be attributed to inherent ability of the species to grow better under riverain soil condition and also accelerated fixing of atmospheric nitrogen through symbiotic association with *Rhizobium* bacteria in nodules on the roots. This can help the plants to survive and grow fast on such soils. The nitrogen fixing ability of Mimosoid species, especially *Acacia* species have been well documented in many earlier studies (Dubey *et al.,* 2004; Kanmegne *et al.,* 2000; Gera *et al.,* 1996) to boost the growth.

Collar diameter of different MPTs differed significantly and it varied from 1.45 cm to 5.87 cm (Table 1). Maximum collar diameter (5.87 cm) was observed in *Terminalia arjuna* followed by *Acacia catechu* (5.65 cm) but as such, the results were statistically at par with each other followed by statistically lower values under *Anthocephalus cadamba* and *Melia azedarach* with collar diameter 4.33 cm and 4.02 cm, respectively. Minimum collar diameter (1.45 cm) was recorded in *Acrocarpus fraxinifolius,* which was statistically at par with *Madhuca indica* (1.50 cm), *Albizia lebbeck* (1.57 cm), *Holoptelia integrifolia* (1.59 cm) and *Acacia auriculiformis* (1.61 cm). Collar diameter is a key indicator of healthy stock, which in turn results in successful establishment of seedlings after field planting. Diameter growth indicates the adaptation of tree species to the site (Kanmegne *et al.,* 2000). Growth in diameter and height is a response of tree to its particular combination of heredity and environment (Singh *et al.,* 2004).

Plant foliage spread varied from 68.12 cm to 266.86 cm. Maximum plant spread (266.86 cm) was recorded in *Acacia catechu*, which was statistically superior than the plant spread in *Anthocephalus cadamba* (185.58 cm) and *Terminalia arjuna* (178.96 cm), the later two were statistically at par with each other. Plant spread in *Eucalyptus tereticornis* and *Acacia nilotica* formed the second group with respective values of 161.00 cm and 148.88 cm. The plant spread in *Syzigium cuminii* (107.39 cm) and *Melia azedarach* (100.43 cm) was found to be statistically at the par with each other. Minimum plant spread (68.12 cm) was recorded under *Madhuca indica* followed by *Pongamia pinnata* (73.28 cm) and *Leucaena leucocephala* i.e., 76.04 cm. Under agroforestry system for proper utilization of

Table 1. Survival percentage and growth performance of different MPTs under riverain soils of Punjab

Name of the Species	Survival (%)	Height (cm)	Collardiameter (cm)	Plant spread (cm)
Acacia auriculiformis	97.50	111.00	1.61	73.04
Acacia catechu	100.00	281.49	5.65	266.86
Acacia nilotica	100.00	195.92	3.55	148.88
Acacia auriculiformis prov. *springvalle*	97.50	139.30	2.29	81.93
Acrocarpus fraxinifolius	75.00	115.30	1.45	85.44
Albizia lebbeck	90.00	100.17	1.57	81.63
Anthocephalus cadamba	90.00	187.20	4.33	185.58
Bombax ceiba	82.50	92.45	2.08	86.20
Eucalyptus tereticornis	72.50	223.99	3.45	161.00
Gmelina arborea	97.50	157.56	2.78	93.61
Holoptelia integrifolia	100.00	103.77	1.59	90.17
Leucaena leucocephala	92.50	143.90	2.20	76.04
Madhuca indica	95.00	66.67	1.50	68.12
Melia azedarach	100.00	196.70	4.02	100.43
Morus alba	90.00	121.20	2.22	83.36
Pongamia pinnata	100.00	120.17	2.17	73.28
Syzigium cuminii	100.00	142.92	2.91	107.39
Terminalia arjuna	100.00	210.28	5.87	178.96
CD (0.05)	3.31	22.86	0.55	7.53

natural resources and optimization, trees with less canopy spread are preferred, on the contrary, larger canopy spread is desired to maximize fodder production, hence, choice of the tree species is made accordingly. It is clear that inspite of the similar microsite environment, tree species exhibited differential intrinsic ability to achieve differential growth. The better growth potential of some tree species can be ascribed to better adaptability and utilization of site resources, which makes these tree species superior to other ones under the prevailing growing conditions.

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Role of Short Rotation Forestry Products in Enhancing Carbon Mitigation in India

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Climate change is a global environmental problem that has been associated with increasing concentrations of greenhouse gases (GHGs). Our modern lifestyles, the products we choose, the emissions of carbon dioxide from industry, society, transport and from our homes, have increased the concentration of CO2 in the atmosphere. The build-up of greenhouse gases (GHGs) in the atmosphere, much of it driven by human activity, is already affecting the global climate. Under current projections, concentrations of GHGs will continue to increase into the indefinite future, entailing a process of continued global warming. Between 1850 and 1998, some 270 billion tonnes of carbon were released into the atmosphere in the form of CO_2, mainly through the combustion of fossil fuels, resulting in a 30 per cent increase of CO_2, in the atmosphere. Accumulation of 3.3 billion tonnes of carbon a year. World GHG emissions have roughly doubled since the early 1970s, and on current policies could rise by over 70% during 2008-2050. In recognition of this, the UN General Convention on Climate Change, drawn up in Rio in 1992, agreed as its principal objective that the concentration of greenhouse gases should be stabilized at a level that does not represent a hazard to the environment. In 1997, the Kyoto Protocol set quantitative targets for how far emissions should be reduced, calling upon the industrialized countries to bring down average emissions between the years 2008 and 2012 by 5.2 per cent from the level of 1990.

GHG emissions through wood substitution, biomass substitution, and avoided land-use change. Substituting wood products obtained from sustainably managed forests addresses climate change in several ways, including fixing the carbon in store. The carbon in lumber and furniture, for example, may not be released for decades. Storage of carbon in harvested wood products is gaining recognition in climate change mitigation programmes. The climate change benefits of wood products lie in the combination of long-term carbon storage with substitution for other materials with higher emissions. As wood can substitute for fossil fuel intensive products, the reduction in carbon emissions to the atmosphere is comparatively larger than even the benefit of the carbon stored in wood products. This effect-displacement of fossil fuel sources could make wood products the most important carbon pool of all. Simplified methods for estimating the fate of carbon in wood products need to be developed to allow estimation at the national level. Economists argue that if the cost of carbon emission was bid in the market, consumers would effectively make purchases that would reduce emissions. Almost every change in product design, product selection, or management results in changed levels of carbon emission across different stages of processing.

Global Instruments for Climate Change Mitigation

The United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in 1992 at the United Nations Conference on Environment and Development (UNCED), aims at stabilizing the concentration of greenhouse gases in the atmosphere so as to prevent dangerous human-induced changes to the global climate system. Parties to the UNFCCC committed themselves to carrying out national inventories of greenhouse gas emissions and carbon sinks. Industrialized countries and the economies in transition (Annex I Parties) committed themselves to working towards voluntary goals in the reduction of emissions. These obligations were intensified and specified in the Kyoto Protocol, which was adopted at the Conference of the Parties (COP)-3 of the UNFCCC, held in Kyoto, Japan in December 1997. By June 2007, a total of 175 states had joined the Kyoto Protocol, accounting for 61.6 per cent of CO_2, emissions of all Parties. The Protocol came into force on February 16, 2005. There are mechanisms under the Kyoto Protocol which allow for some flexibility in how countries make and measure their emission reductions. These include the Joint Implementation (JI) and the Clean Development Mechanism (CDM) which include forestry projects. Today, the Kyoto Protocol is the most universally applied agreement for CO_2 reduction. However, a major shortfall of the Kyoto Protocol is the lack of assertive sanction mechanisms because of which it will be difficult to ascertain its effectiveness as a mechanism for reducing CO_2 emissions.

Role of Short Rotational Species

Carbon mitigation options include reducing emissions from deforestation and forest degradation, enhancing the sequestration rate in existing and new forests providing wood fuels as a substitute for fossil fuels and providing wood products for more energy-intensive material. One of the measures that are receiving increased attention is land management to protect and reforest forest land either by direct forest management or by establishment of fast growing plantations that can be substituted for fossil fuels in energy production. A recent FAO study has indicated that potential industrial wood production from planted forests in 2005 was 1.2 billion m^3 or two thirds of the overall industrial wood production in that year. Establishment of plantations on degraded and waste lands is one of the best and the most promising options for halting deforestation and increasing carbon storage in trees. In India, trees outside forests have a major contribution in meeting timber and fuel wood needs. It is estimated that the amount incurred for total import of timber including paper and pulp into the country is in the order of Rs.12,000 crores per year. A realistic harmonization of various projections indicates a demand for wood for panel products in the range of 30.53 million cu.m. annually. Studies reveal that for short rotation species, the amount of carbon offset increases linearly with time since biomass is continuously harvested and replanted and used. On forest lands, the carbon balance is negative in the beginning (due to enhanced decomposition) but it turns positive after 3 and 14 years respectively for long rotation sal forests and short rotation poplar species. On non-forests lands, at 6 years, the carbon sink attains a maximum value of 11 Mg C ha^{-1} yr^{-1} for short rotation poplar plantation. The carbon benefit at any time is highest for short rotation poplar plantation. This may be attributed to the high carbon sequestration rate and high energy conversion efficiencies. At year 100 a total of 216 Mg C ha^{-1} yr^{-1} is sequestered for afforestation/reforestation using long rotation sal species, as opposed to offset of 412 Mg C ha^{-1} yr^{-1} for carbon storage for short rotation poplar plantations. Using short rotation plantations for electric power generation gives a mitigation potential in the range of 227 to 303 Tg carbon per year form carbons torage and fossil fuel substitution. The energy generation potential of plantation generating 758 Tg wood annually would be 11,370 Pj. Thus plantation biomass could supply about 43% of the total projected energy consumption in India by 2015

Life Cycle Assessment and Carbon Foot Prints

Life cycle assessment of every product being used is very essential tool . In India, the studies related to durability or service life of wood based panel products have been studied which would form a part of life cycle assessment. However, not many studies were made to study the energy, pollution and other issues involved from the manufacturing stage to the final usage of the panel products. IPIRTI has taken up a project to assess the life cycle of wood based panel products. It has been found that the pollution released from panel industries are very negligible compared to concrete, brick, ceramic tiles, aluminium and steel. The energy involved in the production is also less. After the service life of the panel products, the same product can be recycled into a range of products including particleboard. The panel products/timber which are not suitable for reuse or recycling can be utilized to generate renewable energy, releasing the carbon back into the atmosphere to be reabsorbed by the growing trees. For waste not suitable for reuse, recycling or renewable bioenergy, Australian research has shown that end-of-life timber stores the carbon for very long periods of time in well-managed landfills. The use of wood based panel products as a building material creates a much lower carbon footprint than does the use of other common building materials. The research showed that more than 25 tonnes of greenhouse gases could be saved if timber products were used instead of the common alternatives. Greenhouse gas emissions from the manufacture of different building components in a family home are shown in Fig. 1**.** The chemical analysis of wood products buried for 25yrs have revealed that only up to 3.5% of the carbon in wood products was lost through decomposition. It is reported that timber can store up to 15 times the amount of carbon that is released during its manufacture.

The manufacture of timber building components uses considerably less energy than the manufacture of other major products such concrete, brick, ceramic tiles, aluminium and steel. It therefore follows that usage of timber and timber will leave a smaller carbon footprint. Based on the survey of builders it is estimated that at least 25% of the carbon in the wood in dwelling would be sequestered in use for at least 100 years. Timber production also makes a positive contribution to reducing carbon emissions by being part of the short term carbon cycle that involves trees absorbing carbon dioxide from the air, releasing oxygen and storing the carbon in the wood. Using trees for timber and other wood products in this way creates space in plantations and hardwood production forests for replacement trees to absorb more carbon from the atmosphere.

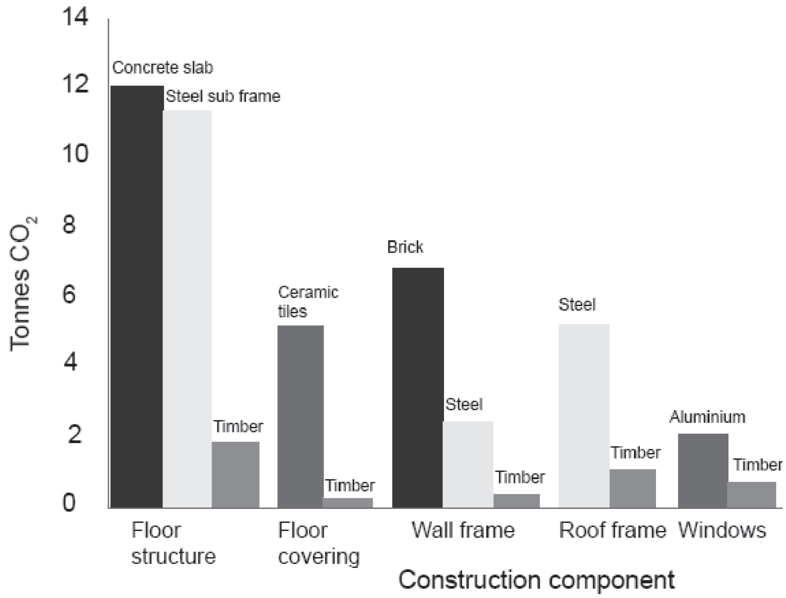

Fig.1. Greenhouse gas emissions from the manufacture of different building components in a family home (Source: CRC for Greenhouse Accounting)

In the early days of development of plywood and panel industries, environmental issues represented a very small component of any decision to build and operate a wood composite plant. However, in today's highly sensitive environmental climate, these issues have come to represent a significant initial and operating investment. The most suitable option for a developing country like India lies in the use of non forest lands for fast growing short rotation plantations. Short rotations plantations with higher growth rates result in greater net carbon benefit at the end of 100 year as compared to long rotation forests used for permanent carbon storage. An understanding of promising new environmental friendly technologies and their application will go a long way in sustainable development of these industries. R & D works done at IPIRTI in the last couple of years in the field of development of bio-adhesives, wood alternatives based on fast growing agro forestry timber species, and other renewable fibres like bamboo and agro residues, and use of eco-friendly preservatives as glue line additive, have significantly contributed to the development of greener engineered panel products. It is therefore envisaged that more use of fast growing plantation wood by the plywood and panel industries and application of green technologies will go a long way in tackling the problems of global warming and climate change mitigation. The inclusion of wood and wood-based products into carbon accounting will constitute a positive step to increase wood consumption and carbon removals from the atmosphere by wood products.

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Prospects and Challenges of Biomass Use in Power Generation

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Biomass is produced by green plants, which converts sunlight into plant material through photosynthesis and includes all land- and water-based vegetation, as well as all organic wastes. The biomass resource can be considered as that organic matter, in which the energy of sunlight is stored in chemical bonds. Biomass is the fourth largest energy source after coal, oil and natural gas. It is the largest and most important renewable energy option at present. Renewability and versatility are the among many other important advantages of biomass as an energy source. Compared to other energy sources biomass resources are common and wide spread viz., woody crops & residues, agricultural crops & residues, sewage, industrial residues, animal residues and municipal solid wastes, waste dry biomass-wood chip, wood pellets, rice husk, waste wood, bark and fruit cones, etc. Burning fossil fuels uses "old" biomass and converts it into "new" CO_2; which contributes to the "greenhouse" effect and depletes a non-renewable resource. Burning new biomass contributes no new carbon dioxide to the atmosphere, because replanting the harvested biomass ensures that CO_2 is absorbed and returned for a cycle of new growth. One important factor, which is often overlooked when considering the use of biomass to assist alleviate global warming, is the time lag between the instantaneous release of CO_2 from burning fossil fuels and its eventual uptake as biomass, which can take many years. One of the dilemmas facing the developed world is the need to recognize this time delay and take appropriate action to mitigate against this lag period. An equal dilemma faces the developing world as it consumes its biomass resources for fuel but does not implement a programme of replacement planting. Numerous crops have been proposed or are being tested for commercial energy farming. Important tree and crops for biomass production for bioenergy are: eucalypts, poplar, leucaena, switch grass, miscanthus, sorghum, sugarcane, canola starch and sugar crops and oilseeds. Energy yield from various crops is presented in Table 1.

Annual global primary production of biomass. Potential of annual global primary production of biomass is estimated to be equivalent to 4500 EJ of Solar energy captured each year. About 5 per cent of this energy i.e., 225 EJ should cover almost 50 per cent of the World's total primary energy (Ladani and Vinterback, 2009). As per the estimates upto 2050, the annual bioenergy requirement to meet global energy demand shall supersede 1000 EJ. More than 30% of the world's biomass resources are located in Asia and in this region, labour inputs and transportation cost are competitive than rest of the world.

Presently sustainable potential of global biomass resources is widely recognized. The land devoted to growing energy crops for biomass fuel is only 0.19 per cent of the world's total land area. It is only 0.5 to 1.7 per cent of global agricultural land (Ladani and Vinterback, 2009). Large potential by algae as biomass resource is not included. Thus, biomass potential for energy production is promising. Sustainably grown biomass fuels such as wood make only very small contributions to atmospheric carbon. The same amount of carbon that is released into the atmosphere when one crop is burned is reabsorbed by the plants grown for the next crop, and the carbon emitted by the machinery used to establish, grow, harvest and transport the biomass is very small. Biomass fuels result in fossil fuel emissions to the atmosphere being avoided by replacing fossil fuel.

Global energy consumption. Global Energy consumption is loosely correlated with gross national product and climate, but there is a large difference even between the most highly developed countries, such as Japan and Germany with 6 kW/person and United States with 11.4 kW/ person. In developing countries, particularly those which are sub-tropical or tropical such as India, the per person energy use is closer to 0.7 kW. Bangladesh has the lowest consumption with 0.2 kW/person. In 2008, total worldwide energy consumption was 474 exajoules (474×10^{18} J) with 80 to 90 per cent derived from the combustion of fossil fuels. This is equivalent to an average annual power consumption rate of 15 terawatts (1.504×10^{13} W). Not all of the world's economies track their energy consumption with the same rigor, and the exact energy content of a barrel of oil or a ton of coal will vary with quality.

Despite advances in efficiency and sustainability, of all the energy harnessed since the industrial revolution, more than half has been consumed in the last two decades. However, while considering this fact, it should not be overlooked that this is primarily the result of global increases in the standard of living and the increase in world population, and not as a failing of energy management as a whole. Energy consumption growth remained vigorous in several developing countries, specifically in Asia (+4%). Conversely, in Organisation for Economic Co-operation and Development (OECD) countries, consumption was severely cut by 4.7 per cent in 2009 and was thus almost down to its 2000 levels. In North America, Europe and Commonwealth of Independent States (CIS), consumptions shrank by 4.5 per cent, 5 per cent and 8.5 per cent, respectively, due to the slow down in economic activity. China became the world's largest energy consumer (18% of the total) since its consumption surged by 8 per cent during 2009 (from 4% in 2008). Oil remained the largest energy source (33%) despite the fact that its share has been decreasing over time. Coal posted a growing role in the world's energy consumption in 2009, it accounted for 27 per cent of the total.

Biomass and biofuel. Until the beginning of the nineteenth century biomass was the predominant fuel, today it has only a small share of the overall energy supply. Electricity produced from biomass sources was estimated at 44 GW for 2005. Biomass electricity generation increased by over 100 per cent in Germany, Hungary, the Netherlands, Poland and Spain. A further 220 GW was used for heating (in 2004), bringing the total energy consumed from biomass to around 264 GW. The use of biomass as firewood for cooking is excluded. World production of bioethnol increased by 8 per cent in 2005 to reach 33 billion liters (8.72 billion US gallons), with most of the increase in the United States, bringing it to the levels of consumption in Brazil. Biodiesel increased by 85 per cent to 3.9 billion liters (1.03 billion US gallons), making it the fastest growing renewable energy source in 2005. Over 50 per cent is produced in Germany.

Effect of changing climate on productivity of biomass. Environmental variables will not act in isolation, but also in combination with one another, and with other pressures such as habitat degradation and loss or the introduction of exotic species. It is suggested that these other drivers of biodiversity change will act in synergy with climate change to increase the pressure on species to survive (Mackey, 2007). Therefore, it is important to know, how C3 and C4 plants will respond in changing climate. Some studies have been reported how C3 and C4 plants will adapt to changing CO_2 and temperatures.

Biomass production by C3 and C4 Plants. The C4 plants are more efficient, resulting in higher biomass productivity. Many promising (tropical) energy crops follow this pathway. They include sugarcane, sorghum, and switch grass (*Panicum virgatum*). The researchers from China's Zhejiang University grew the three C3 grasses (*Poa annua* L., *Lolium perenne L., Avena fatua* L. and the three C4 grasses (*Echinochloa crusgalli* var. mitis (L.) Beauv., *Eleusine indica* (L.), *Setaria glauca* (L.) P. Beauv) from seed to maturity under well irrigated conditions within controlled-environment (maintained at a mean atmospheric CO_2 concentration of either 350 or 700 ppm) in pots containing 2.5 kg of soil that was low in extractable P content. Under these conditions, total aboveground plus belowground plant biomass was enhanced by an average of 9.92 per cent due to the doubling of the air's CO_2 concentration in the group of C3 grasses, but by an average of 12.27 per cent by the doubling of the air's CO_2 concentration in the group of C4 grasses. Tang *et al*. (2006) reported that the C3 grasses they studied had low mycorrhizal colonization and that atmospheric CO_2 enrichment did not significantly enhance this beneficial symbiosis, whereas, injecting extra CO_2 into the air did enhance mycorrhizal colonization in the C4 grasses. Mycorrhizae are the result of the colonization of the roots of the plants by a fungus, in a mutually beneficial relationship (either inside or outside of the root cells); the fungus survives by tapping energy (sugars) from the roots, but in exchange, it allows the plant to make use of the fungus' tremendous surface area to absorb mineral nutrients from the soil). In addition, a positive correlation between mycorrhizal colonization rate and shoot P concentration, between the increase in mycorrhizal colonization rate and the increase in total P uptake under elevated CO_2 was recorded, which indicates that mycorrhizae might enhance P uptake for plants that have high mycorrhizal colonization and then promote host-plant growth response to elevated CO_2 or this may be due to the fact that the grasses used in experiment were also significant mycorrhizal hosts and their mycorrhizal colonization was significantly stimulated by elevated CO_2 on this basis, it has been concluded that this situation may promote the total P uptake of the C4 grass in low P soil and enhance the C4 grasses response to CO_2 enrichment. Tang *et al.* (2006) had also included three C3 forbs (*Veronica didyma* Ten., *Plantago virginica* L., *Gnaphalium affine* D. Don.) in their study, as well as three legumes (*Vicia cracca* L., *Medicago lupulina* L., and *Kummerowia striata* (Thunb.) Schindl.), both of the plant groups responded better to the researchers' enriching of the air with CO_2 than did the two groups of grasses. The C3 forbs, for example, exhibited a mean biomass increase of 35.61 per cent, while the legumes exhibited a mean biomass increase of 41.48 per cent. They reported that high levels of mycorrhizae, and their mycorrhizal symbionts were stimulated greatly by CO_2. They again noted that the higher enhanced total P uptake of legumes under elevated CO_2 concentrations implies that mycorrhizae may facilitate P uptake and enhance legume response to elevated CO_2.

Productivity of C3 and C4 Plants under water stress environments. Plants naturally pump water from the soil and out through the tiny openings on their leaves called stomata by a process known as transpiration. These openings also allow carbon dioxide to be taken in by plants. Some plants have evolved to minimize water losses through transpiration, but they tend to grow very slowly, e.g. cacti. A minority of plants, for example sugarcane and maize, have evolved a different type of metabolism for sugar production called Carbon 4 (C4), whereas, most plants have a Carbon 3 (C3) metabolism. C4 metabolisms make better use of water than C3 in hot arid zones. However, C3 plants are more efficient in cooler moister conditions. C4 metabolisms make better use of water than C3 in hot arid zones. C4 plants have a competitive advantage over plants possessing the more common C3 carbon fixation pathway under conditions of drought, high temperatures, and nitrogen or CO_2 limitation. When grown in the same environment, at 30°C, C3 grasses lose approximately 833 molecules of water per CO_2 molecule that is fixed, whereas, C4 grasses lose only 277 water molecules per CO_2 molecule fixed. This increased water use efficiency of C4 grasses means that soil moisture is conserved, allowing them to grow for longer in arid environments. Ward *et al.* (1999) reported that C3 species may not be more severely affected by drought than C4 species at low partial pressure (þ$CO_{2)}$ and C3 species may not have an advantage over C4 species during drought in elevated partial pressure (þ CO_2). The C4 species may have advantage over C3 species in response to increasing atmospheric CO_2 and more frequent and sever drought.

Challenges to maintain biomass supply for biomass based power plants:

- Provision of genetically improved quality planting stock at low cost.
- Securing the long term supply of biomass fuel source at stable and low prices.
- Developing technologies for various woody crops to grow biomass on problematic sites (salt and waterlogged) and fixing its commercial rotations.
- Selling price of electricity, if connected to the grid to sell electricity
- Small sized biomass needs to be briquetted.
- Maintenance in remote region can be difficult and expensive
- Cheaper packing and transportation of agriculture and forest biomass from farm and its unpacking at power plant to keep the cost low for biomass handling.

Electricity production through biomass usage is viable option. In future, when fossil fuel supply becomes in short supply, the mankind has to rely upon to great extent on energy production through biomass and other renewable energy sources. Therefore, we have to develop strategic planning keeping in view the effect of climate change on biomass production and challenges outlined above to maintain biomass supply at low costs for biomass based power plants and accordingly we have to strengthen research and development efforts in this direction.

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Calorific Value Assessment of Selected Tropical Tree Species of the Southern India for Higher Fuelwood Potential

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In developing countries, the dependence on wood fuels is much greater. They provide about one-third of the total energy in these countries, and as much as 80 percent of energy is derived from biofuels in some sub-regions of Africa. Wood and charcoal, the most commonly used wood-based fuels, are vital to the nutrition of poor rural and urban households in developing countries. In addition to being used for domestic cooking and heating, they are often essential in food processing industries for baking, brewing, smoking, curing and producing electricity. Wood energy is the dominant source of energy for over two billion people, particularly in households in developing countries, it currently provide more than 14 percent of the world's total primary energy. Social and economic scenarios indicate a continuous growth in the demand for wood fuels that is expected to continue for several decades. Hence, in this regard selection of suitable fuelwood tree species with high calorific value is need of the day. The present study was conducted in the College of Forestry, Kerala Agricultural University, Trissur. The state of Kerala is endowed with high rainfall and most favourable humidity conditions which makes the way for growth of numerous tree species. Tropical rain forests with maximum species diversity of flora and fauna are in abundance in the state. Even when so many methods are being developed to improve the natural forests, it would not be possible to meet the increasing demand for food, fuel, fibre and timber. To meet this demand, the degraded forest, marginal land, village common land, strips on sides of roads, canals, railway, rivers and peripheries of agricultural fields could be utilized for planting of trees. For this purpose choice of species is an important criteria. The proper choice of tree species at a particular place which can yield enormous benefits is the need of the day.

The present experiment was carried out in the arboretum of College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, during the period 2006 to 2008. The experimental site is situated at 10°32' N latitude, 76°10' E longitude and at an altitude of 22- 23 m above mean sea level. The study site experiences a warm humid climate, having a mean annual rainfall of 2668 mm, most of which is received during the south west monsoon (June to September). The mean maximum temperature recorded at Vellanikkara varied from 28.4°C in July to 36.0°C in March. The mean minimum temperature varied from 21.6°C in November to 25.0°C in April. The soil of the experimental site is an Ultisol having a pH of 5 to 6, relatively rich in organic matter. The experimental materials consist of 10 trees each of 10 species planted in the instructional farm at a spacing of 4 x 4 m. Uniform seedlings were planted during 1991-92 and are being maintained. Proper watering and weeding were done during the initial stages of establishment and plant protection measures were taken up whenever necessary. The species, *Adenanthera pavonina* L. , *Artocarpus heterophyllus* Lam., *Bridelia retusa* L. A. Juss., *Ceiba pentandra* L. Gaertn, *Hydnocarpus wightiana* Blume., *Hymenodictyon excelsum* Roxb. Wall., *Peltophorum pterocarpum* Baker., *Pterocarpus santalinus* L. f., *Samadera indica* Gaertn. and *Tectona grandis* L.f. were included in the study for evaluation.

For estimation of calorific value of the tree species grown in the arboretum, samples of wood after drying in an electric oven at 103±2°C were chipped separately using a chisel to smaller sizes of approximately 0.3-0.4 cm thickness. The sample chips were then ground in an electric mill. The ground samples were stored in double sealed polythene covers. One gram of the ground material from each sample was accurately weighed and the calorific value was estimated using an Oxygen Bomb Calorimeter. A measured quantity of sample was burnt by supplying high voltage current through the electric terminals in the presence of oxygen and the heat absorbed by the water in the bucket was recorded. This rise in temperature is proportional to the gross energy value of the substance which is burnt. The calorific value was estimated by using the following formula:

$$\text{Calorific value (H)} = \frac{TW-(a+b+c)}{m}$$

H = heat of combustion of sample (cal.)
T = difference in initial and final bucket temperature (°C)
W = energy equivalent of bomb calorimeter (cal.°C)
a = acid correction

b = calories liberated during the ignition of tungsten wire (cal.)
c = calories liberated during the ignition of cotton thread (cal.)
m = weight of the sample (g)

Close perusal of the data indicated that calorific values of wood significantly varied between different species. It could be seen from the data that the basal portion of the trunk of *Pterocarpus santalinus* recorded highest calorific value (7143.63 $cal.g^{-1}$) followed by *Ceiba pentandra* (7088.75 $cal.g^{-1}$). *Samadera indica* has the least calorific value of 3593.01 $cal.g^{-1}$ followed by *Bridelia retusa* (3643.78 $cal.g^{-1}$). In the middle portion of trunk, *Pterocarpus santalinus* recorded the highest calorific value (6025.07 $cal.g^{-1}$) followed by *Hydnocarpus wightiana* (4723.10 $cal.g^{-1}$) and *Adenanthera pavonina* (4367.60 $cal.g^{-1}$), while *Ceiba pentandra* has the least (3345.36 $cal.g^{-1}$). With regard to the top portions of trunk, *Pterocarpus santalinus* recorded highest calorific value (6837.50 $cal.g^{-1}$) followed by *Adenanthera pavonina* (4572.57 $cal.g^{-1}$), while the least calorific value was recorded for *Ceiba pentandra* (2926.29 $cal.g^{-1}$). The data also revealed that the mean calorific value varied from 3626.85 to 6668.73 $cal.g^{-1}$ in various tree species studied. The mean calorific value was maximum for *Pterocarpus santalinus* (6668.73 $cal.g^{-1}$) followed by *Hydnocarpus wightiana* (4810.11 $cal.g^{-1}$) and *Ceiba pentandra* (4453.47 $cal.\ g^{-1}$). Least average calorific value was that of *Samadera indica.* The observations related to calorific value of tree species grown in arboretum are furnished in Table 1.

Based on the mean calorific values, *Pterocarpus santalinus, Hydnocarpus wightiana, Ceiba pentandra, Tectona grandis* and *Adenanthera pavonina* could be classified under high calorific value class indicating the use of these species and their branches as fuel wood trees also in agro/social forestry programmes. Shanavas and Kumar (2003) have reported the calorific values of 45 important fuelwood tree species grown in Kerala. Based on the results, trees were classified into high calorific value trees (>4500 $cal.\ g^{-1}$), medium calorific value trees (3750-4500 $cal.\ g^{-1}$) and low calorific value trees (<3750 $cal.\ g^{-1}$). He has reported high calorific values for bottom portion of trees. In the present study also, generally bottom portion of most of the trees recorded high calorific value. This may be due to the fact that tissues had low moisture content in these portions of the tree. However, this needs further investigations. Haufa and Wojciechowska (1986) reported that moisture content of wood have negative correlation with fuel wood value. Gupta (2006) also reported high calorific values for bottom portion of trees and calorific value decreased with rise in moisture content. The most promising tree species in terms of calorific value were in the order of *Pterocarpus santalinus > Hydnocarpus wightiana > Ceiba pentandra > Tectona grandis > Adenanthera pavonina > Hymenodictyon excelsum > Artocarpus heterophyllus > Peltophorum pterocarpum > Bridelia retusa > Samadera indica*. Study focused on the fuelwood potential of tropical tree species, which are earlier less known species as woodfuels. The present investigation indicated the scope of selecting tropical tree species with higher calorific value along with other qualities for distribution to farmers for social/agroforestry and even for general afforestation programmes.

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Table1. Calorific value of tree species

Species	Calorific value ($cal.g^{-1}$)			
	Base	Middle	Top	Mean
Adenanthera pavonina	4057.45	4367.60	4572.57	4332.54
Artocarpus heterophyllus	3848.28	3595.56	4261.15	3901.66
Bridelia retusa	3643.78	3541.73	4209.03	3798.18
Ceiba pentandra	7088.75	3345.36	2926.29	4453.47
Hydnocarpus wightiana	4776.13	4723.10	4931.10	4810.11
Hymenodictyon excelsum	4370.56	4108.77	4008.27	4162.53
Peltophorum pterocarpum	4261.73	4107.41	3027.64	3798.93
Pterocarpus santalinus	7143.63	6025.07	6837.50	6668.73
Samadera indica	3593.01	3590.74	3696.79	3626.85
Tectona grandis	4367.91	4366.01	4413.48	4382.47
CD (0.02)	2.46	2.66	2.68	
S.Em ±	1.17	1.27	1.28	

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Development of the Goettingen Conservation Chipper Harvester for the Production of Quality Wood Chips from Agroforestry, SRC and Open Land Vegetation

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Based on the experiences with a bush chopper for secondary forest vegetation in Brazil (Wegener and Block, 2005), the Section of Agricultural Engineering and partners have developed and tested a helical chipper prototype that should allow the integrated strip cutting, chipping and salvaging of woody biomass. The aim was to design a rear attachment for a backward steering forest tractor with an engine power of 130 kW that can clear succession vegetation, short rotation coppice, hedgerows, logging trails or roadside vegetation in a single-action move without manual handling. The development took place within the framework of the DBU-supported project "Fully mechanised landscape conservation in nature reserves and Natura 2000 sites". Field trials helped to redesign and improve the device in order to enhance the overall performance and to adapt it to special purposes (Wegener and Block, 2006a).

The background for this development is the vast area of non-productive land that cannot be let prone to natural succession for ecological, statutory and cultural conservation reasons. Further potential for energetic utilization lies in the planned and spontaneous vegetation along roadsides. The main challenges are to handle the often irregular and highly diverse structure of heterogeneous plant stands, spatially as well as under the terms of age, stem diameter, species, growth stage and area relief. Additionally the amount of manual handling is to be reduced to a minimum due to high labor costs in Germany and security demands. A further goal is to fell the stems in a certain height with a thorough cut that does not damage the root stock and enables the plantation to sprout again. This feature would allow for an application in short rotation coppice, too. Unlike self-propelled field choppers used in maize, the device and its carrier cannot be too heavy in order to avoid soil compaction and sod or root damage in protection areas. It has to have a high maneuverability in order to move back and forth and to work along road sides. Mere mulching is not desired because the contained nutrients (especially from leguminous trees) shall be removed from the protection areas and because the dendromass offers an energetic value that can partly cover the costs for harvesting measures. The principle of an energy saving, smoothly spinning and self-feeding helical chipping drum (Fig. 1) known from the bush chopper (Wegener and Block, 2005) shall be used again. Finally the wood chips shall have a coarse (ideally 50 to 100 mm) but even particle size distribution in order to facilitate low-cost drying by blower aeration and their use in district heating incinerators or in special wood gasification reactors depending on a good aeration of the firebed (Wegener and Block, 2006b) .

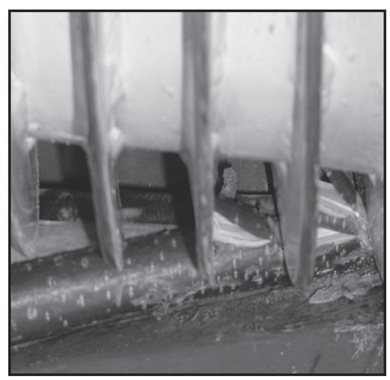

Fig. 1: Helical chipping: Wood chips are hopped and screwed out by the continuous lades

The prototype is a machine with a horizontally oriented and automatically feeding helical chipping drum with conveyor floor, conveying rollers and feed cylinders transporting dendromass from the preceding saw blade beam with a cutting width of 2.4 m. The rotating parts are powered by the tractor hydraulics and the rear power take-off shaft. A clamp above the funnel makes the dendromass (up to 12 cm in stem diameter) fall into the right direction since the often voluminous shape of the bushes makes a vertical entrainment impossible. Simultaneously the tractor moves backward and the discharged wood chips are collected into a container attached to the front end loader, an attached trailer or a shuttle trailer. The working height of the chipper is regulated with the rear hydraulics of the tractor (Fig. 2-3) (Wegener and Block, 2007 and 2008).

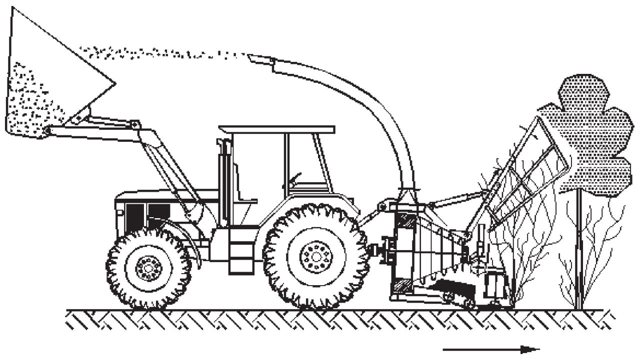

Fig. 2. Schematic representation of the Goettingen conservation chipper harvester.

Fig. 3. Prototype produced by Schmidt Stahlbau

Field trials in different stands (harvesting encroachment vegetation and short rotation plantations) revealed some details that need to be revised (Wegener, 2008) :

The chipper should consist of a basic unit that can be equipped for harvesting tasks in a variety of stands (dispersed, rowed or closed; ground cutting or coppice harvesting). This ability makes it interesting for agricultural, silvicultural and municipal service providers to invest in such an attachment and to gain an economic utilization ratio.

The height adjustment has to be supported by skids or even wheels when used in plantations and for the creation of logging trails in order to avoid ground contact and provide for an even cutting height. It helps to reduce material wear in uneven terrain and minimizes the time for irregular maintenance due to tear by stumps and stones.

The chipper needs an emergency stop and a reverse gear allowing for the removal of blockings. These features serve the operational safety and help to reduce downtimes through the fast ejection of oversized pieces.

The fixation of the saw blades has to be redesigned for cutting stem diameters up to 15 cm which broadens the utilization potential for more aged succession as well as plantation stands. The increased cutting radius requires an enforced carrier beam and a stronger hydraulic drive with an adequate oil supply by the carrier tractor. Still, the exchange of worn or damaged saw blades should be kept simple.

A deflector at the side of the machine is necessary for aligning applications. It reduces the number of bent shoots and machine damage especially in the second and following harvests of short rotation coppice where root stocks sprout to the side and form narrow harvest lanes between multi-stem trees. In agroforestry systems (e.g. alley cropping) and hedgerow harvesting, the neighbor stands have to be protected, too.

A forest crane with a cutting head should be attached between tractor and chipper that can cut trees stem diameter larger than 15 cm, brings them down in a controlled way and feeds them into the funnel. Thus, the manual searching, felling and processing of outliner trees in dense, often thorny vegetation becomes obsolete. The loader has to be attached in such a way that it does not interfere with the discharge chute while its control devices (preferably joysticks) have to be integrated into the cabin of the carrier tractor.

Fine particle content is reduced by a smoother material flow inside the chipper and discharge path reducing abrasion. Hence, the accelerator only serves for throwing out the chips and is not designed as to push oversized chips through a grid or against a counter blade. This presupposes that the generation of oversized chips is mainly prevented through the coordinated design of the draw-in funnel and the helical chipping cone.

The chip quality (especially from heterogeneous parent material) can be increased through an improved cutting action and wedge-shaped counter blade. Still, the gained chip quality (without additional screening and refining) is rather adequate for industrial combustion than for the use in domestic ovens due to the higher ash content (from the bark), the coarser assortment with uncut twigs and high moisture content. Since landscape conservation dendromass and short rotation plantations are harvested in the winter season, they would need drying with e.g. the excess heat from digester gas power plants. As more and more of these plants are built as CHP plants (combined heat and power plants), which supply district heating nets, drying with excess heat would have to take place in the warmer time of the year. This would cause storage and handling costs between harvesting, drying and utilization period and bear the danger of energetic losses and fungi spore formation through rotting processes. Municipal and industrial plants can use coarse and moist chips though will pay a lower price for those qualities, but still this utilization path is more economic than the upgrading for domestic use through harvest and post-harvest measures (Yrjoelae, 2004).

The Goettingen conservation chipper harvester is the first tractor-based harvesting device that can perform cutting, chipping and salvaging in a single-phase mowing action independent from row structures and additional trailers. The modular design makes it probable that applications beyond its original purpose will be developed though the harvesting capacity lies between 0.5 and 3.0 t_{atro}/h in conservation sites (due to heterogeneous stands and discontinuous loading) and 8 – 10 t_{atro}/h in short rotation plantations with even feeding and homogenous trees. The capacity depends on the relief, experience of the driver and the logistics of the site, too. Since the enlargement of the cutting diameter over 15 cm would be associated with technical problems and a reduced controllability of the felling process, the combination with a cutting head attached to a forest crane is a likely solution for handling larger trees. Upon finalization, the chipper will be a viable device for the management of woody growth and the usage of until now decaying biomass along roadsides, waterways fallow land and field margins. The present tasks lie in the fine tuning and coordination of the system components, the development of a serial manufacturing scheme, adjacent material and weight reduction potential, the CAD-rendering of complex chipper parts and their cheaper production with automated machining.

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Comparative Ecological – Economic Study of Short Rotation Tree Cultivation and its Impact on Livelihood of Local Stakeholders in Tamil Nadu

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Conservation, protection and development of natural resources has become a matter of concern in India. Neglect of environmental considerations like unplanned and overuse of natural resources and deforestation is leading to degradation of environment and loss of forest cover. During the early part of 20th century, rapid economic development and release of forest land for agriculture industries and other activities led to large scale deforestation and decline of forest cover. Hence forth Government of India took a policy decision to increase the forest cover to an extent of 1/3rd or 33 per cent of the geographical area. In order to achieve this target, nearly 31 m ha still needs to be covered out of this 26 m ha (83.87%) has to come from outside Government forests. This is a major challenge, which calls for optimum and adequate investment for planting and regeneration of timber and non-timber forest species which give adequate and sustained returns. The industrial demand for short rotation tree crops like *Ailanthus excelsa*, *Eucalyptus spp.*, *Casuarina equisetifolia, Acacia spp.* and others is rising in Tamil Nadu and farmers in Tamil Nadu have started growing short rotation trees on their farm land. The cultivation of short rotation tree crops by the farmers is often promoted by tree based industries and the extent of cultivation is sometimes driven by market demand. These two factors often change the cultivation pattern by farmers affecting wood based industries. However, the present trend of cultivation of short rotation tree crop by the farmers in Tamil Nadu and its impact on ecology and socio-economic aspects of the farmers are not available.Therefore, the present investigations were carried out in four divisions *viz.*, Karur, Villuppuram, Virudha Nagar and Dindigul of Tamil Nadu, document the ecological and economic impact of short rotation tree crops on livelihood of stakeholders.

The study was conducted during the year 2008-09 in, Karur, Dindigul, Villuppuram and Virudhanagar districts of Tamil Nadu. The study was undertaken in these districts because most of the paper, matchbox, splints industries and short rotation tree plantations are concentrated in these districts. Pre-structured schedules were used for collection of data from forest department, industries and farmers. The respondents who were voluntarily willing to provide the necessary information were contacted for the study.

In Tamil Nadu, short rotation trees are mostly cultivated by Tamil Nadu Forest Plantation Corporation (TAFCORN) and industries in their captive plantations. Trees are also raised under Tree Cultivation in Private Land Scheme (TCPL) and contract farming by industries such as Tamil Nadu News Prints and Paper Limited (TNPL). The most commonly cultivated short rotation trees are *Eucalyptus grandis, E. tereticornis, E. camaldulensis, Ceiba pentendra, Casuarina equisetifolia* and *Ailanthus excelsa* (Table 1).

Industries Using Short Rotation Tree Crops

Paper industry. There are 39 paper industries in the state out of which, two industries are wood based and the remaining industries are based on agricultural waste or other source of fibre. The two major paper industries such as TNPL, Karur using predominantly hard woods like *Eucalyptus* and *Casuarina* as raw material. The requirement of wood pulp for this industry earlier was 4.0 lakh tonnes and most of it was supplied by TAFCORN and partly from farm-lands. During 2002-03, this industry expanded its paper production capacity (2300 Mt yr^{-1}) resulting in increase in demand of pulp wood from 4.0 lakh tonnes to nearly 9.0 lakh tonnes per annum.

Match box industry. Bengal is the birth place of match industry in India. The first match wood industry was established in West Bengal in 1920s and second in Tamil Nadu during 1923 at Sivakasi producing lucifer matches**.** The small scale handmade match industries in Sivakasi, Kovilpatti, Sattur, Kalagumalai and Sankarankoil towns of Tamil Nadu state show a highly organized network. The quality of the matches produced by the small scale handmade match industries is as good as the quality of matches produced by the WIMCO. The major success of small scale match industries is the collective self reliance.

There are about 10,150 match industries in India out of which 90% are located in southern districts of Madurai, Tuticorn and Virudhanagar in Tamil Nadu.

Schemes or Corporation Involved in Short Rotation Tree Cultivation

Tamilnadu forest plantation corporation limited (TAFCORN). TAFCORN was formed in 1974, with the objective of raising, maintaining and harvesting forest plantation on sustained yield basis on commercial scale to meet the demand of local industries and people. The corporation has leased land from forest department and pays fixed lease rent to the government.

Tree cultivation in private land scheme (TCPL). In order to encourage tree cultivation outside forests, a new scheme was launched in the State in the year 2007-08 and continued during 2008-09. The scheme aims at improving green cover outside the forest area besides benefiting the farmers economically in the long run. This programme involves planting tree seedlings in the holdings of small and marginal farmers as inter-crops and alley crops in vacant fields, thus covering the waste lands in their holdings. Small and marginal farmers each with a holding of one hectare or less having been selected under the TCPL scheme. The forest department staff will undertake pitting and planting works in the selected areas. Tree planting has been done to the extent of 28,760 acres during 2007-08 and 25,800 acres during 2008-09. Tree planting programme in private lands has benefited 15,000 farmers during the years 2007-08 and about 25,914 farmers during 2008-09. As the scheme has benefited both wood based industries and farmers it is proposed to continue the scheme during 2009-10.

Contract farming by TNPL. The wood based industries such as TNPL, Karur is using species like *Eucalyptus* and *Casuarina* as raw material. Earlier, this paper industry required nearly 4.0 lakh tonnes of wood pulp and most of it was met from the TAFCORN and partly from farm lands. During 2000-03 industry expanded the paper production capacity (2300 Mt yr^{-1}) resulting in increased wood pulp demand of nearly 9.0 lakh t yr^{-1} against the actual availability of around 3.5 to 4.0 lakh t of wood pulp. To meet the additional requirement, the company developed contract farming system with technological support from Forest College and Research Institute of Tamil Nadu Agricultural University (TNAU) at Mettupalayam, Coimbatore,a tripartite and quad-partite models for promotion of pulp wood based farming system .

Tri-partite model. This model incorporates industry, growers and financial institutions. Under this system, the industry supplies quality planting material at subsidized rate and assures minimum support price of Rs. 2,000/t or the prevailing market price whichever is higher. The financial institutions *viz.*, Indian Bank, State Bank of India and Syndicate Bank provide credit facilities to the growers at the rate of Rs.15,000 to 20,000/acre in 3 installments. For credit facilities, a simple interest rate at 8.5 per cent is charged and the repayment starts after felling. The contract farming system extends no collateral security for loan amount up to Rs.1,00,000 per farmer.

Quad-partite model. This system is similar to tri-partite model with the exception of an involvement of research institute. In this system, research institute plays the role of technological advancements through varietal development and also to advice site specific precision silvicultural

Table 1. Status of short rotation tree cultivation in Tamil Nadu

Scheme/corporation	Year of implementation	Species planted	Rotation period (yrs)	Area (ha)
TAFCORN	1974	*Euclaptus grandis*	7	
		E. tereticornis	7	45,000
		E. camaldulensis	7	
		Casuarina equisetifolia	6	6,000
TCPL	2007	*C. equisetifolia*	6	
		Alianthus excelsa	12	
		Ceiba. pentandra	-	55,000
		T. grandis	-	
Captive		*E. grandis*	7	
plantation	1979	*E. tereticornis*	7	
by TNPL		*E. camaldulensis*	7	2,000
		C. equisetifolia	6	
Contract		*E. grandis*	7	
farming by	2005	*E. tereticornis*	7	15,000
TNPL		*E. camaldulensis*	7	
		C. equisetifolia	6	2,000

technology to the growers. A pre and post-plantation technical advice helps to develop human resources through on and off institute mode to farmers and plantation staff of the industries.

The soft wood, short rotation tree plantations raised under various schemes have provided direct employment to about 19,500 people and indirect employment to about 1,02,000 people (Table 2).

Employment generation. Short rotation tree cultivation plays important role in providing shelter to birds, improves micro-climate of the region, makes easy availability of fuel wood, fodder, timber, enriches the soil fertility, acts as bio-drainer in flood prone areas, increases green cover, provides recreational facilities, maintains nutrient and hydrological cycles, decreases soil erosion and barriers against tidal waves mitigates the climatic change. Besides these ecological services**,** these above facts resulted in increase in socio-economic status of villagers through direct and indirect employment and moreover cultivation of short rotation has become other alternative livelihood activities of the local stakeholders. Presently there are no such studies conducted on impact of short rotation tree cultivation on livelihood of stakeholders in Tamil Nadu.

Karur Division. *Eucalyptus tereiticornis* cultivated by farmers through TNPL contract farming scheme. *Eucalyptus* is grown in block plantations. A minimum of Rs. 1800/t is assured by the buyback from TNPL. The average yield of eucalyptus ranges from 18-20 Mt/ha. The average expected income is Rs. 36,000/- to 40,000/ha/rotation. During the 2 and 3 rotations the farmers retain two coppices per stump.

Dindigul Division. Important short rotation species are *Ailanthus excelsa*, *Eucalyptus tereiticornis* and *Casuarina equisetifolia* sponsored by TCPL scheme. Under TCPL scheme, planting of seedlings, technical support and an additional grant of 25 paise/seedling are provided to the farmers through the Forest Department. Recommended spacing for *Casuarina* is 1mx1m and 4000 seedlings/acre are planted. The scheme is open to farmers who have a maximum 2 ha land area.

Villupuram Division. *Casuarina* (block plantation) and *Ailanthus excelsa* (bund plantation) are cultivated through TCPL scheme, while *Eucalyptus tereiticornis* is grown under TAFCORN. It started was during 1974 and commands an area of 45,032 ha in the state. Almost 1 lakh Mt of pulp wood is supplied to wood based industries (mainly to TNPL). Clones of *E. camuldalensis* are now preferred to seedlings distributed prior to 1999. Coastal plantation of *Casuarina equisetifolia* in Villupuram division are effective barriers against tidal waves. The farmers are free to sell the produce under TNPL scheme.

Virudhanagar Division. The main species grown by farmers in Virudhanagar are *Casuarina* and *Ailanthus excelsa* in addition to *Ceiba pentandra.* About 500 – 600 small scale and 40-50 medium scale match industries are located in Sivakasi and nearby areas of Virudhanagar District, which use *A. excelsa, A. malabarica, C. pentandra* and others produce from short rotation crops. The match splints and veneers for match box industry are mainly supplied by companies from Kerala. At present, because of the low availability of short rotation species, the companies are making splints from *Hevea brasilliensis* and supplying these to match industries. For making match boxes, the industry is using veneers and also card board as an alternative.

These activites helped in uplifiting the socio-economic status of villagers due to direct and indirect employment generations have become other alternative livelihood activities of villagers

The short rotation trees such as *Eucalyptus grandis, E. tereticornis, E. camaldulensis, Casuarina equisetifolia* and *Ailanthus excelsa* are cultivated in block plantation by TAFCORN under TCPL and contract farming by industries such as TNPL. Forest Department provides additional grant of 25 paise/seedling, planting material and technical support under TCPL scheme. The scheme is open to farmers who have a maximum 2 ha land. Plantations raised under various schemes have helped in generating direct employment to about 19,500 people and indirect employment of about 1,02,000 peoples.

Table 2. Employment generation in short rotation tree plantations

Scheme/Corporation / Company	Year of initiation	Total area planted (ha)	Employment generation	
			Direct employee / labour	Indirect
TAFCORN	1975	48,000	5,000	20,000
TNPL	1982	32,000	8,000	80,000
TCPL	2007	30,000	2,000	1,000
Farmers	-	5,000	4,500	500
Total		1,15000	19,500	1,02,000

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Evaluation of Seed Source Influence on Quality of *Albizia lebbek* Seeds Using Standard Sampling Technique

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There has been tremendous pressure on the forests in the recent years. To reduce this pressure on forests, new approaches like social forestry, agroforestry, etc. have emerged as alternative resource generation options. Considering these new approaches, species which are fast growing, enrich soil and fulfill rural needs are in great demand. *Albizia lebbek* is an important multipurpose tree species widely distributed from Himachal Pradesh upto Assam in sub Himalaya tract and ascends upto 1000 m in western Himalaya. The tree yields fuel, fodder, agricultural implements, small timber, sports goods and raw material for paper industry. *Albizia lebbek* being a leguminous and multipurpose tree species has attained added importance in various social forestry as well as in agroforestry programmes. The availability of quality seeds in increasing the productivity of this species is therefore of utmost importance as the seed source is known to have significant influence on the species and ecosystem productivity. The present investigations were therefore carried out to study the influence of seed source on quality traits of *A. lebbek* seedlings, which will enable the forester, farmers and field practioners in raising the quality planting stock.

The seeds of *A. lebbek* were collected from middle aged plus tree starting at physiological maturity in the month of February when pods turn yellow from green. Ripe and healthy pods were collected from the trees between December and March, or collected from the ground soon after they fall from the trees from the following seed sources:

HP Zone I: Nahan, Rajgarh, Solan
HP Zone II: Kunihar, Bilaspur, Arki
HP Zone III: Suket, Seraz, Hamirpur
HP Zone IV: Kangra
HP Zone V : Mandi

Pods collected from the trees were sun dried for 4-5 days by spreading them on taruplin in a thin layer when pods become dry; seeds were extracted from them by opening pods with hand and beating the pods with sticks. The experiment was laid out in CRD design having four replicates. In each replicate, there were 100 seeds kept in sterilized germination paper in the germinator at a temperature of 25 °C and RH of 94-96 %. Initial count was made one week after starting the test and further counts were made at 7 days interval till the test ended. Seed vigour index was calculated by determining the germination percentage and seedling length of the same lot. While evaluating the number of normal seedling at the time of the final count, the seedling length of 5 randomly selected seedlings were also measured. S.V.I. was calculated by multiplying per cent germination and seedling length. The data, wherever possible were subjected to statistical analysis by the methods described by Gomez and Gomez (1984).

The seeds of *A. lebbek* were collected from various seed zones of HP in the month of February and March and studied for physical and physiological characteristics. On an average seeds were found to be light brown in colour, smooth, compressed with hard seed test (Table 1). The number of seeds per kg varied from 8798 to 10472 in different seed zones. As regards to normal seeds percentage, its value ranged from 77.45 - 90.42. The seeds collected from different seed sources (seed zones and sub-zones in Himachal Pradesh) recorded a significant difference in physical and physiological characteristics such as number of seed per kilogram, seed purity, hard seediness, germination, seedling length and seed vigour index. The number of seeds per kilogram, moisture, normal seeds, immature seeds, germination and hard seeds percentage varied in the range of 8798-10472, 10.0-10.82, 77.45-90.42, 5.80-9.66, 37.50-48.12 and 17.50-26.25, respectively due to variation in seed sources.

A perusal of the data presented in the Fig. 1 revealed that seed germination was found maximum (80.50 %) for the seeds collected from Zone II, which was found statistically at par with Zone IV (80.0%). Zone II (Fig. 2 & 3) i.e., seeds collected from Bilaspur district of (H.P.) displayed maximum seedling length (19.52 cm) and seedling vigour index (1571.36), which showed significant differences from other seed zones. Minimum value (17.94 cm) for seedling

Table 1. Location wise physical seed characteristics of *Albizia lebbek*

Location	Physical characteristics	Moisture (%)	Seed per kg (No.)	Seed purity (%)		
				Normal seed	Immature seed	Insect infested seed
Solan (Z I)	Light brown, smooth, compressed with hard testa	10.00	9000	85.45	7.80	5.97
Sirmour (Z I)	Light brown, smooth, compressed with	10.57	8798	86.65	7.17	5.43
Bilaspur (Z II)	Light brown, smooth, compressed with	10.82	9413	77.45	9.66	16.10
Hamirpur (Z III)	Light brown, smooth, compressed with	10.22	9346	87.60	5.80	6.20
Kangra (Z IV)	Light brown, smooth, compressed with	10.70	10472	90.42	3.92	5.49

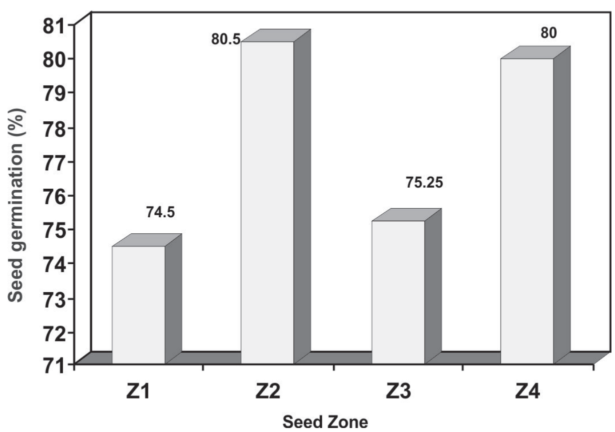

Fig. 1. Effect of seed source on seed germination (%) characteristics of *Albizia lebbek*

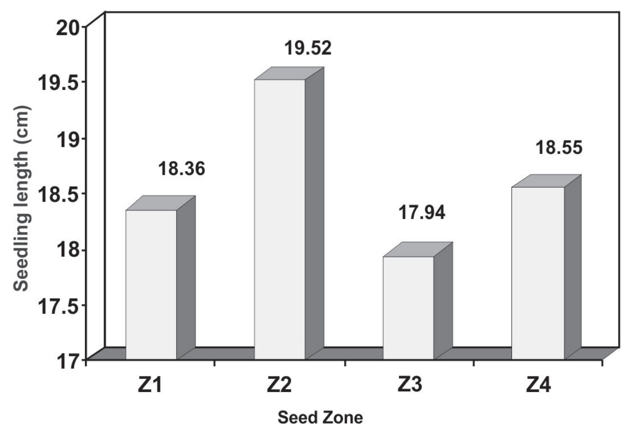

Fig. 2. Effect of seed source on seedling length (cm) characteristics of *Albizia lebbek*

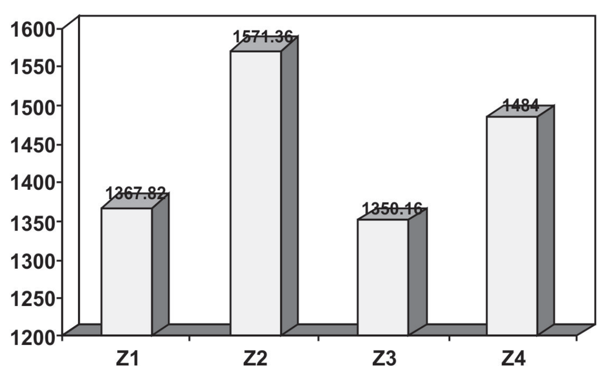

Fig. 3. Effect of seed source on seed vigour index characteristics of *Albizia lebbek*

length was recorded for seed zone III, which also recorded minimum seed vigour index (1350.16). In general, the seed sources which showed lesser number of seeds per kg and hence more food reserve displayed more per cent germination, seedling length and seedling vigour index.

For raising quality seedling stock quickly and efficiently, the seeds of *Albizia lebbek* should be collected from Zone II i.e., Kunihar, Arki (Solan) and Bilaspur areas of Himachal Pradesh.

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Weed Management through Soil Solarization in Primary Nursery of *Eucalyptus tereticornis*

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Eucalyptus tereticornis (Mysore gum) is one of the preferred species for short rotation plantation due to its various features like fast growth, wide adaptability, straight bole and least post plantation care (Mathur *et al*., 1984). The common method of raising eucalyptus seedlings involves sowing of seeds in primary nursery beds and later transplanting tender seedlings into suitable containers. Raising the seedlings in primary nursery is very crucial, as weed competition at this stage is one of the major constraints. Moreover, eucalyptus is found to be very sensitive to weeds especially grasses during initial phase. For this species initial weed free period of 15-20 days is essential for good growth and development in primary nursery. At this stage, manual weeding is quite difficult as tender seedlings are damaged. Chemical weeding has led to environmental pollution, residue problems in soil and water, toxicity to animals and development of resistance in weeds. Thus, the time demands for new method besides being cost effective and non-hazardous to the users as well as to the environment. In this context, use of soil solarization for weed control is gaining importance. Soil solarization is a method of soil disinfection which is basically a method of heating the surface of soil by plastic sheets placed on the moist soil to trap the solar radiation and thereby increasing the soil temperature. Solarization process would increase the surface soil temperature by 8-12^{0}C due to this effect many annuals, perennials and parasitic weeds are effectively controlled (Katan, 1980).

The experiment was carried out at the Karnataka Forest nursery, Kalave near Sirsi. There were 9 treatment combinations comprising of 3 levels of thickness of polythene sheet (G_1 – 0.03 mm, G_2 – 0.06 mm and G_3 – 0.12 mm) and 3 levels of duration of soil solarization (D_1 – 30 days, D_2 – 45 days and D_3 – 60 days). In each replication, control (normal weeding without solarization) and unweeded check (no solarization and no weeding) plots were maintained for comparison as well as for computing other parameters. The experiment was laid out in Completely Randomized Block Design (Factorial) with 3 replications. The raised nursery bed of size 0.7m x 1.0 m was prepared for each treatment. After preparation of beds 2.5 kg FYM per bed was added and mixed thoroughly with the soil. Prior to spreading of polythene sheets, uniform irrigation was given and the plots were allowed to attain the moisture level nearly at field capacity. Transparent polythene sheets were spread on the nursery beds as per treatments. The free sides of the polythene sheets were buried in the soil to make it air tight. The soil temperature of solarized plots was recorded at 5 cm depth by using thermometer. Eucalyptus seeds were broadcasted on the nursery bed after the removal of polythene sheet. Weed flora and the number of individual weed species were counted at 15 days interval in different treatments and expressed as number per standard nursery bed. Weed samples were removed and oven dried at 60^0 C for 48 hours and dry weight was recorded and expressed in g per standard bed. Weed Control Efficiency (WCE) was calculated by using standard formula.

$$WCE = \frac{\text{Weed dry matter production in control plots} - \text{Weed dry matter production in treated plots}}{\text{Weed dry matter production in control plots}} \times 100$$

Thickness of polythene sheet used in soil solarization is associated with efficacy of weed control and cost involved in weed management. Hence, finding optimum thickness of polythene sheet for weed management in primary forest nursery is of great significance. The solarization treatment with thin polythene sheet (0.03 mm) recorded significantly higher shoot, root and total dry matter production in eucalyptus seedlings (Table 1). The extent of increase in total seedling dry weight due to thin polythene sheet over medium (0.06 mm) and thick polythene (0.12 mm) was 21.49 and 40.69 per cent, respectively. Similar observations of increased biomass production due to solarization with thinner polythene sheet was made by Mudalagiriappa *et al*. (1999) in ground nut crop. This increase was mainly through its favourable effect on growth parameters like plant height

Table 1. Soil temperature (^{0}C) weed parameters and seedling parameters as influenced by thickness of polythene sheet (G) and duration of solarization (D)

Treatment	Soil temp. (^{0}C)	Weed count per bed	weed dry weight (g)	WCE	Plant height (cm)	Number of leaves	Seedling dry weight (g)
Thickness of polythene sheet (G)							
G_1	56.0	415.97	154.04	92.70	2.01	5.86	7.13
G_2	54.4	435.73	211.17	90.07	1.48	5.71	6.01
G_3	53.7	763.38	413.37	79.75	1.56	5.34	5.09
SEm±	0.21	58.91	5.82	0.712	0.08	0.16	0.20
CD (5%)	0.68	188.46	18.63	2.28	0.27	0.53	0.61
Duration of solarization (D)							
D_1	54.3	734.72	400.75	80.20	1.62	5.72	5.30
D_2	54.4	573.67	241.62	80.20	1.66	5.94	5.83
D_3	55.3	306.69	136.19	93.68	1.78	6.25	7.10
SEm±	0.21	58.91	5.82	0.712	0.08	0.16	0.20
CD (5%)	0.68	188.46	18.63	2.28	NS*	NS*	0.61
Interaction (GXD)							
G_1D_1	55.0	733.66	314.39	84.99	1.70	6.13	5.48
G_1D_2	55.3	445.68	143.30		2.03	6.13	6.99
G_1D_3	57.3	68.57	4.42	99.87	2.30	6.76	8.92
G_2D_1	54.0	544.84	368	82.74	1.43	5.33	5.28
G_2D_2	54.0	521.11	174.47	91.75	1.45	6.00	5.35
G_2D_3	55.7	241.25	91.03	95.73	1.54	6.26	7.41
G_3D_1	53.3	925.65	519.87	72.86	1.71	5.70	5.14
G_3D_2	53.7	754.23	407.08	80.95	1.49	5.70	5.14
G_3D_3	54.3	610.24	313.14	93.68	1.49	5.70	5.01
SEm±	0.37	102.04	10.09	1.23	0.15	0.28	0.33
CD (5%)	1.18	326.43	32.27	2.78	NS*	0.92	1.06

NS* = Non- significant

and number of leaves per plant. The increase in growth parameters in eucalyptus seedlings can be attributed to effective weed control. The number and diversity of weed were significantly reduced with thin polythene sheet than medium and thick polythene sheet. The reduction in number and diversity of weeds might be due to increased temperature build up at 5 cm depth was 56.0 ^{0}C as compared to 53.7 and 54.4^{0}C in treatment with medium and thick polythene sheet, respectively. Higher soil temperature due to thin polythene sheet resulted in killing of weed seeds thus reducing diversity and density of weeds species. The reduced diversity and density of weed species led to reduction in weed count. It was 416, 435.7 and 763.4 in thin, medium and thick polythene sheet, respectively (Table 1). Reduction in weed count in turn resulted in significantly lower weed dry weight in treatments with thin polythene sheet (154.04 g) compared to medium (211.17 g) and thick polythene sheet (413.37 g). This ultimately reflected in higher weed control efficiency (92.7 %) compared to medium (90.07 %) and thick polythene sheet (79.75 %).

Duration of solarization is associated with period of exposure of nursery beds to higher temperature regime, which in turn decides weed control efficiency. Treatment with long duration of solarization (60 days) showed significantly higher total dry matter production in eucalyptus seedlings. Compared to control, soil temperature was higher by 12.3, 11.4 and 11.3^{0}C under to high, medium and short duration of solarisation, respectively. The extended soil exposure to higher temperature resulted in killing of weed seeds in long duration solarization which caused reduction in diversity and density of weed species. The reduced diversity and density of weed species lead to reduction in weed count i.e 306.69, 573.67 and 734.72 in long, medium and short duration of solarization respectively. Reduction in weed count resulted in significantly lower weed dry weight in long duration of solarization (136.19 g) compared to medium (241.62 g) and short duration treatment (400.75 g). This ultimately resulted in higher weed control efficiency (93.68 %) than medium and short (i.e., 80.20 %) duration of solarization (Table 1). The higher weed control efficiency due to long duration of solarization was responsible for improved growth of eucalyptus seedlings due to greater availability of growth resources.

The combination of thin polythene sheet for longer duration of solarization (G_1D_3) recorded significantly higher total seedling dry weight of eucalyptus seedlings (8.92 g) than in any other combinations (Table 1). This increase in seedling dry weight due to the combination of thin polythene sheet and longer duration of solarization was mainly because of its favourable effect on growth parameters due to effective weed control. such as plant height (2.30 cm) and number of leaves per plant (6.76). The density and diversity of weeds were reduced in treatments with combination of thin polythene sheet and longer duration of solarization compared to other combinations.

The solarization experiment indicated that, the optimum period of exposure of nursery beds to higher soil temperature regimes and there by controlling the weeds through solarization can be achieved by using an appropriate combination of thin polythene sheet (0.03 mm) with long duration (60 days) of exposure of polythene. The increase in temperature significant affect weed count, weed dry weight and there is an increase in weed control efficiency, which ultimately reflected on survival per cent and growth attributes of eucalyptus seedling.

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Promising Subabul *(Leucaena leucocephala)* Genotypes for Shallow Vertisols of Northern Dry Zone of Karnataka

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Subabul *(Leucaena leucocephala* L. dewit*)* is a miracle tree with a wide assortment of cultivars for different uses like forage, timber, wind break, nitrogen fixation, pulp, etc. for shallow marginal Vertisols. Subabul has been introduced in India mainly as an agroforestry crop to meet the increasing demand for fuel, fodder and timber for poles and posts. It can be grown in variety of soils and climatic conditions due to its tolerance to high temperature and extended drought and remarkable regenerative capacity (Devaranavadgi *et al.,* 1996;1999). The northern dry zone of Karnataka is characterized by hostile environment conditions like low and erotic rainfall, intense solar radiation and poor fertility status of the soil. Therefore, cultivation of field crops in the shallow black soil is uneconomical and it has become necessary to adopt alternative land use systems in such soils. Considering all these factors, a study was conducted to identify the fast growing subabul genotypes for shallow vertisols of northern dry zone of Karnataka.

The field experiment was carried out at Regional Agricultural Research Station, Bijapur (Karnataka) during 1999 to 2010. The soils of the experimental site were analyzed for various physico-chemical properties (Sand 25%, Silt 23%, Clay 52%, bulk density 1.43 g/cc, pH- 8.5, EC- 0.34 dSm^{-1}, $CaCO_3$ 18.5% and soil depth 30-35 cm). The average rainfall of the site is 585 mm in 39 rainy days. The experiment was laid out in Randomized Block Design with three replications during July 1999 with eight genotypes *viz.,* K-8, K-28, K-29, K-67, K-409, K-636, S-10 and S-24. In each replication, the treatment was represented by 25 plants of same genotype at a spacing of 2 X 2 m in five rows. Only the middle 9 plants were used for recording observations in last four years on tree height (m), clear bole height (m), diameter at breast height (DBH)(cm) and crown spread (m). These parameter were further used to calculate wood volume by using Huber's formula (Avery and Burkhart, 1983) and average annual increment. The data recorded on various characters during the course of investigation were subjected to Fisher's method of analysis of variance and interpretation of data was made as per the procedure given by Gomez and Gomez (1984).

The data on tree height (m), diameter at breast height (cm), clear bole height (m) and crown spread of ten year old trees are presented in table 1. The genotype S-10 recorded the highest tree height (11.70 m), diameter at breast height (10.27 cm), clear bole height (3.57 m) and crown spread (E-W: 3.42 m, N-S: 3.47 m) followed K-636 (11.60 m, 10.13 cm, 3.38 m and E-W: 3.21 m, N-S: 3.14 m, respectively) and S-24 (11.53 m, 10.09 cm, 3.27 m and E-W: 3.13 m, N-S: 2.98 m, respectively). The lowest values were observed in genotype K-29.

Table 1. Silvicultural parameters of subabul genotypes

Treatments	Tree height (m)	Clear bole height (m)	DBH (cm)	Crown spread (m)	
				E–W	N–S
K - 8	10.34	3.26	9.34	3.13	3.33
K - 28	9.81	2.99	8.52	3.08	3.17
K - 29	8.44	2.51	5.84	2.97	3.15
K - 67	9.53	2.94	7.53	3.19	2.81
K - 409	10.82	3.86	7.62	2.88	3.01
K - 636	11.60	3.38	10.13	3.21	3.14
S - 10	11.70	3.57	10.27	3.42	3.47
S - 24	11.53	3.27	10.09	3.13	2.98
S.Em±	0.40	0.17	0.41	0.16	0.16
CD @ 5%	1.22	0.51	1.24	0.48	0.49

Table 2. Wood yielding ability of subabul genotypes for four years

Genotypes	Wood yield (m^3 ha^{-1})				Average wood yield (m^3 ha^{-1} $year^{-1}$)			
	08th Year	09th Year	10th Year	11th Year	08th Year	09th Year	10th Year	11th Year
K-8	73.00	105.32	120.16	141.62	9.13	11.70	12.02	12.87
K-28	51.69	85.30	97.75	111.80	6.46	9.48	9.78	10.16
K-29	24.42	33.60	40.26	45.19	3.05	3.73	4.03	4.11
K-67	36.89	62.84	72.62	84.81	4.61	6.98	7.26	7.71
K-409	53.82	72.79	83.03	98.67	6.73	8.09	8.30	8.97
K-636	73.27	118.80	157.63	186.94	9.16	13.20	15.76	16.99
S-10	91.11	123.67	163.20	193.74	11.39	13.74	16.32	17.61
S-24	67.71	117.60	156.21	184.24	8.46	13.07	15.62	16.75

The data on total woody biomass production of four years (Table 2) revealed that genotype S-10 produced 91.11 m^3 ha^{-1}, 123.67 m^3 ha^{-1}, 163.20 m^3 ha^{-1} and 193.74 m^3 ha^{-1} in all the four years i.e., 8, 9, 10 and 11th year of planting respectively, followed by K-636 and S-24. The average yield of wood increased as the years of planting increased in all the eight genotypes but the genotype S-10 obtained highest annual average wood yield of 11.39, 13.74, 16.32 and 17.61 m^3 ha^{-1} $year^{-1}$ in all four years i.e., 8, 9, 10 and 11th year of planting, respectively followed by S-24 and K-636. According to Gupta (1993), 18.75-23.75 m^3 of average annual wood can be harvested from *Leucaena* on marginal site with 6-8 year rotation. At Bijapur on marginal soils, 102.50 m^3 wood was harvested with 6 year rotation (Guled *et al.,* 1996).

Considering the all these parameters, it may be inferred that the subabul genotypes, S-10, is the most promising to grow on shallow vertisols of northern dry zone of Karnataka for minor timber purpose.

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Paulownia fortunei: A Pragmatic Approach to Intensive Forest Farming under Temperate Conditions of Kashmir Region

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Paulownia fortunei is a multipurpose tree growing on variety of varied climatic and soil conditions. It is popularly known as "Chinese Wonder Tree" which belongs to family Scrophularaceae. It was introduced in India by Forest Research Institute, Dehradun from China in the last decade. The said tree is grown extensively in farm forestry sector in China. It is a strong light demander, does not tolerate shade and prefers to grow better in absence of top and side shade. It can withstand temperature between -20 to +40°C but optimal conditions for growth are between 24 to 29 °C. The deciduous nature of plant forces it to remain leafless during winter months. The soil pH requirement varies from 5.0 to 8.9 for the *Paulownia* plantations. It has wide range of natural distribution which extends from tropical (plains) to temperate regions up to an elevation of 2400m amsl. The annual rainfall requirement varies between 500 to 2000mm in its natural zone.

It is fast growing tree species considered to be economically and ecologically viable option to the farm forestry sector in the Kashmir region. The poplar clones existed in the region are pre-dominantly females and are responsible to create un-healthy aero-environment due to cottony mass generated during May and June months of each year, which is responsible for many allergic diseases and other ill effects to human as well as livestock health. Every year, state government is spending huge amount of money to check this problem. However, so far no expected results have been obtained.

Paulownia fortunei is looked upon as substitute to poplar due to its short rotation and other broad spectrum of uses like wood for carving, furniture, cabinet plywood and fuel. This species adds large quantities of nitrogen to soil and can as such be used to restore the fertility of degraded soils. It is also well documented that the absorbing roots of *P. fortunei* are located below the rooting zone of annual crops and thus, make the species suitable for different agroforestry systems. With such multi-dimensional uses, an attempt was made to study its establishment, growth, biomass, soil binding capacity and nutrient composition before it could be considered for plantation on waste, farm and degraded lands of the State.

MATERIAL AND METHODS

The present investigations were carried out in the department of Forestry, FOA & RRS, Wadura, Sopore, SKUAST-K under rainfed conditions. The climate of the area is temperate with moderate summer and severe cool winter with wide variations in the mean maximum and minimum temperatures. The soil of the experimental site was acidic to neutral (5.8 to 7.2).

One-year-old entire plants raised from cuttings were planted in 45cm^3 pits at 3x5m spacing during mid-week of December 2001. Plantation is done deep enough to provide good anchorage for young trees. No fertilizer or manure was applied to the soil in the pits. Observations on growth, biomass, soil binding capacity and fodder values were recorded every year at the end of growth period. Soil conservation value was determined by using the formulae given below:

$$F = \frac{V}{r^2}$$

Where, F= Binding factor V= Volume of roots r= Radius of roots in mm

The values of nutrient composition were determined by employing standard tested procedures. However, the palatability of the leaves has not been tested.

RESULTS AND DISCUSSION

The growth of *P. fortunei* was recorded for 6 years between 2001 to 2007. The data presented in table 1 revealed that 6-year-old plants of this species attained an average height of 8.05 m with diameter of 14.56 cm. The height and diameter recorded for tallest tree was 9.27 m and 18.30 cm, respectively. The results further revealed that annual increase in growth is rapid in the first few years, which declined later with major fluctuations. The increase in height of main stem in the 2nd year was 43 per cent, which decreased to 36, 28, 24 and 22 per cent during the

Table 1. Growth trends of *Paulownia fortunei* during 1st and 6th year

Age (years)	Height (m)	DBH (cm)	Above ground (kg/ plant)	Below ground (kg/ plant)	Total (kg/ plant)
1	1.22(± 0.007)	1.72*(± 0.014)	1.304 (±0.008)	1.466 (± 0.006)	2.770 (± 0.018)
2	2.15(± 0.006)	3.00(± 0.13)	4.632 (±0.03)	5.223 (± 0.050)	9.855 (± 0.016)
3	3.37(± 0.016)	5.10(± 0.015)	11.613 (±0.012)	9.501(± 0.015)	21.114 (± 0.017)
4	4.72(± 0.009)	7.84(± 0.012)	26.912 (±1.22)	17.941(± 1.42)	44.853 (± 1.36)
5	6.27(± 0.03)	10.68(± 0.016)	55.565 (± 1.61)	23.248 (± 1.32)	78.813 (± 1.58)
6	8.05(± 0.11)	14.02(± 0.011)	78.887 (± 1.83)	34.192 (± 1.73)	113.079 (± 1.76)

subsequent years. The rate of increase in diameter also followed the similar trend and decreased progressively with advancing in age. These results are in line with those recorded under 6 year old plants of *P. fortunei* in Kwangsi China.

The data in table 1 shows that total biomass increased from 2.77 kg/plant at the age of one year to 113 Kg/plant over a period of six years. The above ground biomass comprised about 47 and 70 percent of total biomass at the age of one and six years respectively. The data further show that at the age of one year the biomass was ranked as roots> trunk>leaves and after 5 years, the trend was trunk>roots>branches>leaves>fruits. This indicated that at the age of one year Paulownia invests more assimilates to root growth and as the age progress the growth of trunk becomes faster to accumulate more biomass. The results on partioning show that at the age of six years stem constitutes 53 per cent of above ground biomass followed by 22, 17 and 8 per cent by branches, leaves and fruits, respectively (Table 2).

The contribution of main, 1st, 2nd and 3rd order roots to total root biomass was 59, 19, 12 and 10 per cent at the age of one year and 27, 34, 22 and 17 per cent after attaining an age of 6 years (Table 3). The distribution of root biomass at various depths at the age of one year was 18 per cent from 0-20 cm, 61 per cent from 20–40 cm, 16 per cent from 40–60 cm and 5 per cent from 60-80cm. On the other hand, the distribution of roots at the age of 6 years was in order of 4 per cent from 0-20 cm, 25 per cent from 20–40 cm, 33 per cent from 40–60 cm, 19 per cent from 60-80 cm, 15 per cent from 80–100 cm and 5 per cent below the depth of 100 cm .The data further showed that more than 80 and 96 per cent of roots were found below the depth of 20 cm after the age of 1 and 6 years, respectively. It can be inferred that *P. fortunei* could be considered as an ideal species for introduction in any agroforestry systems involving annual crops, which generally have a limited root zone of 0-25 cm.

The absorptive roots with an average diameter of 1.8 mm constituted 77 and 79 per cent of total root length in one and six year old plants, respectively. The estimates of root surface area manifests that one and six year old plants of *P. fortunei* exhibited a respective surface area of 2173 and 8254 cm^2 $plant^{-1}$. Generally, the third order roots (tertiary roots) accounted for more than 54 and 44 per cent in one

Table 2. Above ground biomass (fresh weight kg/plant) distribution of *P. fortunei*

Particulars	Stem	Branch	Leaves	Fruits	Total
1 year old	1.095 (±0.06)	-	0.209 (±0.003)	-	1.304 (±0.05)
6 year old	41.68 (±1.12)	17.21 (±0.17)	13.48 (±0.19)	6.52 (±0. 08)	78.89 (±1.21)

Table 3. Below ground biomass (fresh weight kg/plant) distribution of *P. fortunei* at various soil depths

Soil depth (cm)	Main root		1st order		2nd order		3rd order		Total	
	1 yr	6 Yr	1 yr	6 Yr	1 yr	6 Yr	1 yr	6 Yr	1 yr	6 Yr
0 – 20cm	0.163	0.256	0.047	0.455	0.033	0.260	0.029	0.378	0.272	1.302
20 – 40cm	0.515	3.026	0.153	1.986	0.124	1.736	0.100	1.903	0.892	8.631
40 – 60cm	0.138	2.691	0.059	4.075	0.022	2.055	0.014	2.240	0.233	11.133
60 – 80cm	0.043	1.517	0.019	1.875	0.004	1.606	0.003	1.530	0.069	6.340
80 – 100cm	-	1.447	-	1.556	-	1.150	-	0.561	-	5.000
>100cm	-	0.350	-	0.664	-	0.638	-	0.257	-	1.786
Total	0.859	9.287	0.278	11.591	0.183	7.445	0.146	5.869	1.466	34.192

Table 4. Root growth and soil conservation value of *P. fortunei*

Particulars	Main root			1st order			2nd order			3rd order			Total		
	1st year	5th year	6th year	1st year	5th year	6th year	1st year	5th year	6th year	1st year	5th year	6th year	1st year	5th year	6th year
Root length (cm/plant)	132.5	295.2	315.3	380.3	1093.7	1292.6	1531.4	3372.82	3656.7	6962.7	17688.3	19313.26	9006.90	22450.00	24577.86
Root surface area (cm^2/plant)	180.955	1151.03	1230.20	266.210	1260.95	1512.34	542.116	1679.36	1901.48	1183.54	3307.71	3610.85	2172.821	7399.05	8254.87
Soil binding value	22.68	83.35	89.14	25.30	593.56	709.73	122.14	788.18	854.36	220.47	2627.09	1776.07	390.59	4092.18	4429.30

and six year old plants, respectively. The root surface area of 6 year old plants was 3.8 times more as compared to one old plant. Further, about 80 per cent of absorptive roots were spread in a radius of 20 to 100 cm. These results indicate that this species has a well-developed root system, which provides very suitable conditions for intercropping.

Soil conservation value. The soil conservation value of one and six year old plants was 391 and 3429 per plant, respectively (Table 4). Again, tertiary roots had the highest soil binding capacity of 220 and 1776 per plant in one and six year old plants. The binding factor increased by more than 8.8 times over a period of 6 years. These data indicated that *Paulownia* roots have a high potential for stabilizing and conserving degraded lands prone to soil erosion. In addition, the deep rooting system does not compete for soil nutrients and water with crops, therefore, *P. fortunei* is considered most promising multiple purpose agroforestry species.

It is also clearly observed that deep rooted system (76% of the absorbing root system is distributed at a depth of 40-100cm under the ground surface) is not only reducing the competition for water and nutrients with inter-crops but also equally responsible for increasing the moisture and nutrients from top soils. The phenological behaviour of the species favours its cultivation under tree farm lands. The late leaf emergence favours the growth of under crop and late leaf fall protects the crops from frost injury. The moisture content of the soil at 0-40cm is 19.7 per cent higher than that of the open field.

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Agro-Sericulture Pastorial System for Income Generation

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Agroforestry is a sustainable land management system which increases the overall yields of lands, combine trees and shrubs with agriculture crops and lives stock on the same unit of land either simultaneously or sequentially. Mulberry is a fast growing tree and hence produces very large quantities of renewable biomass in the form of branches, shoots, leaves and fruits. Thus by growing mulberry it is possible to use the leaves as food for silkworms and as a fodder for cattle and goats. The dried branches can be used as a fuel. One kg of mulberry wood produces 4600 calories. Thus mulberry can be cultivated as a trained tree in a wide variety of soil condition and adoptable to be cultivated as a rain-fed crop and plays an important role in soil conservation and prevention of soil erosion. This form of cultivation is already been practiced in temperate and hilly regions. Of late, the concept of tree plantation has also spread in to the plains as a sustainable crop under severe water stress conditions in waste and denuded lands. It is possible to grow short duration high yielding varieties of ground nut, mung, soybeans, cowpea, ragi and various vegetables as intercrops in mulberry (Ahsan *et al.,* 1989). Under these advantages, evolved packages pertaining to various agronomical practices are discussed for the use of different agencies.

MATERIALS AND METHODS

Central Silk Board's R&D institutes evolved various viable agronomical practices pertaining to mulberry tree farming and suitable intercrops. These techniques were validated at different agro-climatic conditions. Based on the viabilities a package of alternatives are formulated and documented for the field application.

RESULTS AND DISCUSSION

Raising of saplings. Saplings should be raised 5-6 months prior to their direct plantation in the month of February with the onset of warm weather. Saplings meant for tree mulberry are raised in nursery beds of convenient size (8.5 X 1.2 cm). Cuttings are planted with a spacing of 15 cm within the row and 30 cm between rows. About 168 cuttings can be accommodated in a nursery bed of 10 m^2 (Dandin *et al.,* 1988).

Planting season. Plantations carried out during monsoon season are more successful than the one carried out during winter season. Plantation should be carried out within 1-2 days of uprooting from nursery site. Saplings are transported only during morning/evening hours and covered with moist gunny cloth during transportation/Storage.

Mulberry varieties. S_{13}, S_{146}, S_1 and S_{1635} varieties are suitable for plain areas under rainfed conditions. $Kanva_2$ and V_1 in irrigated areas.

Method of plantation. In case of loosely textured and deep soils, pits of 45x45x45 cm can be dug. In case of hard and shallow soils, pits of 60x60x60 cm can be dug. Pits must be filled with FYM or compost (5 kg/pit) and soil. Forest soils are generally acidic, lime application @ 500 g/pit is necessary along with farmyard manure.

Spacing. In large extent of cleared forestland with undulating surface, 2.4 x 2.4 m or 3 x 3 m spacing is more suitable. In marginal land holdings, 1.5 x 1.5 m spacing and along with the border of the field, also two sides of irrigation drainage channels 2.4 x 2.4 m spacing.

Sapling planting. Saplings of 5-6 months age with a height of 1.5-1.8 m can be used for planting. One sapling must be planted in each pit and it should be planted deep and straight in the center of the pit.

Training. The first apical cut should be given to the sapling after about 15 days of planting. All the buds sprouting below 150 cm should be removed allowing only the uppermost 4-5 branches to grow during the first year of plantation. Thereafter, these branches should be given a cut at 60-75 cm each and crown allowed to be formed. No pruning is advocated for the first two years of plantation.

Maintenance. During the first year of establishment, all the lower buds should be removed regularly. Plants must be protected from the grazing animals like cattle and goats through a tree guard. Plants will attain a height of 2.4 – 3.0 m after one year of planting. During May-June (2^{nd} year) plants are given the first pruning at a height of 90 cm from ground level in a spacing of 1.5 x 1.5 m and at a height of 120 cm in spacing of 2.4 x 2.4 m and 3.0 x 3.0 m leaving 3-4 buds on each primary branch (15-20 cm). Soon after pruning 5 kg of well decomposed FYM or compost must be applied around the plant followed by the thorough digging and weeding. After digging, a basin of 60 cm radius around each plant is made for water retention. The second pruning is done 15 cm above the first cut before the cessation of rains (October-November). The third pruning is done another 15 cm above the send cut with onset of monsoon showers to maintain a final crown height of 120 cm in case of 1.5 x 1.5 m spacing and 150 cm in case of 2.4 x 2.4 m and 3.0 x 3.0 m spacing.

Nutritive management. FYM @ 10 mt/ha/yr and 2 mt Vermi-compost plus green manure crop sunhemp or dhaincha once in a year in rainy season followed by mulching. Chemical fertilizer N:P:K @ 50:25:25 in two split doses plus the use of VAM (Benchmin *et al.*, 1997).

Mulberry Cocoon Production

With the proper care and maintenance in 3-5 years mulberry attains tree form and gives 6-8 mt/ha/yr through 4-5 harvests and can very easily rear 500-700 dfls which in turn yields 250-300 kg mulberry silk cocoons and as a sole crop Rs.15,000/- to Rs.25,000/- per annum per hectare can be obtained. Thus, selection of mulberry tree in agro forestry is based on cultural and economic as well as environmental and biological factors (Nadagoudar, 1998). Karnataka state has a leading role in the development of several model watersheds, with which mulberry has been considered as one of the important component.

Intercropping in Mulberry

Intercropping in mulberry has been attempted by growing legumes (Sinha *et al.*, 1987), vegetables (Koul *et al.*, 1996) and pulses. It is possible to grow short duration high yielding varieties of ground nut (Kasivishwanathan, 1977), mung, soybeans, cowpea, ragi and various vegetables (Gargi *et al.*, 1997) as intercrops in mulberry. This not only augments the farmer's income but also improves the soil fertility. Growing horsegram, cowpea (Das *et al.*, 1990) and moth beans as intercrops in mulberry helps in retention of soil moisture in rainfed areas, thereby improving leaf yield. Intercropping helps in economic distribution of labour, insurance against natural calamities, higher yield per unit, better control of weeds, pests or diseases and continuous leaf cover gives better protection against erosion.

Mulberry can be extensively used for social forestry, panchayat lands, community lands, schools land, etc. needs to be encouraged, besides trees could be grown on road sides and on backyard of farmers dwellings, as a boarder fencing. The tree is suitable for row intercropping, mixed intercropping, strip intercropping, parallel multiple cropping, relay intercropping, multi-tier intercropping and alley cropping.

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Developing Sustainable Horticulture Based Farming Systems for the Semi-Arid Rain-fed Areas in Gujarat

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Exponential increase in human and livestock population in India has put tremendous pressure on natural resources, owing to not only degradation of principal resources like land, water and vegetation but also reduced per capita availability of land. The prime agricultural lands continue to be diverted to non-agricultural uses like industrialization and urbanization with the result that marginal rainfed lands are brought under cultivation with least attention on resource conservation. Out of 143 million hectares arable land in India, nearly 74 per cent is rainfed, which contributes about 42 per cent of total food production. However, soil moisture stress due to vagaries of weather, moderate to severe soil erosion and poor soil fertility are the major limiting factors of low productivity in rainfed areas. Therefore, this trend needs to be discouraged. Virtually, a sizable area (171 m ha) in our country is categorized as degraded lands. Such lands are subjected to problem of water and wind erosion, salinity, alkalinity, acidity, water logging, gullied and ravine lands, shifting cultivation, etc. are either lying vacant or under utilized. Therefore for fulfilling the basic needs of food, fruit, fuel, fodder, fiber, fertilizer, etc. horticulture based farming systems can play a major role by adopting practically feasible, economically viable and eco-friendly technologies developed in recent past. Considering above facts, horticulture based composite farming systems were evaluated to establish a viable model for rehabilitation and utilization of semi-arid rainfed areas.

The experiment was carried out at Central Horiticulture Experiment Station Vejalpur farm with aonla and neem based cropping systems, grown under rainfed conditions. The climate of the area is semi- arid with rainfall of 750mm during the experimental period. The mean minimum and maximum temperature was 44^0 C and 10^0 C .The soil of the site has 0.75 to 1m depth, with a pH range of 7.5 to 8.1 .The soil of the area is saline in nature The aonla crop was raised at 10x10 m spacing (100 plants ha^{-1}) and neem at 10X5m spacing (200 plants ha^{-1}).Vegetables and fodder crops were grown as intercrops during kharif season *in* the interspaces. The system was compared with traditional system of the farmers of the area. Data on growth, biomass, yield and productivity of various crops grown in the system were recorded along with their economics.

Observations recorded on seven year old aonla plants revealed that mean plant height was 4.84m, mean stock diameter 28.11mm, plant spread 20.11 m^2 and a leaf area index (LAI) of 20.56. In aonla based cropping system, maximum LER (1.71) was recorded in aonla + okra cropping system. Highest mean net return (Rs. 68,715/-) was noted in aonla + maize cropping system. Aonla +maize was found to be the most suitable for the semi- arid area as maize being a traditional crop of the farmers of the region and also provide fodder for their cattle. Biomass production was highest on fresh weight basis (163.48 q ha^{-1}) as well as dry weight basis in maize (34.33 q ha^{-1}).Total biomass production from the aonla with maize system was 332.30 q ha^{-1}. Root weight was 21.94 per cent of total biomass produced by the trees (Hiwale, 2004).

Growth observation in neem based production system indicated that mean plant height in seven year old plants was 6.25 m, stock diameter was 19.32 mm, plant spread was 25.5 m^2 with leaf area index of 25.38 $m^{2.}$. Highest net returns of Rs.14, 543/- was recorded in neem + cenchrus. Neem tree above ground biomass at seven years of age was 218.84 q ha^{-1}, whereas, below ground biomass was 80.94 q ha^{-1}. Total biomass production in the seventh year was 414.39 q ha^{-1}. (Table1). Root weight was 21.94 per cent of total biomass produced by the aonla tree and 24.93 per cent in neem tree. Lower below ground biomass production has also been recorded in arid conditions by Tokey and Bisht (1992).

Comparative performance of both the systems indicated that plant height and LAI was more in neem where as, stock diameter and plant spread was more in aonla. Higher biomass was produced by neem tree compared to aonla, which is because of double the plant population per hectare.

Table 1. Mean plant growth, LAI, biomass production in horti-agriculture and silvi-pasture production system

	Plant height (m)	Stock dia. (mm)	Spread (m^2)	LAI	Biomass produced (q ha^{-1}) on fresh wt basis				Total biomass (q ha^{-1})
					Above ground	Below ground	Fruit	Intercrop	
Aonla 7Yr.old	4.84	28.11	25.5	20.56	62.02	37.05	69.75	163.48	332.30
Neem7yr.old	6.25	19.32	20.11	25.38	218.84	80.94	24.86	89.75	414.39

Table 2. Leaf litter fall, decomposition and nutrient recycling

	Litter fall q/ha	Litter decomposition %	Nutrient addition(kg/ha)		
			N	P	K
Aonla 7 year old	9.37	28.53	7.46	1.03	3.38
Neem7 year old	9.62	25.27	13.70	1.15	3.08

Table 3. Economic analysis of agroforestry systems

Particulars	Horti-Agricultural system	Silvi-Pastural system	Traditional system
1. Tree component	Aonla (100plants ha^{-1}) (*Emblica officinalis* Gaertn.)	Neem (200plants ha^{-1}) (*Azadirchata indica*)	Maize
2. Crop component	Maize	Cenchrus	Red Gram
3. Rotation (yrs)	7Yrs.	7yrs.	7yrs.
4. Cost of cultivation (Rs.)	46,500/-	15,000/-	24,500/-
5. Gross return(Rs.)	217100/-	152725/-	81,200/-
6. Net return (Rs.)	203610/-	121560/-	56,700/-
7. Annual average net return (Rs.)	29087.14/-	17365.71/-	8,100/-
8. B.C. Ratio	4.66	10.18	3.31
9. B.C. Ratio at 12 % discount	4.11	8.96	2.91
10. Annual average employment	185	72	88

Studies on leaf litter fall and estimation of nutrient addition indicated that maximum leaf litter was recorded in neem. N and P per hectare was recycled by neem (13.70 and 1,15kg/ha, respectively whereas maximum K was recycled by aonla (3.38 kg ha^{-1}). Rate of decomposition was higher in aonla (28.53%).

Horti-agriculture production system composed of aonla intercropped with maize was the best as it not only provides food, fruit and fodder to the farming families but provides additional income also. Among the different silvipastoral systems neem intercropped with cenchrus grass was the best.

The comparative economics worked out indicated that in a seven year rotation aonla with maize gave a net return of Rs. 2,03,610 with a annual net return of Rs. 29,087/-and a B:C ratio of 4.66. However, neem with cenchrus grass gave a net return of Rs.1,52,725/- with a annual average return of Rs.17,365/- and a B:C ratio of 10.18 (Table 3) . The traditional system gave lowest net return of Rs. 56,700/- with a B:C ratio of 3.31. Thus, it can be concluded that instead of monocropping, it is advisable to go in for horti-agri cropping system for the farmers who have less land area to meet the requirement and silvipastoral system to the farmers having excess land to meet their basic requirement. The composite system helps in increasing the productivity per unit area but also helps in maintaining the sustainability of the soil, besides proving food, fodder and fuel.

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Potency of *Acacia nilotica* as Invasive Species at Baluran National Park, East Java- Indonesia

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Most of the introduced plant species that become naturalized do not cause significant problems as they are confined to highly disturbed sites or are not expanding their range but few species do, which are called invasive species. In the last few decades, ecologist and natural resource managers have recognized that the spread of non-native or alien organisms poses a serious threat to the conservation of natural and semi-natural habitat, and such invaders can have a tremendous impact on the native faunal and floral communities. The spread of alien plants is a pervasive threat as the invaders proliferate and continue to spread, even if their introduction has ceased or ecosystems are not longer under the influence and pollution, fragmentation, and climate change. The problem of biological invasions has become a central issue in the conservation of our biological diversity, and their control and management become costly and labor intensive.

Within the last 100 years, the number of established alien plant species increased rapidly in many regions of the world as a result of increasing trade volume and travel around the globe (Rajmanek and Randall, 1994). In Indonesia, there are few comprehensive information on invasive alien species and *Acacia nilotica* is one among them. *Acacia nilotica* (L) is a thorny wattle native in India, Pakistan and Africa. This species is widely distributed in tropical and subtropical Africa from Egypt and Mauritania to South Africa. In Africa and the Indian subcontinent, *Acacia nilotica* is extensively used as browse, timber and fire- wood species. The bark and the seeds are used as source of tannins. The species is also used for medicinal purposes. Bark of *Acacia nilotica* has been used for treating haemorrhages, colds, diarrhea, tuberculosis, and lesion, while the roots have been used as an aphrodisiac and the flowers for treating syphilis lesions. The invasion of *Acacia nilotica* has resulted in the reduction of savanna in Baluran National Park reaching about 50%. Pressure to savanna has a great impact on the balance and preservation of whole ecosystem in Baluran National Park. The objective of this study is to know about potency *Acacia nilotica* as invasive species at Baluran National Park in East Java Indonesia.

This study conducted in June 2007 at Baluran National Park. The methods here focus on collecting primary information by using questionnaire to interview the leaders in the village, and observing directly to the site study. Besides, this study also got secondary data from literature study such as papers, proceeding, journals, edited books, and internet.

Baluran National Park is one of National Parks in Indonesia. It is located in the East Java Province, the capital city of East Java Province is Surabaya. It is located between 7°29' - 7°55' S and between 114°17' - 114°28' E, with 0-1247 m up sea level, rain fall 900-1600 mm/yr and air temperature ranges from 27° - 34°C. Baluran National Park is dry specific ecosystem in Java Island. It contains savanna vegetation type, coastal forest, mountain forest, mangrove forest, and ever green forest. Savanna vegetation dominate 40 per cent of the total forest at baluran National Park. There are 444 plant species there. Some of them are *Ziziphus rotundifolia*, *Azadirachta indica*, *Acacia leucophloea,* etc. These species can adapt to the drought condition, while the others can't. The other plant species are *Tamarindus indica*, *Dioscorea hispida*, *Aleurites moluccana*, *Corypha utan*, *Avicennia* sp, *Cordia obliqua*, *Syzygium polyanthum*, and *Sterculia foetida*. There are 26 mammals *(Bos javanicus javanicus*, *Bubalus bubalis*, *Cuon alpinus javanicus*, *Muntiacus muntjak muntjak*, *Cervus timorensis russa*, *Panthera pardus melas*, *Tragulus javanicus pelandoc*, and *Prionailurus viverrinus)*. *Bos javanicus* is the mascot of Baluran National Park. Besides, there are 155 kinds of birds (*Hirundo rustica*, *Eudynamys scolopacea*, *Pavo muticus*, *Gallus gallus*, *Anthracoceros convecus*, *Buceros rhinoceros*, *Leptoptilos javanicus,* etc.).

Acacia nilotica has spread on the most of savana at Baluran National Park, in Banyuwangi-East Java, they are savanna Bekol, Kramat, Kajang, Balanan, Lempuyang, Dadap, Asam Sabuk, Curah Udang, Widuri, and Merak. At the site of savanna Kramat, Kajang, and Balanan, this plants have formed closed canopy. Savana Taipat is the only savanna hasn't been invasived. Besides at savanna area, *Acacia nilotica* is also found at the coastal forest. The climate condition at Baluran National Park is one factor that accelerate the spread of *Acacia nilotica* growth. Intensive sun shine and drought are the main factors that the seeds of these plants eaten by herbivores in that area, such as *Bos javanicus, Cervus timorensis, Muntiacus muntjak, Bubalus bubalis*, etc. On the result, the seeds come out with the feces spread in the almost of the Baluran National Park Area. High intense of sun light and rain fall trigger the growth of the dormant seed. At savanna Bekol, the area is open because *Acacia nilotica* plants were pulled out. Not long after that this species grow as soon as possible. The spread speed of this species at savanna Bekol is very fast. Many efforts have been done to eradicate this species. In 1998/1999, 175 ha *Acacia nilotica* had been pulled out, and ten years later, the height of this species reach 100 cm in high density.

Baluran savanna is specific identity (mascot) at Baluran National Park, that is very important for the ecosystem. If the environment is disturbed, it can influence the ecosystem. One of threat to this ecosystem is *Acacia nilotica*, the species become invasive, and invaded almost the Baluran National Park Area. The speed of this species growth resulted in decreasing the quality and quantity Baluran Savanna, and influenced behavior of herbivore that live there.

The result of the study showed that carrying capacity of savanna at Baluran National Park to source of feeding has decreased to support wildlife, thus threatening the survival of wildlife. Many efforts have been made to eradicate *Acacia nilotica*, mechanically and chemically. The eradication of *Acacia nilotica* by chemical method was not effective and efficient. This method spent a lot of budget, because it needed a lot of chemical material compared to area to be treated. While eradication by mechanical method by cutting have also not found successful. This method triggerd the dormant seed to grow, and supported coppicing. Mechanical methods are time consuming, while heavy machines like bulldozers are quite effective but that will change the land structure.

Now, method that applied to eradicate this species is by cutting and burning the coppice and pull out the seedling. These activities need a lot of labor, continuity, and monitoring. Until now, about 63 ha/year has been eradicated, which needs another 73 years to eradicate this species completely, provided there is no additional reinvasion to this area.

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Introduction of Compatible *Populus* Species in Different Areas of Iran

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Nowadays mankind needs the wood and paper more than the earlier times. The main resources of paper are biomass cellulose. Deforestation increased in developing countries to meet their own requirements and the demands of rich industrialized counties thus led to large scale deforestation, degrading the natural resources and the climate. Planting the short rotation trees can conserve the natural forests and mitigate the green house gases from the atmosphere. In this paper, an attempt has been made to review the introduction of some suitable *Populus* species in different parts of Iran. This is a library research to review documents in order to identifying compatible *Populus* species as a short rotation tree in different parts of Iran.

Because of variable climates in different regions of Iran, many different species of *Populus* exists there. In different regions of Iran, different species have been noticed, which are compatible wit the existing ecosystems and their productivity was also found quite variable. Zanjan province (north-west of Iran) is a good area for *Populus* plantation and about 60 per cent of *Populus* species in province is *P. nigra* var *pubescens* and 30 per cent is *P. alba* var *shirazi,* though the growth of *P.alba* has been observed better than *P.nigra*. This species can reach the maximum height of 25 m and 2.5m³ volume with the diameter of 50 cm, whereas, *P. nigra* can only reach the maximum height of 22.5 m and 1.6 m³ volume at same diameter. In Chahar Mahal-o-Bakhtiari province (south-west of Iran), *P. nigra* is the main species, whereas, *P. alba* and *P. euphratica* are found in natural stands with lowest percentages of diffusion. In this province, the average production of wood is 30 m³ per hectare per year, so with considering it's surface area, province can produce totally 540,000 m³ wood yearly.

In Gilan province, *P. deltoides, P. euramericana, P. caspica, P. nigra* and *P. alba* are available but because of suitable climate of this province to planting other species such as *Fagus* and *Quercus*, *Populus* planting is not a good choice. In Systan–va-Baloochestan province (south-east of Iran), there are natural stands of *P. euphratica*. This part of Iran has a dry climate with salty soil. *P. euphratica* could tolerate this condition. The average basal area for this species in Systan is about 20 cm^2 and average height can be 5-7 meters. In Markazi province (center of Iran), *P.euphratica, P.alba, P.nigra* and *P. deltoides* with average growth of 12.5 m³ per hectare per year has been noticed. It is lower than average of Iran (22.5 m³ $ha^{-1}yr^{-1}$) and also average of world (45-60m³ ha^{-1} yr^{-1}). The total stand volume and growth in this province are about 616,000 m³ and 106,000 m³ per year, respectively. In Kerman, Kordestan, Khoozestan and Yazd province *P. euphratica* are used for plantation. Additonally, in West Azarbayjan, *P. nigra* attains 27.5 m³ ha^{-1} yr^{-1} growth. In Kermanshah, *P.euramericana* with 39 m³/ha/yr growth and *P. deltoides* has comparatively lower rates of growth with 27 m³. In Kordistan, *P.deltoides* has 25.18 m³ ha yr^{-1} growth and *P. euramericana* has lower rate of growth (25.18 m³), whereas, in Karaj, *P. nigra* var *betulifolia* has 30.83m³ ha^{-1} yr^{-1} growth and *P. euramericana* recorded lower rates of growth of 27.45m³.

According to Iran forest organization study, *Populus* plantation area in Iran is 150,000 ha, with average 20m³ growth per hectare per year (Asadi, 1994; Kalagari, 1997). This area can produce 3,000,000 m³ wood yearly. Regarding to 10,000,000 m³ use of wood in Iran per year, this production is not enough so the surplus need of wood is secured from other natural forests (Hyrcani forest) and importing of wood. It is possible to increase the *Populus* plantation area to 500,000 hectare in Iran with attention of planting compatible species in each eco-regions. It can happen with education and motivation of the farmers. The plantations of fast growing tree species will certainly help in protecting and conserving the natural forests of Iran.

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Floral Biology and Crossability Pattern in *Grewia optiva* Drummond

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Grewia optiva, commonly known as 'Beul' belongs to family Tiliaceae, and it is a very important agroforestry tree of the low and mid-hills regions in the western and central Himalaya. It is naturally distributed in Indian subcontinent; Bhutan, Nepal, Pakistan and in India, it is distributed in areas of Himachal Pradesh, Jammu and Kashmir, Punjab, Sikkim and Uttar Pradesh. It is a very popular tree which is grown in different parts of Himachal Pradesh on account of its utility as fodder, fuel and fibre. *G. optiva* is a small to medium-sized deciduous tree of 9-12 m in height; crown spreading type; clear bole of 3-4 m with about 1 m diameter. Branches smooth pale silvery-brown; bark dark brown, thick and roughish, exfoliating in small woody scales. Leaves opposite, ovate, acuminate, closely serrate, rough and hairy. Flowers 1-8, together; penducles solitary, leaf opposed or exceptionally a few axillary. Sepals linear oblong green outside, white, pale yellow or red inside; petals white or pale yellow, shorter than the sepals, linear, claw distinct. Fruit is a drupe, 1-4 lobed, olive green and black when ripe. It flowers from the end of March to June; flowers are monoecious and lemon yellow in colour. Pollen grains exhibit sulphur yellow colour and viability is upto 75 per cent. About 60 genotypes of *Grewia optiva* are available in the department which have been collected from different districts of Himachal Pradesh. The aim of present study was to investigate the relationship between the floral biology and breeding system of *Grewia optiva*.

The present study was carried out in the department of Tree Improvement and Genetic Resources in the College of Forestry, University of Horticulture and Forestry, Solan (HP). 12 genotypes from a collection of 60 genotypes were selected to study floral biology and crossability pattern on the basis of their growth performance. Visual observations were made on flowering habit, initiation and duration of flowering period, floral bud development, morphology of flower, pattern of anthesis, dehiscence of anthers and receptivity of stigma. The selected genotypes were used for controlled crossing. For self pollination flowers were left enclosed in cotton cloth bags. For hand pollination, the flowers were emasculated in the evening hours and were bagged with cotton cloth bag. Next morning, the emasculated flowers were hand pollinated. The hand pollinated flowers were rebagged and tagged properly indicating the date, time and genotypes which were cross pollinated. Finally, the percentage of self pollination, cross pollination and the per cent fruit set data was recorded.

The flowering buds started appearing along with the appearance of new leaves during the end of March month. Flowering started in first week of April and continued till the end of June and first week of July, but a little variation from genotype to genotype was observed. The date of appearance of first and last flower and duration of flowering in different genotypes used for study is given in Table 1. The flower buds appeared in the axils of the leaves in acropetal succession. The inflorescence is an umbellate cyme, there were 2-8 flowers on one peduncel, the axils of the basal leaves bore more number of flowers than the axil of the terminal one. The flowers of *G. optiva* are complete, cyclic, regular with 5 sepals, polysepalous and 5 petals, polypetalous. Androecium contains numerous anthers, ranging from 65-150 in number. Ovary monocarpellary having 4 lobes, superior.

The dehiscence of anther took place prior to anthesis. The entire anther dehisced longitudinally. The dehiscence starts from the point which is attached with the filament and progresses towards the periphery, thus releasing pollen

Table 1. Date of initiation and flowering period in *Grewia optiva*

Genotypes	Date of appearance		Length of flowering period (days)
	First flower	Last flower	
CH-4	16-4-2010	30-6-2010	76
CH-6	2-5-2010	15-7-2010	75
KA-1	28-4-2010	10-7-2010	74
KA-2	25-4-2010	14-7-2010	81
MA-3	27-4-2010	18-7-2010	83
MA-4	23-4-2010	10-7-2010	79
SH-2	30-4-2010	16-7-2010	78
SI-2	21-4-2010	11-7-2010	82
SI-7	24-4-2010	8-7-2010	76
SO-1	16-4-2010	5-7-2010	81
SO-2	16-4-2010	3-7-2010	79
SO-5	15-4-2010	5-7-2010	82

Table 2. Percentage of crossing and fruit set in self pollination and cross pollination in *Grewia optiva*

Mode of Pollination	No. of flowers pollinated	No. of flowers left after pollination	Percentage	No. of fruit set	Fruit set percentage
Self pollination	120	40	33.33	26	21.66
Cross pollination	400	179	44.75	103	25.80

grains. The process of dehiscence of anther took place within 10-20 minutes. Pollen grains were dark yellow in colour and the size of pollen varied between 43-53.1 micron in size in different genotypes. Acetocarmine test was used to determine the viability of the pollens. Percentage of fertile pollen grains of the individual plant was determined. The average viability percentage varied from 77.19% to 80.39 per cent. The maximum receptivity of the stigma was observed on the day of anthesis, when stigma becomes shiny, sticky and have some viscous liquid on its surface, but the receptivity remains for a very short period. The total number of crosses made in all the selected genotypes were 400 out of which 179 crosses were left hence, the percentage of cross pollination is higher (44.75%) than self pollination (33.3 %). Overall fruit set in all the crosses made was 25.80 per cent (Table 2).

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Role of Biotechnology for the Production and Improvement of Fast Growing Tree Species

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Since ancient times trees have been important components of human beings and an excellent part of biodiversity. Trees are source of food, fodder, fuel wood, fiber, timber and lot of non-timber products like resins, biochemical used in pharmaceuticals, oils etc. Due to deforestation, depletion of genetic resources due to with escalating present population needs, the forest cover has declined at a very high rate. So there is a need to increase area under trees. To improve forest vegetations especially trees, conventional approaches have been exploited for propagation, but tree breeding efforts are most important for the valuable fast growing tree species. However, such methods or approaches are limited with several inherent bottlenecks because these are generally long lived, sexually self incompatible and highly heterozygous in nature. Due to the prevalence of high heterozygosity in these species, a number of recessive lethal alleles are retained within existing population, resulting in high genetic load and inbreeding depression (Williams and Savolainen, 1996). Thus conventional breeding is rather slow and less productive and cannot be used efficiently for the genetic improvement of fast growing tree species (Srinidhi and Chauhan, 2007). Plant biotechnological approaches mainly plant tissue culture, genetic engineering or transformation offer an epitomized option for effective multiplication and genetic improvement of trees with a limited time span.

Interventions of biotechnological approaches for *in vitro* regeneration, mass multiplication and transgenic studies in fast growing tree species have been encouraged particularly in last few decades. Development of molecular marker technology, the variation at chromosomal or DNA level can be detected easily. Elite and rare genetic material of tree species can be multiplied true to type with the help of molecular markers.

Somatic embryogenesis also offers immense potential to speed up the propagation of forest trees (Attree and Fowke, 1993; Gupta *et al.,* 1993). It is of great importance in forestry biotechnology because this system offers the capacity to produce unlimited number of somatic embryo derived propagules (Attree *et al.,* 1994) and artificial seeds (Lulsdorf *et al.,* 1993); in spite of this it can be the best source for genetic transformation.

Among fast growing tree species, the genus *Populus* has been adopted by the scientific community as the model choice because it offers numerous advantages such as fast growing nature, facile vegetative propagation, interspecific hybridization, amenability to tissue culture and genetic transformation, and a small genomic size approximately 500 mb (Taylor, 2002).

Micropropagation of Forest Trees

Many biotechnologists have been working on plant tissue culture in different forest tree species for decades. The first achievement in this was reported by Winton (1968) from leaf explants of *Populus trichocarpa*. Some forest tree species or genotypes do show positive response while some others are still recalcitrant during *in vitro* conditions. In general juvenile tissues of trees are more responsive to *in vitro* manipulations than mature tissues. The longer life span of trees may add to the problem of contamination *in vitro* by the symbiotic association of many microbes. Besides the age of the tree, the response of explant is primarily determined by genotype, physiological status of tissue, and time of year when the explants are collected and cultured (Giri *et al.,* 2004). The concentration of plant growth regulators and the composition of cultural media for *in vitro* aseptic culture is very important.

In addition, there are many more limitations such as low shoot prolification, excessive phenolic exudation (Linington, 1991), callus formation at the base of explant (Marks and Simpson, 1994), vitrification (Monsalede *et al.,* 1995) and shoot tip necrosis (Bargchi and Alderson, 1996). Micropropagation without an intervening callus phase is advantageous over conventional vegetative propagation in terms of quantity, quality and economics (Altman and Loberant., 1998). Micropropagation of trees *in vitro* is not only a means for mass multiplication of superior clones but it can be used for developing transgenic plants and conservation of germplasm through cryopreservation.

Somatic Embryogenesis in Tree Species

In some cases somatic embryo formation occurred directly on the callus induction medium, whereas, in some cases different media and different hormones are needed for callus induction, somatic embryo formation, shoot organogenesis and plant conversion. Using cotyledon explants with high concentrations of picloram or IBA somatic embryos have been produced from *in vitro* cultures of *Eucalyptus globules* (Nugent *et al.,* 2001).

Genetic Modifications in Tree Species

The main advantage of the genetic modification is that the genetic constitution of the elite clone can be maintained, whereas in classical tree breeding programs it is lost with every new cross, and inbred lines cannot be obtained because of high inbreeding depression (Boerjan, 2005). The largest effort in genetic engineering has been devoted to modifying the amounts and composition of lignin in trees to improve lignin extractability during pulp (Baucher *et al.,* 2003). The deployment of such transgenic trees could enhance the capability of the pulp mill while decreasing chemical costs and, importantly, reducing the ecological impact on the environment. Over-expression of ferulate-5-hydroxylase (F5H) in poplar results in a less condensed lignin and in significant improvements in lignin extractability and bleaching, whereas, fiber quality remained equal or even better (Huntley *et al.,* 2003).

By co-transformation poplar with two different constructs – one armed at increasing F5H expression and the other at reducing 4-coumarate CoA-ligase expression – the combined effect expected for the single transformation was obtained, lignin amount was reduced and compensated for by more cellulose and lignin was less condensed (Li *et al.,* 2003). Such type of work revealed the potential of modifying one genotype simultaneously for multiple traits by stacking transgenes, a strategy that could circumvent numerous generations of conventional breeding (Halpin and Boerjan, 2003).

Besides quality, in case of fast growing or short rotation forestry yield is one of the most important traits and several genes involved in different process have been shown to impact on growth in transgenic poplar. Over-expression of a cytosolic pine glutamine synthase (GS), a key enzyme involved in nitrogen assimilation, increases height by 41 per cent and stem diameter by 36 per cent as measured for three year old field grown transgenic poplar (Jing *et al.,* 2004). The main obstacle for genetic transformation of trees is the regeneration of transformed plantlets (Giri *et al.,* 2004). In addition, it was found that *Agrobacterium* based genetic transformation is the main method used for developing transgenic trees. Selection of explant for transformation is a very crucial factor.

Reduction in the Reproductive Phase

The long generation period of tree species is one of the major limiting factors for genetic improvement. However, by taking advantage of biotechnology the time needed to produce a new tree variety could be identified and manipulated to enable flowering to be induced at will, the fixing of beneficial recessive mutations, and introgression or back crossing to increase rare alleles in breeding population could become realities. For example, flowering in aspen is generally observed after 8 to 20 years but one of the genes, LFY has been expressed in transgenic aspen and was able to produce flowers after 7 months of vegetative growth (Weigel and Nilsson, 1995; Pena and Sequin, 2001). This approach, thus, can be extended to other economically important tree species.

Change of Tree Architecture and Size

Plant growth regulators play an important role in growth and development, and also affect formation of wood (Little and Savidge, 1987). Thus the manipulation of plant hormones synthesis in tree looks very interesting. Some progress has been made using T-DNA, auxin and cytokinin biosynthesis genes from *Agrobacterium tumefaciens* and *A. rhizogenes*. It has been demonstrated that the manipulation of IAA levels by the over expression of *iaaM* and *iaaH A. tumefaciens* T-DNA in *Populus* can change growth, development and wood formation (Tuominen *et al.,* 1995). Over expression of such genes in the transgenic plants bring about alterations in growth pattern and wood properties (Tzfira *et al.,* 1998).

Product Quality Traits

Quality traits for trees are quite different from quality traits being developed for other agricultural based crops. Tree quality comprises wood and fiber properties, feedstock for pulp and timber mills, for furniture manufacture, chemical cellulose source and other special chemical products. The modification of lignin is a focus given the possibilities of affecting and products through its manipulation (Baucher *et al.,* 2003). Genes other than those in the lignin biosynthesis pathway have also been used to alter wood composition. Reduction in laccase through antisense lac3S expression in transgenic poplar has led to an alteration of the phenolic content and aberrations in xylem fiber structure without altering lignin content or composition. It is also reported that a gene that affects lignin biosynthesis can also affect growth. Down regulation of 4-coumarate ligase (4CL) leads to reduce of lignin levels, increased cellulose and also biomass accumulation (Nehra *et al.,* 2005). Biomass increased by introducing bacterial cellulose binding domain gene into poplar (Levy *et al.,* 2002). Poplar transformed with a pine glutamine synthatase gene was found to have increased drought resistance (El-Khatib *et al.,* 2004).

Marker Assisted Selection (MAS)

The next important approach to boost up the improvement of forest trees is based on the more efficient exploitation of genetic diversity in the existing germplasm. Over the past few decades, genetic maps have been made for many tree species and QTLs have been mapped for a range of agronomically important traits, such as wood properties, with the aim of using genetic markers linked to QTLs to follow the trait in breeding programme (Brown *et al.,* 2003). However, the potential of marker assisted selection in forest tree breeding is limited because linkage between a trait and a linked marker decreases with each generation owing to genetic recombination, unless the marker is in the gene itself. Presently, there are no examples of genes that have been positionally cloned from any forest tree species.

CONCLUSIONS

The productivity of tree species has benefited immensely from development and implementation of improved silviculture and forest management practices during the past century. A second wave of improvement has been brought about by the introduction of elite and new germplasm developed through genetics and breeding efforts. Coupled with the genetic gains achieved through breeding, the emergence of biotechnological strategies has added a new horizon to tree improvement and production. The use of tissue culture methods as a micropropagation system for tree is an established technology compared to traditional systems. True to type plants via direct or indirect somatic embryogenesis may boost tree micropropagation. It has been found that *Agrobacterium* mediated genetic transformation is used in most cases and marker genes have been transformed and a genetic transformation protocol has been standardized. Recent developments in transgenic trees can have multiple benefits like manipulating generation time, plant protection against biotic and abiotic stresses, wood quality, compounds of pharmaceutical value and improvements of polluted soils. *Populus* trees have several advantages as a model system including rapid growth, prolific sexual reproduction, ease of cloning, small genome, etc. If current progress in biotechnological application continues, the future may witness super tree species tailored for special agronomic characteristics.

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Bamboo Propagation by Branch Cuttings: A Farmer's Friendly Technology for Mass Clonal Multiplication

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Dendrocalamus giganteus is the largest of the Indian bamboos and grows well in humid tropical and sub-tropical regions, in the North and North Eastern part of the country. It produces culms up to 25 cm in diameter. *B. vulgaris* is a moderate-sized bamboo of 6m to 30m height and 5 to 11 cm diameter, with yellow or green striped culms growing separate from one another. It is found in all the tropical region (origin unknown) and is frequently cultivated. In warmer areas, it has run wild. Flowering has not been recorded so far. It has spineless culms, forming an open or loose clump. Generally the bamboo culm is hollow; widely used for furniture, toys, cages and other essential items. *B. vulgaris* var. *striata* Gamble is an ornamental variety.

Availability of suitable planting material of bamboo is always a problem as the unavailability of seeds every year as well as difficult conventional vegetative propagation methods. Vegetative propagation is not a breeding method but a way to rapidly multiply disseminate the desired clonal material according to its genetic potential. In vegetative propagation, the genetic potential of a species, including the non-additive variance, is automatically transferred to the new plant. However, in nature the tree populations are highly heterozygous and vegetative population helps to utilize maximum genetic gains in the shortest possible time. The success of vegetative propagation depends upon a proper environment, genetic component and the physiological status of cuttings, etc. (Cunningham, 1986).

Vegetative propagation is a good tool for propagating the selective genotype. Cloning by rooting of cuttings has developed a lot because it became possible to use improved genetic material in the establishment of seed orchards, in nutrition trials, in increasing hybrids with more genetic accuracy for tests and establishment of large industrial forests through mass propagation of clonal planting material.

Generally rooting response varies with season (Nanda *et al.*, 1968, 1970). In general, rooting is more profuse during summer months especially from April to July (Nanda, 1970), declines from August onwards and there is no rooting in winter (Nanda *et al.*, 1968). Microproliferation of many bamboo species including *B. vulgaris* for mass propagation has been done successfully by Plant Physiology Division of FRI (A. Kumar, 1989), but here again seeds are required to begin with.

Due to unavailability of seeds every year propagation techniques for many bamboo species is a major bottleneck in regeneration. Keeping in view of this problem, branch cuttings of *D. giganteus* and *B. vulgaris* which are easily available were tried for their rooting response to produced quality planting material.

The branch cutting of *D. giganteus* and *B. vulgaris* were collected from the already established planting material in Forest Research Institute, Dehradun Nursery in the month of April. About 30 cm long trinodal cuttings were made. After surface treatments of cuttings by $HgCl_2$ solution these cuttings were divided into 4 groups of 20 cuttings each. The basal ends of the cuttings were dipped in test solutions (IBA 100 ppm, Boric acid 100 ppm IBA + Boric acid 100 ppm and water) and kept for 24 hours for giving them treatment of the appropriate solution. Treated cuttings were planted in the poly bags containing sand, soil, and FYM (Farm yard Manure) in the ratio 2:1:1, the basal ends of the cuttings were inserted in the soil by keeping 1/3 portion of the cutting under the soil level in the earthen pots. These pots were kept in open and watered regularly. The rooted cuttings were finally harvested for knowing the number of roots and roots length of roots after four months of planting.

The rooting response of branch cuttings of *D. giganteus* was very encouraging. The maximum rooting of *D. giganteus* was observed in untreated cuttings followed by Boric acid 100 ppm and IBA 100 ppm treatment. The combination of Boric acid and IBA 100 ppm showed minimum rooting. It is interesting to note that the maximum rooting was initiated in the untreated cuttings that mean this species does not require any rooting hormone treatment. Moreover, hormones may be playing inhibitory role in the rooting of the cuttings in this case. As compared to individual treatment, the combination to two rooting hormone has most root inhibiting

Table 1. Rooting response of branch cuttings of *Dendrocalamus giganteus* and *Bambusa vulgaris* under different hormonal treatment.

Treatment	No. of cuttings/ treatment	% Rooting of cutting	No. of main roots	Root length (cm)	No. of sprouts
Dendrocalamus giganteus					
Control	20	80	3	38	2.0
IBA 100 ppm	20	70	5	25	1.5
Boric acid 100 ppm	20	75	2	23	1.5
Boric acid + IBA 100 ppm	20	50	2	21	1.0
Bambusa vulgaris					
Control	20	70	2	18	1.5
IBA 100 ppm	20	80	4	20	2.0
Boric acid 100 ppm	20	70	2	19	2.0
Boric acid + IBA 100 ppm	20	50	3	15	1.0

effect.

In *B. vulgaris*, the maximum 80 per cent rooting was observed in the cuttings treated with IBA 100 ppm followed by Boric acid 100 ppm (70%) and control (70%). However, the minimum rooting percentage was observed in case of Boric acid + IBA 100 ppm (50%). It is interesting to not that the number of roots and root length per cutting was higher in case of IBA 100 ppm treated cuttings, however, number of sprouts was almost same (Table 1). The horizontal planting of cuttings normally practical is dicots but equally responsive in bamboos as well. The IBA was found to be the best rooting hormone in case of many other tree species also as reported by Gurumurti and Bhandari (1988); Nautiyal *et al*. (1991); Pal (1992); Kaushal and Tewari (2009) .

Rooting of branch cutting of these species has opened a new area of propagation of bamboos particularly of these species. While using the main culms for different purposes, the thin branches are left unused. These branches after making binodal cuttings can be used for mass propagation by rooting of these cuttings. This technology, which is easy and farmer's friendly can be tested for other bamboo species as well. Therefore, serious efforts will be made to test this technology for other commercially important bamboo species as well to meet the huge demand of quality planting stock of bamboos.

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Effect of IBA on Rooting of Bamboo Species

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Bamboos are the fastest growing woody plants in the world. Bamboo cultivation, especially in intensively managed and productive plantation has attracted a great deal of interest in the recent years. The current demand of bamboo is 26.69 million tonnes against supply of 13.47 million tonnes in the country. To cater the growing demand of bamboos, there is immediate need of large scale cultivation. Conventional methods of propagation are based on seed and vegetative methods. Vegetative propagation especially by culm cuttings has tremendous potential for mass production of quality bamboo plating stock.

For propagating bamboo, culm segments resulted in 45-56% rooting in thick walled bamboo viz., *Bambusa nutans, B. polymorpha, Dendrocalamus giganteus,* whereas thin walled bamboos like *Melocana bacifera, B. tulda, D. longispathus* and *Oclandra nigrociliata* failed to produce any propagule Banik (1984). *Bambusa nutans* is reluctant to root species (McClure and Kennard, 1955; Stapleton,1987**)**. Keeping in mind above facts, effect of IBA for rooting during different seasons on *Bambusa nutans*, *B. tulda* and *D. Giganteus* has been investigated.

Culm cuttings of *Bambusa nutans, Bambusa tulda* and *Dendrocalamus giganteus* were collected in different seasons viz. spring (March), summer (June) and rainy (August). Each culm was then cut into sections, leaving 2-4 nodes on each section and retaining about 5 to 7 cm of culm portions at either end beyond the node. The prepared culm cuttings were given prophylactic treatment with 0.2 % (w/v) solution of Bavistin against fungal infection before putting them in the propagation beds. Five nodes each of four IBA treatments 100ppm, 200ppm, 5000ppm, 10000ppm and control for *Bambusa nutans* (Bn), *Bambusa tulda* (Bt), and *Dendrocalamus giganteus* (Dg), were replicated four times. In culm cutting, a hole in the middle of the internodal cavity was drilled with the help of electric drill machine and intermodal cavity was filed in IBA before planting of culm cutting in the beds. Control was also maintained by pouring water in the internodal cavity. The treated cuttings were kept horizontally with the opening facing upwards. Watering of the beds was done by intermittent misting. Cuttings and the new sprouts were covered with agroshade nets of 50 per cent transmission capacity to prevent drying due to intense heat as excessive heat can increase the respiration rate and can lead to depletion of the stored food. After 2-3 months, the cuttings were scored for rooting and sprouting per cent. The data obtained were subjected to three factor statistical analysis, employing analysis of variance (ANOVA), F-test for significance at $P \leq 0.05$.

During all the season viz. spring, summer and rainy sprouting and rooting percent showed significant variations in species and interaction effect of species and treatment. Among species (Fig. 1), irrespective of treatment highest sprouting 58, 32 and 21 per cent was observed in Bt during spring and in Dg during summer (38.00%) and rainy (25.00%) season. Control (T_1) produced maximum rooting 46.67 and 26.67 per cent during spring and rainy season, respectively.

Overall the trend for sprouting and rooting was of the order spring > summer > rainy (Fig. 2). Season has influence on the physiological state of the plant and hence it has vital role in induction and growth of sprouting and rooting of cuttings. Role of external factors especially temperature and photoperiod in adventitious rooting is well established (Dykemen, 1976; Hartmann and Kester, 1983;

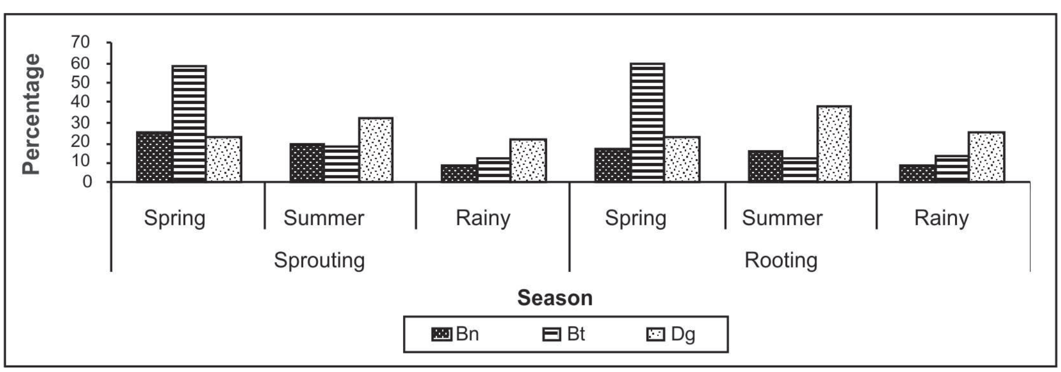

Fig. 1. Sprouting and rooting behaviour in culm cuttings of bamboo species during different season

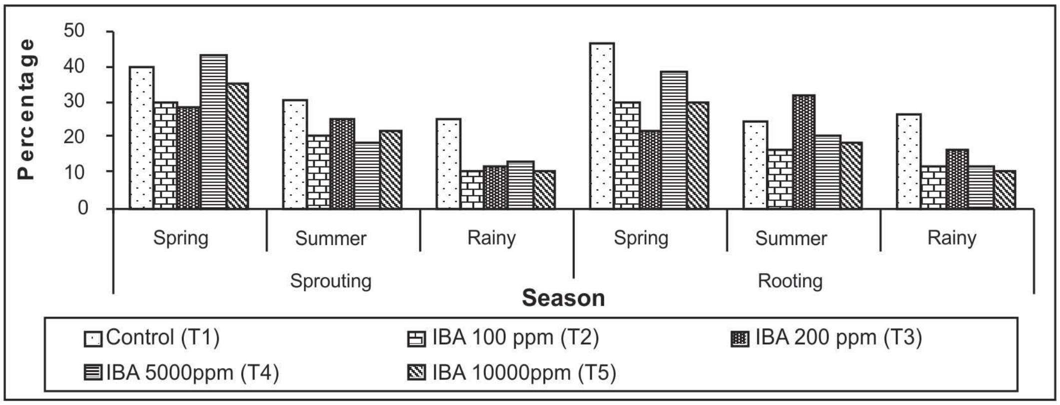

Fig. 2. Effect of IBA treatments and season on sprouting and rooting in culm cuttings of bamboo species

Carpenter *et al.,* 1973; Stoutemyer *et al.,* 1961). In bamboos of North India, the cessation of winter and onset of summer, results in resumption of active extension growth and upward mobilization of stored photosynthates and axillary substances from the underground rhizome which may become available for differentiation and growth of organs such as culms and adventitious roots (Agnihotri and Ansari 2000; Singh *et al.,* 2004). Thus, higher rooting and sprouting in spring and summer is understandable.

Dendrocalamus giganteus showed lower sprouting and rooting. In *D. giganteus,* branching is usually observed at the top of culm. The basal and middle portion from where the culm cuttings were made are unbranched and possess buds. The branch culm segments on culm cuttings offer an advantage of higher photosynthesis which may divert the carbohydrates for early growth of cuttings. Contrary, in unbranched cuttings, buds are below the soil due to which there are more chances of fungal attack. In the present study also, very high mortality was observed in *D. giganteus* due to fungal attack.

Exogenous application of growth regulators mainly auxins has been reported to positively influence induction and growth of adventitious roots in culm cuttings**.** IBA is considered as most important auxin due to its ability of initiating rooting in large number of species. Better formation of roots due to IBA may be attributed to accumulation of metabolites at the site of application, synthesis of new protein cell division and cell enlargement (Nanda, 1970). Therefore enhanced rooting of *B. tulda* in spring and *D. giganteus* in both summer and rainy seasons may be attributed to increase in the auxin concentration to optimum level. Such species apparently lack sufficient non-auxin endogenous root forming stimulus (ERS), an essential for predisposing them to root for which applied auxin cannot substitute (Hartmann *et al*., 1997).

The ‘cavity method’ which involves pouring the solution of IBA/water (control) into the culm cavity, gave very good sprouting and rooting in cuttings The advantage of ‘cavity method’ could be to keep the cuttings moistened and maintain certain degree of humidity.

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An Assessment of Non-Timber Forest Products and Their Contribution in Livelihood Security

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Forest provides a wide range of natural assets, including household goods, cultural values, physical and biological products, and other services that are vital to the livelihood of many people. Nepal ranges from 58 m above mean sea level to the 8848 m. The summit of Mount Everest, this unique geography of Nepal has made it rich in biological resources having valuable non-timber forest products, comprising about 10 per cent of the vascular plant species (Malla and Shakya, 1984). The term NTFPs encompasses all biological materials other than timber, which are extracted from natural forests for human use; these include foods, medicines, ornamental plants, wildlife, fuel-wood and raw materials, notably rattan, bamboo, small wood and fibers. Variation in topography is the prime factor, which reflects contrasts in climatic, habitat, vegetation, flora and fauna. Essential oils, spices and medicines are the most common intermediate or the end products, which result from the processing of NTFPs and these are often sold to the national or international markets. The role and contributions of NTFPs are crucial amongst the rural communities of developing countries. About 80 per cent of the population of developing countries depends on NTFP for their primary health, nutritional needs and income generation. This is particularly true to a country like Nepal, where alternative economic opportunities are limited. The increasing commercial demand for the NTFPs found in Nepal presents an economically, environmentally and socially viable means of assisting rural communities in controlling the transition from subsistence to cash economy. The tenth five-year plan (2003-2007) had emphasized on the research and development of NTFPs to create employment by promoting IGA for the people below the poverty line (targeted population) to get benefit from NTFPs management. The majority of Nepalese population use wild plants in various ways. Some of plants hold immense potentiality for livelihood support of the local people while some are still unidentified due to lack of knowledge and get decayed naturally in the forest. In the absence of proper management and control in collection and trade, NTFPs are going to be vulnerable, endangered and even extinct (Acharya, 2000).

The sustainable livelihoods framework is best understood with reference to five livelihood assets i.e., human capital, natural capital, financial capital, social capital, and physical capital. Sustainable livelihood is a holistic approach that tries to capture, and provide means of understanding, the vital causes and the dimensions of poverty without collapsing the focus on to just a few factors (e.g., economic issues, food security, etc). It also tries to sketch out the relationship between the different aspects (causes, manifestations) of poverty, allowing for effective prioritization of action at an operational level. Since proper attention hasn't been paid regarding the value and conservation of NTFPs and its contribution to the livelihood on local level. This study attempted to assess the non-timber forest product and its contribution in CFUG livelihood. This task was selected with a view to quantifying and promoting NTFPs in community forestry and also private land by listing of the existing NTFPs in community forests, to explore the potential NTFPs, which are economically and socially viable, to assess the contribution of NTFPs to livelihood assets and to find out the ethno-botanical uses of NTFPs found in the study area.

Geographically, Baglung is a hilly and naturally beautiful district of Dhabligari Zone, which is located between $28^0 15'$ to $28^0 37'$ N latitude and $83^0 00'$ to $83^0 36'$ East longitude. The altitude varies as 600m (Binamare) to 4690m (Phagunedhuri) from the mean sea level.It represents sub-tropical to sub-alpine region; the average annual temperature is 19.1 -26.6 °C and annual rainfall ranges from 1500-3000mm with average rainfall of 2200mm. Most of the area represents with sandy loam and loamy soil. The Baglung district is rich in biological diversity. The study was conducted in two community forests under Batakachaur village development committee (VDC) of Baglung district namely Aansar and Bhalukodarbar community forest. The study area was selected through multistage stratified sampling on the basis of richness and availability of NTFPs. Total population of the Baglung district is 268598 (123422 male and 145176 female). Total number of households is 53945 and the population density is 150.75 people per square kilometer with national average of 157.30 people per square kilometer.

The forest type comprised of sub-tropical to temperate type. The major timber species of the study area were sirmu, chilaune, katus, utis, laligurans, mallato, tooni, etc and major NTFPs species found in the forest were kalikaphal, pashanbed, bhalayo, bhirpurani, timur, padamchhal chhiraito, kudki, jatamasi, nigalo, kurilo, amala, tarul, dalchhini, etc. The major animal found in the forest leopard, deer, beer, rabbit, dumsi, bandel, nyaurimusa, monkey, etc. Both CFUGs comprises different caste/ethnicity people, which include mainly brahmin/chettri (49%), dalit (46%) and magar (5%).

Availability of NTFPs and their Ethnobotanical Uses

Availability of the NTFPs in both community forests were listed by using different method like participatory maping, focus group discussion, key informant interview and verified them from observation. Altogether 150 species of NTFPs were found in the study area, excluding unidentified herbs and shrubs (Fig. 1). The traditional medical practitioners are from all castes (ethnicity) in the study area engaged in the folklore medicines and jhankris are practicing local medical treatment in this area. Present practitioners also hesitate to give complete information regarding the knowledge and use practices as their popularity in the society will be lost. It indicated that indigenous knowledge and use practices of local medical practitioners is not properly transferring to the new generation and this is a consequential drawback of the knowledge transfer in the society.

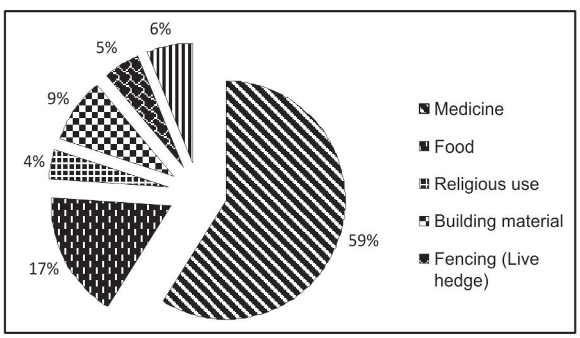

Fig.1. Different uses of NTFP

Potential NTFPs for Livelihood Support

Twenty species were found viable for livelihood support on the basis of resource availability, local uses and market availability. Bans/nigalo (*Dandrocalamus/Arundinaria spp*) was the most available species, followed by kalikaphal, sisno (*Urtica dioca*), chutro (*Berberis aristata*) and amriso (*Thysanolaena maxima*). Others important available speces were timur (*Zenthazilum arborim*), hadekaphal (*Myrica esculenta*), bankara *(Berginia ciliate*), baruwa (*Daphne bhollua*), sinkauli (*Cinamomum zeylanica)*, kurilo (*Asparagus recemosus*), pashanbed (*Berginia ciliate)*, bhalayo (*Semicarpus anacardium*), bhirpurani, chiraito (*Swertia chrirayita*), saur (*Betula alnoides*), satuwa (*Paris polyphylla*). Ganegurgo (*Cissampelos pereira)*, kharsunkuti (*Quercus semicarpifolia*) and padamchal (*Rheum emodi*) had least availability in the study area. *Dandrocalamus/ Arundinaria* spp. was the most preferered and used species whereas, bankera was least preferred species out of twenty selected species. *B. ciliate* was highly available but people know a little about its use.

People's participation is the key apporach to successful community forestry management and consequently the NTFPs management, which reflects the status of biodiversity conservation as well. Beside this, users are trying to maintain good governance and participation (inclusion) in the all processes of resource development and management from planning to evaluation. After handing over the forest to the CFUG, over all forest has been well managed and has easily fulfilled the user's forest based basic needs; like, fodder, firewood, medicinal plant, live litter, timber, etc. (Fig. 2) People have also got an opportunity to generate income and saving from NTFPs.

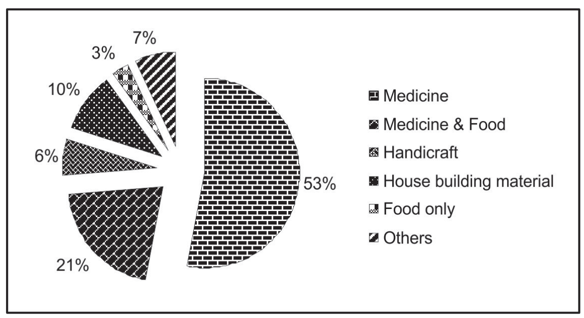

Fig. 2. Benefits of NTFPs

The livelihood pentagon has five assets (Fig. 3). The over all household assets were grouped into different five broad groups. In the asset pentagon, the value of center point is zero for all the assets and the outer margins is the maximum. For the uniformity the maximum point is taken as 100. The area occupied by the pentagon determines the overall contribution. The smaller the area occupied, the lesser is the contribution. Above asset pentagon revealed the total covered area by all five capitals due to the NTFPs. It depicted that natural capital covers highest part followed by financial capital (95.72) and human capital (67.38).

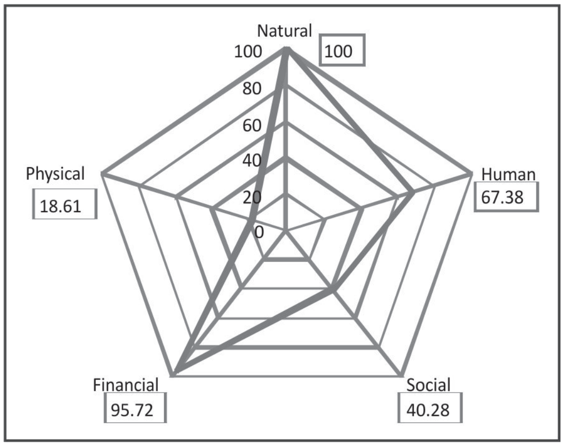

Fig. 3. Asset pentagon

CONCLUSION

People have indigenous knowledge on the use of medicinal plants but they did not have the scientific knowledge about propagation techniques, and commercialization of available NTFPs. Old men, women and Jhankri were the most knowledgeable persons about medicinal plants in comparison the younger generation. Since, the younger generations are reluctant to learn about the traditional practices, there are great chance of loss of wealth of knowledge and rich diversity. Some medicinal plants are being used by local and traditional healers in different form for the treatment of common ailments to human and animals as well. These treatment practices are done without being paid, so it's difficult to calculate the cash value of these practices. It can be said that these customs benefit people economically in indirect way.

In rural areas, NTFPs are mostly use as medicine, food and vegetable, handicraft/IGA, ceremonial species, fiber, oil, etc. Different parts of the plant including fruit, seed, leaf, root, stem, bark, bud, rhizome, flower and sap are used. The study concluded that there has been appriciative and inclusive peoples participation in forest management activities and benefit sharing. NTFPs and other forest products have ultimately been supported in CFUG members livelihoods and environmental amelioration.

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Indian Journal of Ecology

Forest Tree Diseases in Relation to Climate Change

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The abrupt climatic changes cause great impact on plant diseases. This is well documented in great epidemics of brown spot of rice (*Helminthosporium oryzae*) in Bengal in 1942, which was triggered by floods. Tropical storms rapidly spread the Maydis leaf blight of corn to mid west and southern USA in 1970s. Intensity of western disturbances affected the climate in north western parts of India, which intensified wheat rust damage in the region causing huge losses prior to the introduction of dwarf wheat varieties. However, in case of forest tree species, where life cycles of trees extend over the decades, this is a new and complex phenomenon. The abrupt climate changes are conflicting heavy damage to already fragile forest cover of the world. As the length of conducive environmental conditions determine the development of plant disease epidemics, the present scenario of prolong dry or wet weather have significant effect on diseases. Furthermore, the shift in temperature, moisture and CO_2 levels may result into development of new disease problems along with failure of present day disease management strategies. The adverse climatic conditions may suppress the pathogens but at the same time may result into development of weak parasites to potent pathogens. Thus, it is a win-win situation for pathogens. The establishment of new host pathogens relationships due to changed physiology of the trees will be a major challenge for plant pathologists. The precise prediction of how these factors affect the physiology of the host plant and its interaction with the pathogen is a major challenge in order to understand emerging disease problems of trees.

Climate change can have serious consequences on forest health, as more growth is expected under elevated carbon dioxide levels. The more succulent growth under high CO_2 levels leading to more conservation of moisture is sure to have exponential multiplication of pathogens. The loss of wood to the tune of 20x 105 m^3 in Ontario, Canada due to lignin degrading fungi under changing climate conditions is very well documented (Hepting, 1963; Karlman *et al*., 1994). A number of diseases were found closely related to stress, which made trees more susceptible to infections.

Under Asian conditions, similar effect was observed in Pakistan, north-western India, Nepal and Bangladesh in the form of large scale mortality of indigenous tree species of *Dalbergia sissoo* (shisham) and *Acacia nilotica* (kikar) in last decade. The phenomenon has since been puzzling the researchers with no conclusive reasons for large scale mortality. The prolonged warming and shrinking of rainy periods may have detrimental effect on tree physiology and hyper activity of pathogens. It is a known fact that, the two most important environmental factors in the development of plant disease epidemics are temperature and moisture (Agrios, 2005). While some diseases are favoured by cool temperatures, whereas, others are influenced by hot conditions. Under different environmental conditions, the pathogen-host interact differently and result into complex problems, which are very difficult to manage. Thus, it becomes all important to study the environmental requirements of plant pathogens before predicting their responses to climate change (Coakley *et al*., 1999). Therefore, there is a need to study tree diseases in a holistic perspective as climate changes are a global phenomenon. The present approach of selecting few trees to study disease dynamics needs to be changed to generalize epidemic processes at spatial scales.

Survey of agro-plantations, forest nurseries and roadside plantations was done in Punjab in which incidence and severity of tree diseases were recorded. Disease symptoms were recorded and pathogen associated were identified by standard methods. The literature was reviewed to find out already reported diseases of trees. With this knowledge as background, the emerging tree diseases were identified and correlated with the climate changes occurred in last few decades. In Punjab, the last two decades proved very crucial. The change in monsoon trend in terms of delayed approach has led to stretching out of hot months (Situation 1). The delayed rains which come in comparatively milder temperatures have led to prolonged periods of soil wetness, causing increased activity of soil borne fungi/pathogens (Situation 2). High CO_2 levels leading to more succulent leaves and increased activity of foliar pathogens (Situation 3). All these conditions have resulted in degradation of tree cover in the region and these situations have been evaluated fro their influence on tree diseases.

Situation 1. Actual rainfall (June-September) of north-west India comprising states of Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Chandigarh, Delhi, Uttarakhand, Uttar Pradesh and Rajasthan shows that the average monsoon rainfall received over 90 years (from 1901 to 1990) was 640.0 mm. But in last two decades there was a deficit of 2.5 to 38% (IMD, 2011). Fewer rains have resulted in stretching of hot months. The effect of the phenomenon is the induction of physiological stress in trees. The lowering down of defence mechanism, specially due to drought stress, predisposes the plants to several new diseases. The weakened plant defense is also leading to development of weak parasites to potent pathogens. This has resulted in the heat induced cankers mainly caused by *Botryodiplodia theobromae* on poplar, eucalypts and shisham, and *Phomopsis* sp. on kachnar (*Bauhinia variagata*). The incidence of these diseases was observed varying from 15 to 65 per cent in block and avenue plantations. Both these fungi are weak pathogens but the prolonged periods of scorching sun specially on southern side of the trees have resulted in weakening of defence mechanism, thereby, predisposing the tree stem to attack and establishment of these pathogens. Poplar nursery cuttings were found with heavy incidence of cutting rot due to *Botryodiplodia* sp. in kandi belt of Punjab (Hoshiarpur, Nawanshahr and Ropar). It was found that higher soil temperatures in absence of adequate rainfall and scarce irrigation facilities have led to its increased incidence. Hot and dry climate was attributed to the establishment of *Botryodiplodia* canker in sycamore and oak (Thomas and Boza, 1984), *Acacia auriculiformis* in India, *Acacia mangium* in Malaysia and *Acacia nilotica* in India/Kenya (Gibson, 1975).

Situation 2. The delayed rainfalls in comparatively milder climates of August to September have resulted in saturated soil conditions for longer periods of time. Flooding over prolonged periods resulted in inadequate exchange of gases in the rhizosphere of trees. The anaerobic conditions led to accumulation of toxic metabolites causing adverse affect on tree health. It also hinders water and nutrient uptake. All these conditions weakens the tree and makes it susceptible to attack by soil borne fungi like *Fusarium*, *Pyhthium*, *Phytophthora*, etc. (Schoeneweiss, 1981).

The canal side nurseries of forest department growing jamun and dheau was found with 50 per cent mortality in Gurdaspur district due to *Pythium* spp. and *Rhizoctonia* spp. under water logging conditions. Similarly, roadside plantations of shisham (*Dalbergia sissoo*), kikar (*Acacia nilotica*) and siris (*Albizia lebbek*) were found infected with *Fusarium* sp., *Armillaria mellea* and *Ganoderma lucidum*,

Table 1. Tree diseases under different environmental stresses in Punjab (India)

Environmental stress/Disease	Pathogen (s)	Tree species infected	Disease incidence (%)
High temperature induced diseases			
Stem cankers, cutting rot	*Botryodiplodia* sp., *Phomopsis* sp.	Poplar, shisham, eucalypts, kachnar	15-65
High soil moisture			
Root rot	*Pythium spp.* and *Rhizoctonia* sp.	Dhaeu, jamun	50
Wilt	*Fusarium* spp., *Armillaria mellea, Ganoderma lucidum*	Shisham, kikar, siris	Traces to 35
Increased CO_2 levels			
Leaf spots	*Cercospora* spp.	Kachnar	Traces to 45
	Septoria sp.	Neem and dek	Traces to 70
	Drechslera spp., *Alternaria* spp., *Cercospora* spp.	Poplar	Traces to 100
	Gleosporium sp.	Eucalypts, banyan	Traces-100
	Cercospora spp.	Mulberry	Traces-100
	Gleosporium sp.	Banyan	Traces-20
Anthracnose	C*olletotrichum gloeoesporioides*	Mango	Traces to 90
Sooty mold (increased aphid population)	*Capnodium* sp.	Shisham, mulberry, karanj, banyan	Traces-100

especially when they were growing in low-lying areas adjoining roads where rainwater remain stagnant for long times. The incidence of diseased trees varied from traces to 35 per cent (Table 1). Under high soil moisture conditions *Fusarium solani, Phytophthora* spp., *Pythium* spp. and *Rhizoctonia solani* were found causing serious damping-off of tree legume seedlings (Lee, 1985; Zakaria, 1990). Mehrotra (1990) reported that leaf web blight of neem (*Azadirachta indica*) caused by *Rhizoctonia solani* appeared in the nursery after the regular monsoon rains set in.

Situation 3. The increased CO_2 emissions have resulted in enhanced soluble carbohydrates levels in the phloem of the trees. This increased succulence levels in leaves have led to appearance of foliar diseases with high incidence. These include leaf spots of kachnar, neem, dek, poplar, eucalypts, banyan, mulberry; anthracnose in mango and sooty moulds in shisham, mulberry, banyan and karanj. The pathogens include fungi like *Cercospora* spp., *Septoria* sp., *Drechslera* spp., *Alternaria* spp., *Cercospora* spp., *Gleosporium* sp., *Colletotrichum gloeosporioides* and *Capnodium* sp. (Table 1).

Since, climate change is a global phenomenon, it is very difficult to mitigate its harmful effects. In case of cankers due to heat stress, some control can be achieved by applying white lime paint on tree trunk. Tree breeding for heavy foliage bearing species could be another way out. But both these methods have their limitations in terms of large operational areas and long gestation period. There are indications that in future more crop residue and faster decomposition will increase pathogen survival due to milder winters, which would result in an increased initial inoculum. There is a need to develop necessary epidemiological data through long term field studies where more than one climate change variable can be examined in relation to tree diseases.

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Studies on the Management of Eucalyptus Gall Wasp *Leptocybe Invasa* Fisher and La Salle in Haryana

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Eucalyptus is the backbone of Haryana's successful agroforestry forestry programme. It is the main species of agroforestry of the state, introduced in state during 1961 and has become part and parcel of Haryana's farming programme and seen everywhere in the fields, on road sides, canal banks and along railway lines. Farmers of central plains of Haryana supplement their agriculture farming by growing *Eucalyptus* either on the bunds of their fields or in block plantations alongwith suitable agriculture crop. Out of about forty million seedlings being raised annually by Forest Department Haryana, about forty per cent share goes to *Eucalyptus* alone. *Eucalyptus* seedlings are supplied to the farmers free of cost and there is no restriction on the sale of agroforestry produce in the state. This has encouraged farmers to take up agroforestry in a big way and about 15,000 hectares of *Eucalyptus* are planted every year in Haryana. It is harvested after seven to eight years and more than 0.1 million hectare of area remains under *Eucalyptus* plantations in the state.

Eucalyptus has brought prosperity to the farmers of North-western states. Agroforestry has emerged as a most desirable and viable strategy for maintaining social, economic and ecological sustainability in this region of the country. The success of agroforestry in Haryana and neighbouring districts of Punjab, U.P, and Uttrakhand states of the northern region of India has led to evolution of an annual market for agroforestry based wood products worth more than Rs.10,000 million (US$ 210 million, US$1= Rs.46) in Yamunanagar district of Haryana, benefiting not only farmers, but has also generated employment of various kinds at different levels in the northern region of India (Saxena, 2004).

By and large *Eucalyptus* did not face any major pest problem in Haryana but recently a tiny wasp called *Eucalyptus* Gall Wasp (*Leptocybe invasa* Fisher & La Salle) also called Blue Gum Chalcid, has severely infested young *Eucalyptus* plants in the nursery and in the field, and threatening the *Eucalyptus* plantations in the state. Gall Wasp of *Eucalyptus* is causing loss to the tune of 25 crores annually. Resultantly, farmers have temporarily stoped *Eucalyptus* plantations on their farm lands, which may cause huge setback to agroforestry in Haryana and other *Eucalyptus* growing states.

The history of this wasp pest is not very old and probably of Australian origin but its distribution within Australia is still not fully known. It was first of all reported from the Middle East in 2000 and subsequently it has spread to most Mediterranean countries and Northern and Eastern Africa. In India, it was first noticed in the year 2001 in Mandya district of Karnataka, in Marakkanam area of Villupuram District of Tamilnadu in 2002 (Kumar *et al*., 2007) and travelled from south to north and reached Haryana in 2007. Sporadic incidences of its infestation were noticed in northern part of Haryana in the year 2008-2009 and neither anybody could identify the pest at that time nor was it taken seriously. By the year 2010, the pest became serious and infested almost hundred per cent nursery plants and the plantations. The western part of Haryana is although a semi arid tract, yet due to the prevalence of good canal irrigation system, *Eucalyptus* is grown on banks of canals. The surveys were conducted in the western part of Haryana in May and June and no Gall Wasp infestation was noticed. It was felt that very high temperature prevailing in the region during summer months deters the pest from establishing in the region and therefore, this region of the state was considered as Gall Wasp free zone. However, the pest was first time noticed in Hisar region in July 2010 and by September, 2010 severe Gall Wasp infestation was noticed there. April, 2011 saw the emergence of swarms of the adults of the pest and a number of adult wasps were seen hovering over the young plants and coppiced shoots all over the state. At present, the wasp has been reported from all *Eucalyptus* growing countries including Algeria, Iran, Israel, Italy, Jordan, Kenya, Morocco, Spain, South Africa, Syria, Tanzania, Turkey, Uganda, Vietnam and India.

Realizing the importance of the species and threat due to the insect, a study was conducted in Haryana state on young plantations on the farmer's fields and also on the plantations raised by Forest Department Haryana with a view to suggest Integrated Pest Management (IPM) for *Leptocybe invasa*.

The results of the survey conducted throughout Haryana state reveal that at present no clone or hybrid of *Eucalyptus* is tolerant or resistant to *Leptocybe invasa.* Though *Eucalyptus pellita* has been reported to be resistant to the gall Wasp but under Haryana conditions, even *Eucalyptus pellita* was found susceptible to Gall Wasp. Pure *E. pellita* is definitely resistant to *L. invasa* but susceptability of *E. pellita* may be because of natural hybridization, which has made *E. pellita* susceptible to Gall Wasp.

On the basis of analysis, the most affected *Eucalyptus* clones under Haryana conditions were 10, 271, 316, 83 and 2070. The lease affected clones in the order, 7, 288, 130 and 526 under Haryana conditions. Hence, if gall wasp infestation is the major criterion, the above mentioned least affected clones should be planted. The counting of galls was done only upto January 2011 as infestation had touched hundred per cent in the case of clone number 10 and equal to ninety per cent or more than that in the case of clone number 271. Hence, further counting was stopped. This gave an impression that the pest remains active under north Indian conditions throughout the year. However, regular monitoring will be continued. It was found that galls became black after about a month due to the growth of some fungus. Later on the galls disappeared giving the impression that the plant has become gall free. This happened till the 3rd week of March, 2011. Later on by the last week of March, 2011 a huge swarm of tiny insects hovering over the fresh shoots was noticed. These tiny insects were identified as *Leptocybe invasa*. By the second week of April, 2011, the leaves of all susceptible germplasm got folded indicating the initiation of gall formation due to the presence of foreign material in the soft tissues. Use of light traps is very safe and pollution free method of pest control for phototropic insects. But this insect was not attracted to light.

As regards the efficacy of different insecticides, anti-feedants and repellents of plant and synthetic origin for controlling the pest, it can be concluded that the application of the pesticides (Imidachloropid, Dimethoate, Carbaryl, Monocrotophos, Profenphos, Cypermethrin, Carbofuron, etc.) was not a effective solution for the control of the pest. Biological control of *L. invasa* by using *Quadrastichus mendeli* as parasite was also found ineffective, and more studies are required to be done on *Q. mendeli*. Detailed entomological surveys are required to be done under the north Indian conditions for the presence of natural enemies *of L. invasa.*

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Employment Generation Potential in Pulpboard Mills of Punjab

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Rice straw is a cheap, abundant, and annually renewable source suitable for producing high-quality natural cellulose fibers. With a production of more than 10 million tonnes of paddy about 15 million tonnes of rice straw is produced in Punjab. Natural cellulose fibers from rice straw with properties similar to those of linen have been produced using cheap and common chemicals for the first time (Reddy and Yang, 2006). Rice straw contains about 40 per cent cellulose, 30 per cent hemi-cellulose, 15 per cent silica, and about 15 per cent lignin. They patented method and kit for rice fiber extraction of high quality and long natural cellulose fibers from rice straw and method of producing rice straw fibers. In addition, extracted rice fibers that are at least 10 millimeters in length, no more than 0.5 millimeters in width and include a generally smooth surface, which may be used for development of textile or composite products (www.wipo.int). On the basis of the structure and properties of the fibers, rice straw fibers could be used to produce textiles, composites, and other fibrous products similar to those produced from the common natural and synthetic fibers. The chemical composition and heterogeneous structure of rice straw make it an ideal raw material for composite panels (Smith *et al.,* 2002; Inglesby *et al.,* 2004). However, the silica content of rice straw is still a concern regarding cutting tool wear, and more studies need to be carried out in this area to understand the problem.

Using rice straw for high-quality fibrous applications will add value to the rice crops, mitigate our concerns regarding the burning or disposing of rice straw, and provide us an environment friendly alternative (emissions from burning of rice straw : 70 per cent CO_2, 7 per cent CO, 0.66 per cent CH_4 and 2.09 per cent N_2O). Estimated emissions of greenhouse gases caused by the burning of rice straw in three states in the Indo-Gangetic Plain of India are noteworthy. Alkaline ash left on the soil surface after the burning of crop residues causes an increase in urease activity and may cause N losses from soil and applied fertilizer because of ammonia volatilization (Bacon and Freney, 1989). But still 85 per cent of the farmers of Ludhiana (Punjab, India) preferred to burn the rice straw in field while very few of poor farmers feed rice straw to animals and 5 per cent of farmers were also using rice straw as substrate for mushroom production or as fuel or bedding material for animals. Since the straw has potential to be used for pulp-board and presently units are operating in Punjab and generating employment in rural areas. This study was undertaken to know employment generation profile of these industrial units.

An exhaustive list of industries was prepared with the help of State Department of Industries, Chandigarh; Small Scale Industries Department, Chandigarh and District Industry Centers, situated at all district headquarters. The demographic and geographic data for all the blocks of Punjab state were collected from the office of Economic Advisor to the Punjab Government. Prior to the start of survey, a comprehensive proforma was prepared after consulting the extension scientists/experienced concerned experts. After preparing the list of industries, the survey of pulp board industries in Punjab was started in different zones (sub-montane zone, central plains, and southern districts).

Total geographical area of Punjab is 50,362 sq km with 2642 sq km area under paddy during 2005-06 with production of 10193 thousand metric tons. Out of 20 districts of Punjab, Ludhiana district had maximum area under paddy, while SAS Nagar had the minimum area under paddy among all districts. In paddy production, Sangrur ranked first with 1626 thousand metric tons and SAS Nagar has the lowest production of 111 thousand metric tons (Anonymous, 2007).

It was observed that 2239 persons (2187 Males + 52 Females) were employed in the pulp board mills of the state. Out of these 477 (189 locals + 288 migrants) are technical employees and 1710 (307 locals + 1403 migrants) were non-technical employees (Fig.1). Sixty per cent of technical employees and 82 per cent of non-technical employees in pulp board mills were migrants and rest are locals (Fig. 2&3). The percentage of female workers in the pulp board industry is shown in Fig. 4. As stated by the mill owners, majority of non-technical work in this industry is

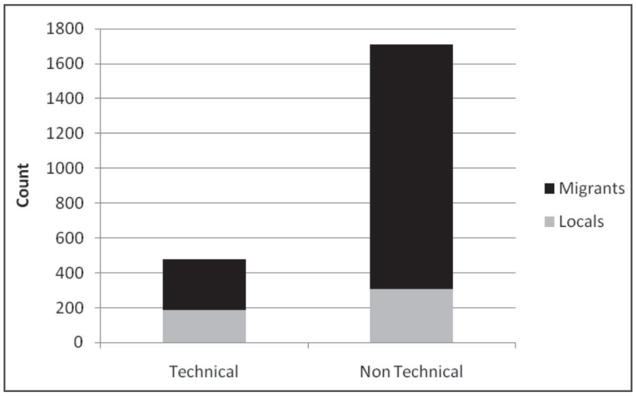

Fig. 1. Employment categorization of employees in pulpboard mills of Punjab

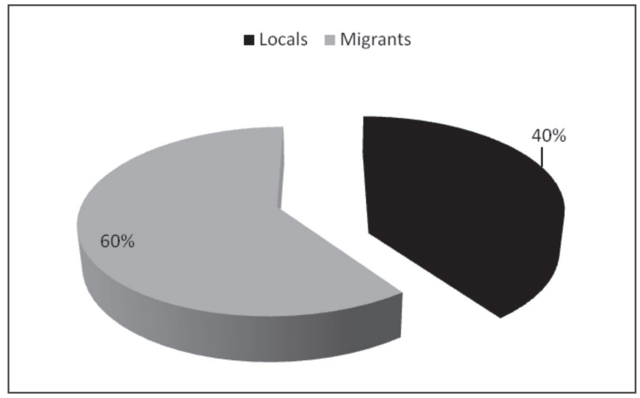

Fig. 2. Background of technical employees in pulpboard mills of Punjab

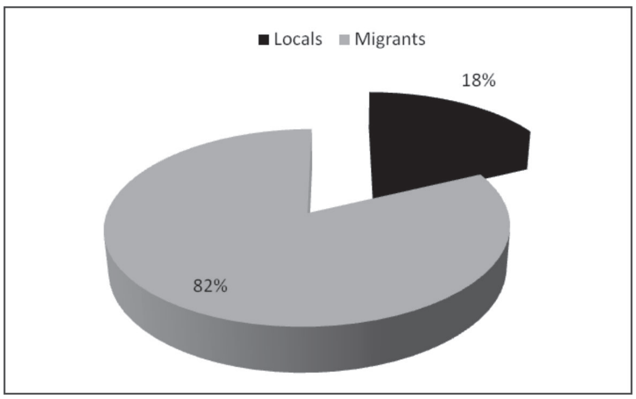

Fig. 3. Background of non-technical employees in pulpboard mills of Punjab

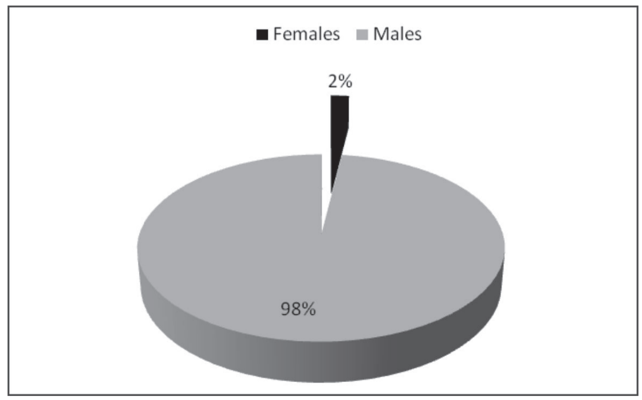

Fig. 4. Proportion of females in pulpboard mills of Punjab

being performed by the labour from other states like Himachal Pradesh, Bihar, Jharkhand, Uttar Pradesh, etc. This industry is also providing huge employment opportunities to the unemployed and even uneducated youth in the form of indirect employment in various activities like loading, unloading, shifting, transportation, etc. of raw materials as well as finished products. The indirect employment generated by the pulp board mills in the area where they are located was also estimated as quoted by mill owners and farmers. The indirect employment generated by the pulp board mills in the Punjab state is about 54,900 mandays.

The pulp board industry of Punjab is also providing huge employment opportunities to the unemployed and even uneducated youth in the form of indirect employment in various activities like loading, unloading, shifting, transportation, etc. of raw materials as well as finished products. Majority of work was being handled by migrants from other states, which shows the scope of employment to even uneducated youth of Punjab. Only a meager 2 per cent of the total persons employed in these mills were females. This low proportion of the female workers may be attributed to the nature of work being carried out by labour in these mills.

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Short Rotation Forestry for Economic and Environmental Benefits: Country Report (India)

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The tree farming is ecologically as well as economically more viable than traditional agriculture. Investment in tree plantations always remained relatively low in India, inspite of the fact that the existing forests cannot continue to meet our wood requirements. However, realizing the existing problem, the expenditure on afforestation has increased enormously from fifth five year plan onwards but still the results on the land are not encouraging and we have not been able to increase area as well as the forest productivity to the desited level. The misery caused to the entire nation due to unprecedented eco-degradation is enormous and warrants immediate remedial measures. To counteract the impending crisis, use of fast growing tree species managed with intensive cultural operations especially in tree farming have opened up new vistas in wood biomass production. The short rotation forestry has attained a success and many private concerns have initiated plantation activities. *Populus deltoides, Eucalyptus tereticornis, Acacia mangium*, *Ceiba pentendra, Gmelina arborea*, *Leucaena leucocephala, Robinia pseudoacacia, Melia composita, Prosopis juliflora,* etc. have been exploited by the private companies in the country because of their market potential and fast growth. Exotic species though continues to be encouraged over the indigenous ones (Chauhan *et al*., 2008). Private companies have been offering spectacular returns through investment in teak plantation programme also.

With the view to improve the productivity and profitability of plantations and making farm forestry an attractive landuse option, focus on genetic improvement of planting stock and improvement of practices in silviculture have been emphasized. Major gain in plantation productivity has been achieved within a short span through the application of vegetative and cloning techniques for gainful exploitation of the existing useful variations. *Eucalyptus* clones and poplar plantations have achieved record productivity in north-western states exceeding 50m^3/ha/yr under ideal site conditions with intensive management compared to less than 1m^3/ha/yr of Indian natural forests. Clonal plantations of jortor (*Casuarina equisetifolia*) in southern states, costal areas and salt affected soils have repeated the success story of eucalypt clones. The three year old *Eucalyptus tereticornis* and *Casuarina equisetifolia* under high density of 40,000 plants/ha produced nearly ten times more volume than the conventional density of 2,500 plants/ha. Similarly the *Leucaena* and *Acacia* species are exploited extensively under short rotation intensive culture to meet industrial requirements and generate ample employment during the complete chain from nursery to finished wood products. Short rotation clonal plantations on 20 mha degraded lands with existing achievable productivity can meet country's current wood energy requirements of approximately 250 million tonnes per year.

It is however, not only the short fall in wood productivity but the increased atmospheric concentration of greenhouse gases, especially carbon dioxide has raised the threat of rapid increase of global temperature. Various options have emerged for mitigating the problem of increase in CO_2 concentration and threats associated with climate change. The investment in forestry sector to store carbon in trees and forests is one of the viable options for offsetting the gases released by fossil fuel burning and mitigating the potential effects of global warming. Perennial vegetation, notably forests have an important role to play in regional, national and international green house gas balances. Moreover, under the Kyoto Protocol recognition has been given to this option but at the global level, approximately 14.6 mha actual forest area is cut annually, which is also adding million tons of carbon to the atmosphere along with other sources of pollution every year. Short rotation forestry including agroforestry can act as a good source of carbon sink, which is linked to enhanced photosynthetic fixation of CO_2 per unit land area. The harvest yield in forest trees is vegetative rather than reproductive and most of the biomass consists of carbon compounds. In addition, the trees compatible with agricultural crops form unique combination for carbon sequestration. The rapid growth of short rotation woody crop results in high rates of nutrient uptake and large amounts of carbon storage over rotation lengths as short as 5 to 15 years. Net carbon benefits are realized if the wood fiber is used for solid wood products. In some regions, agreements are in place that allows nations or corporations to offset their greenhouse gas emissions by buying credits from farmers who increase their stores of carbon in the soil or in trees. The potential market for these carbon credits could be beneficial to tree growers.

Waste management is another issue of concern including and water scarcity in many countries. Good quality water supplies are not sufficient to meet the rising demands from agricultural, domestic use and industry. The urban and industrial waste water is the major cause of river water pollution, ground water contamination, spread of diseases and environmental degradation in the country. Treatment of such water is costly, requires lot of energy and man power, which is beyond the capacity of municipal corporations/ committees. Many a times, this untreated water is used for higher production of vegetable and fodder crops, however, their unrestricted use without proper treatment aggravates the contamination of food chain system and poses serious threat to soil also. Many techniques like waste water treatment plants, oxidation ponds, fish culture, use of blue green algae, water hyacinth, etc. are used to clean polluted water to make it safer for use in agriculture yet most of these methods are costly. But the use of this water in afforestation programme is an effective alternative, where the chances of pollutants to enter into the food chain are minimum or negligible. The nutrient rich irrigation water can be used for afforestation programme on infertile and inhospitable wastelands and the higher transpiration rate of trees can be exploited to get rid of excess water. Wasted lands along the roads, railway tracts, drains, panchyat/village lands, etc. can be profitably used for direct material benefits besides meeting the ameliorative requirements in the urban and sub-urban areas. Developed countries are also effectively making use of this waste water and waste land for the plantation programmes. A brief country report presented here for the benefits of the participants of the symposium (Table 1).

Table 1. Short rotation forestry : Country report (India)

1a	State of country forests (Forest area)	:	69.09mha (21.02% of total geographical area) plus 9.28mha (2.82%) tree cover outside forest (FSI, 2009)
1b	Per capita forest area	:	0.10 ha
1c	Reserved/protected/ unclassified forest area (%)	:	54.44/28.14/17.41
2	Trees outside forest (%age of non- forest area or arable land/geographical area)	:	9.28mha (2.82%)
3	Productivity of forests along with growing stock (m^3 wood / ha per year)	:	0.7m^3/ha/year Growing stock of forest= 4.499 billion m^3 Growing stock of trees outside forest = 1.599 billion m^3 Total = 6.098 billion m^3, which gives an average growing area of 80.9 m^3 per ha in 78.37 mha of forest be covered (FSI, 2009)
4	Major commercial tree species of the country (in the forests as well as outside forests)	:	*Acacia catechu, A. nilotica A. mollissima, A. auriculiformis, A. mangium, Azadirachta indica, Anogeissus latifolia, Abies pindrow,* Bamboo, *Cedrus deodara, Casuarina equisetifolia, Dalbergia sissoo, Eucalyptus* spp.,*Picea smithiana, Pinus roxburghii, Quercus* spp., *Prosopis juliflora*, *Shorea robusta, Tectona grandis, Terminalia spp, Toona ciliata,* etc.
5	List of fast growing tree species	:	*Acrocarpus fraxinifolius, Anthocephalus cadamba, Ailanthus excelsa, Acacia mangium,A. auriculiformis,* Bamboo, *Eucalyptus tereticornis, Bombax ceiba, Casuarina equisetifolia, Cryptomeria japonica, Gmelina arborea,Grevillea robusta, Leucaena leucocephala, Melia composita, Morus alba, Prosopis juliflora, Populus deltoides*, *Robinia pseudoacacia, Salix alba, Trewia nudiflora, Terminalia arjuna,* etc.

6	Productivity of Short Rotation Tree Species (SRTS) (m^3 wood / ha per year)	:	Productivity can be raised only by appropriate choice of species, application of forest tree genetic principles supported by appropriate silvicultural practices. Approximately 4-5 m^3 ha^{-1} yr^{-1} growth of fast growing species in forest against 20-25 m^3 ha^{-1} r^{-1} under agroforestry/ farm forestry, whereas, the productivity of natural forest is 0.7m^3 ha^{-1} yr^{-1} (Lal, 2004).
7a	Usage of SRTS: timber, pulp, plywood, fuel, coal, etc.	:	Fast growing tree species are mostly used in paper/pulp, plywood, match and other wood based industry. Biomass power plants have also started raising captive plantations for their own use.
7b	Domestic/industry		It is used for energy and construction purposes. Wood based industries like plywood/board, paper/pulp and power plant are dependent upon SRTS.
8a	Prospects of Short Rotation Forestry	:	The Govt. of India under the National Action Plan on climate change has identified the National Mission for Green India as one of the eight missions. Greening Indian Mission puts the greening in the contact of climate change adaptation and mitigation meant to enhance ecosystem services like carbon sequestration and storage, hydrological services and biodiversity, along with provisioning services like fuel, fodder, small timber and non-timber forest products. National policy on biofuel (2009) has proposed target of 20 per cent blending of biofuels, both for biodiesel and bioethanol by 2017, which needs approximately 13mha afforestation of oil seed plants. Proposed plantation and processing involves huge business opportunities (13mha area to be brought under biofuel plantations which is 30 times than the presently available) and employment generation. Therefore, raising plantation on non-forest areas including agroforestry/farm forestry has bright prospects in enhancing the green cover.
8b	Potential available area	:	43 million ha, a two-pronged National Action Plan is proposed for achieving this goal in 10 years: 28 m ha to be developed through agroforestry (10mha on irrigated and 18mha on rain-fed area) 15 m ha of degraded forest having good root stock to be regenerated through JFM.
8c	Industry back up for purchase, etc.	:	WIMCO Ltd., ITC Bhadrachalam Paper Ltd. (AP), West-coast Paper ltd., Dandeli (Karnataka), Ballarpur paper Industries, Balarshah, (Maharastra), JK Paper Mill (Koraput, Orissa), etc. have been supporting SRF tree plantations. The twin towns of Yamunanagar and Jagadhri are hubs of ply-board. Additionally, biomass based power plants are dependent on *Prosopis, Eucalyptus, Leucaena,* etc.
8d	Industry back up for supply of planting material	:	Industrial incentive in terms of quality planting stock extension support, buy back etc. are provided to private growers.
8e	Extension support	:	Clonal planting stock of poplar, eucalypts, casuarina, etc. have been promoted by the wood based industries on a limited scale supported with technical extension services. Clonal technology has improved productivity to an average of 20-25 m^3 ha^{-1} yr^{-1} with significant improvement in the quality and supply of timber.
8f	Govt. Institutional support for extension, training, etc.	:	State Forest Department have been supporting stakeholders in meeting their requirement of planting stock, marketing, technical support, policy issue, etc. Strong commitment among the government agencies, research

			institutes/Universities, NGO, private sector, etc. is helping in restoring the lost glory of green India.
8g	Superior planting stock availability	:	WIMCO Seedling Ltd, Rudrapur, ITC Ltd, Bhadrachalam, West-coast Paper Ltd., Dandeli (Karnataka), Pargati Biotechnologies, Hoshiarpur, Prakriti Conal Agrotech, Ambala, State Forest Departments, Research organizations, etc. are producing quality clonal planting stock of different SRT species.
8h	Gap of Wood demand & supply	:	**Demand** Year — Fuelwood — Timber (million cum) 2010 — 362 — 95 2015 — 398 — 123 2020 — 437 — 153 **Supply** 2010 — 169 — 36 The demand and domestic supply gap is increasing and there is need to take possible steps to expand plantations with substantial improvement in productivity. Supply will be supplemented from agroforestry, tree growing on waste land/community land, etc. At present imported wood is important source to bridge the demand and supply gap.
8i	Wood Import/export	:	Industrial requirement are to be met from outside forest area including farmer fields or through import. Import specifically in paper, plywood, power generation, etc. is not cost effective. Therefore, industry is dependent on SRF/Agroforestry and ready to offer incentives like quality planting material, technical support, buy back guarantee, etc. Wood import has been liberalised due to clean ban on green felling from national forests. Export is allowed in finished products only.
8j	Legal bindings on harvesting, transport & sale	:	Harvesting and interstate movement of timber is restricted, however, in some states like Punjab, the farm grown timber is considered equivalent to agricultural produce, therefore involves no restriction on harvesting and interstate transport.
9	Carbon sequestration at the country land by forests	:	The carbon storage/estimates depend upon the composition, age, site quality, management, etc. Studies indicate that Indian Forests store 3907.67MtC (above and below ground) and additionally the Carbon storage in forest soil is estimated to be 9815.95Mt (Melkania, 2009). The planted forests of SRF have more potential for carbon sequestration in soils, whereas, the long rotation species fix more carbon in wood. Mixed forests of exotic and indigenous species could be more efficient in carbon sequestration than monoculture.
10	Carbon sequestration potential of SRTS – country reports	:	Three different scenarios i.e., LUCS1: put max. land into forestry sector and is an economically feasible scenario; LUCS2: as usual; LUCS3: put max. land in the plantations and is also a potential scenario. Total carbon sequestration per year in billion tons (projected) Year — LUCS1 — LUCS2 — LUCS3 2000 — 5.273 — 5.273 — 5.273 2010 — 7.403 — 7.037 — 7.229

			2020 9.401 8.574 9.143 2030 10.800 9.545 10.640 2040 11.500 10.140 11.580 2050 11.920 10.500 12.210 These projects indicate much scope for carbon sequestration under forests as well as putting land under plantations. (Bhadwal and Singh, 2002)
11a	Phyto-remediation	:	Clean up the contaminants and subside it to a reduced amount is called as phyto-remediation. Waste water utilization is mandatory for the industry and the municipal corporations. Phyto-remediation is cost effective way of waste water management. For example, Eucalyptus can dispose of 5-15cm of effluent per day per hectare.
11b	Species in usage for phyto-remediation	:	*Eucalyptus tereticornis, Salix alba, Terminalia arjuna, Leucaena leucocephala, Grevillea robusta, Casuarina equisetifolia,* etc. **List of tree species known o accumulate heavy metals** Tree species — Heavy metals *Azadirachta indica* — Hg,Cu,Ni *Eucalyptus tereticornis* — Cd, Cr, Pb, *Albizia spp.* — Cd, Cr, Cu,Zn, Hg, Mn *Salix acamophylla* — Cu,Pb, Ni *Leucaena lecucocephala* — Fe, Zn, Cu, Mn *Grevillea robusta* — Cd, Cr, Zn,Pb, Ni, Mn, *Trema orientalis, Prosopis juliflora* — Cd,Cu (Srinidhi *et al.*, 2007)
11c	Utilization	:	Phyto-remediation takes advantage of plant nutrients through roots, transpires water through leaves and act as a transformation system to metabolize organic compounds such as oil and pesticides. They may absorb and bio-accumulate toxic trace elements in wood.
12	Rotation age	:	Varies from species to species and their end use. *Poplar* : 5-8 years; *Eucalyptus*: 2-15 years; *Melia composita*: 8-12 years, etc. Poplar — 5x4m (block plantation) — 5-8 years 3 m (boundary plantation) *Eucalyptus* — 2x2m,3x3m,4x4m — 2-15 years *Leucaena* — 4x2m under agroforestry lopped for fodder and fuelwood — 3rd year onwards 2x2 m for energy — 3rd year onwards *Gmelina* — 6x6m (Agroforestry) — 10-12 years *Melia* — 6x6m — 8-12 years *Salix* — 4m on bunds and 5x5m (block) — 10-15 years Bamboo — 5x5m — 4th year onwards
13	Agro-forestry interventions : potential agro-forestry systems/ models (Detail of species and productivity)	:	The country's current need of timber, fuel wood, fodder, industrial wood and medicinal plants must be met from private/community lands in order to reduce the growing demand from forests. The National Forest Commission, 2006 has laid stress on improving productivity of degraded forest (10-40 per cent crown density) by regeneration and afforestation, growing high plantations and promotion of social/agroforestry plantations based on genetically improved seed/planting stock. Species: Eucalypts,

			poplar, C*asuarinas equisetifolia, Acacia nilotica, Prosopis juliflora, b*amboo have been recommended by Greening India Task Force for mass plantation under JFM and agroforestry. Detailed information of agroforestry systems and productivity is available at www.nrcaf.ernet.in.
14a	Constraints	:	Low awareness level of the farmers towards technical, legal, financial, policy, marketing, etc. are the factors resulting in low adoption of SRF plantations.
14b	Planting stock availability	:	There is no certification criteria for the forest tree planting stock. Very limited reputed nursery growers provide the quality planting stock.
14c	Awareness/attitude of farmers on towards SRTS	:	Less favourable attitude, poor motivation and absence of awareness among the farmers is the root cause for less adoption of fast-growing trees on their farm lands in comparison to agricultural crops.
14d	Legal constraints	:	Legal, policy, marketing, etc. constrains have been experienced by the farmers and at the government institution as well
14e	Technological constraints	:	Technology dissemination from research laboratory to land mechanism is not appropriate, which is essential to motivate the public in favour of JFM/ agroforestry.
14f	Financial constraints	:	Financial/marketing support is an issue of immediate consideration. Because of long gestation period than agricultural crops, financial institutions don't support tree plantation activities.
15a	Exotic species and their potential	:	Most of the fast growing species are exotic i.e., *Eucalyptus* spp., *Populus deltoides*, *Leucaena leucocephala, Acacia* spp. *Salix alba, Robinia pseudoacacia, Casuarina equisetifolia, Prosopis juliflora*, etc. and are much in demand due to their fast growth.
15b	Adverse effects of exotics including the invasive species	:	Chemical like tannins in *Acacia leucocephala, A. mangium* and *A. auriculiformis*, phytotoxins in *Eucalyptus* and *Casaurina,* Mimosine content in *Leucaena leucocephala* and other allelochemicals include phenolics, terpenoids, etc. cause reduction in understorey crop yield. Litter fall is main source of allelochemicals (glycosides and polyphenols). **Invasive species**: Indian Council of Forestry Resarch and Education, Dehradun has released list of 20 invasive species i.e., *Acacia mearnsii* De Wild.; *Ageratum conyzoides* (L.) Sieber; *Ageratum houstonianum* P. Mill.*; Chromolaena odorata* (L.) King and Robinson; *Cytisus scoparius* L.; *Eichhornia crassipes* (Mart.) Solms; *Eupatorium adenophorum* Spreng.; *Ipomaea carnea* Jacq.; *Lantana camara* L.; *Mikania micrantha* (L.) Kunth.; *Mimosa invisa* Mart.; *Parthenium hysterophorus* L.; *Salvinia molesta* D.S. Mitch.; *Ulex europaeus* L.; *Xanthium strumarium* L.; *Ectropis deodarae* Prout; *Lymantria obfuscata* Walker; *Pityogenus scitus* Blanford; *Polygraphus longifolia* Stebbing and *Fusarium monoliforme* Sheldon.
16a	Clonal v/s seeding sources	:	The outstanding advantage of use of cutting to increase growth rate of plantations is established and the same are almost 1½ to 2 times that of plantations established from unimproved seed sources. Uniformity of wood in turn can enable reduction in the manufacturing cost, better energy, efficiency and increase in product quality apart from increase in overall productivity.

16b	Productivity	:	With the productivity of 6-10m^3 and 20-25m^3 ha^{-1} yr^{-1} through seedling and clonally propagated material, respectively the output differences would also be more than double. Better management of existing dense forest, improving regeneration of open and degraded forest and multipurpose reforestation on non-forest and forest waste lands/community lands are some of the required initiatives for enhanced productivity.
16c	Risk	:	Invasiveness, high water and nutrition requirements, loss of biodiversity, allelo-chemicals, reduced agricultural productivity, etc. are associated disadvantages.
17	Emergence of plantation forestry	:	Investment in plantations always remained relatively low in India, inspite of the fact that existing forests cannot continue to meet wood requirements. The III National Forest Policy of 1988 was the turning point, when wood based industries were emphasized to generate their own raw material outside forests. Even Government increased its expenditure manifolds on plantations thereafter, resultantly today India stands at number 2 in plantations after China. Private plantations have come up in a big-way with substantial high productivity than the natural forests. **Top ten countries with largest forest area** Russian Fedration, Brazil, Canada, USA, China, Australia, Congo, Indonesia, Peru and India. **Top ten countries with largest proportion of world's plantations** China, India, Russian Fedration, USA, Japan, Indonesia, Brazil, Thailand, Ukrain and Iran. **Top ten countries with highest above ground biomass** Brazil, Russian Fedration, Congo, USA,Canada, Peru, Indonesia, Venezuela, China and Columbia. (www.fao.org)
18	Future directions	:	Increasing demand-supply gap (domestic as well as industrial), GHG mitigation and carbon trading, shifting from non-renewable to renewable energy (coal to biomass power plants), awareness towards clean environment, etc. are some of the issues support factors to increased plantation drive.
19	Soil carbon sequestration	:	9815,95 Mt.
20	Initiatives on adoption of SRF	:	Availability of quality planting stock, removal of barriers (legal, technical, financial, policy, etc.), site/need specific research, motivation to change attitude of the growers, etc. are some of the initiatives to promote adoption of tree plantations.
21a	Perspective of energy plantation	:	The shift from fossil fuel to bio-energy has enhanced the prospects of energy plantation in the country. Industrial units have started investing in captive plantations because of increased competition for the biomass. In this context, Short Rotation Forest Tree Species (*Eucalyptus, Prosopis, Leucaena, Casuarina, Acacia*, etc.) have emerged as a viable option to meet the growing renewable energy requirements. On an average 50 per cent of electricity generated in biomass power projects is derived from rice husk, 30 per cent from wood and remaining 20 per cent is derived from other agricultural crop residues. This energy production has brought about changes in cropping pattern, and increased production of energy crops in agriculture fields. Agricultural residue production is not going to change

			but wood resources have to be generated substantially to feed the industrial energy requirements.
21b	Government	:	Government is providing incentives for energy shift as well as for energy efficiency. India is a progressing economy and the pace of the development is hampered by inadequate availability of energy. In addition, the rural electrification programme is an uphill task. The Government is reportedly aiming to generate enough power from different renewable sources to accelerate the economic growth rate in the 21st century.
21c	Society	:	The environmental awareness among the masses is encouraging them to use renewable energy in stead of fossil fuel. Efforts have been made by the non-governmental organizations for plantation drives for clean environment. People realise that the polluted air does not need a passport to enter into the geographical boundary of other nation, therefore clean air is the responsibility of each and every one globally.
21d	Corporate houses	:	Social obligations, Governmental restrictions and their own requirements make them realise the situation and accordingly they have been fulfilling their commitments. In net shell, they realise that clean energy, energy efficiency, GHG mitigation, employment generation, socio-economic uplift-ment, etc. are predictable outcomes of bio-energy and plantations.
22	Alternatives to meet wood demand (strategies)	:	The Honourable Supreme Court of India imposed clean ban on the green felling from the forests in 1996. Therefore, there are only two options i.e., either import or produce outside forest area (social forestry/agroforestry). Greening India Mission emphasizes to double the area for afforestation/ eco-restoration in the next 10 years i.e., 20mha.
23	Use of Agricultural waste in paper industry/biomass based power plants	:	Number of paper industries are operating on material like *Saccharum spp.,Arundo donax*, *Eulaliopsis binnata,* paddy/wheat straw, other farm residues/fibers, etc.
24	Initiatives to reduce GHG release	:	Enhanced forestation, installed capacity of hydro and other renewable energy technologies, technological upgradation, energy shift from fossil to renewable, energy efficiency, introduction of CNG vehicles, etc. are same.
25	Incentives for reducing the emissions	:	CDM is a viable option and number of projects have been registered and are earning through the mechanism (detail below at column 33 below).
26	Initiatives to shift from non-renewable sources to renewable energy.	:	Ministry of New and Renewable Energy (MNRE), GOI is stressing hard on renewable energy and large scale projects have been initiated on solar, wind, hydro, biomass energy, etc. Energy shift, energy efficiency, renewable energy, afforestation/ reforestation and conservation/reduces deforestation, etc. are prominent initiatives in this direction.
27	Incentives for shifting from non-renewable to renewable sources.	:	MNRE is providing subsidy on shifting from non-renewable to renewable energy (domestic as well as industries) and much emphasis is placed on renewable (www.mnre.gov.in)
28	Any other community efforts about SRF.	:	Many religious/social organizations have been working on SRTS for their adoption to meet material requirements, mitigate GHGs, phyto-remediation, etc. Individually farmers are integrating trees with agricultural crops for higher economic benefits.
29	Institutional capacity building	:	Institutions are equipped with technological backup and efforts are being made to disseminate the required technology to the end users. International

			collaborations in afforestation/ reforestation, energy sector specifically energy efficiency, energy shift, renewable energy, etc. has been encouraged.
30	Technological constraints, if any	:	The emphasis of SRTS is mainly on clonally propagated stock, therefore, the genetic base is narrowing down, the additional introductions of more diverse material with high productivity of different species is essential. Efforts are required for multi-species/clonal plantations including leguminous species.
31	State of CDM A/R projects		Indian projects submitted for approval = 14 Registered till dated = 04 {ITC (AP), Sirsa (Haryana), Saber Paper Ltd. Una (HP) and TIST (TN)} Validation contract terminated = 02 Correction action requested = 05 Globally registered = 32 {one each in Maldova (179472), Vietnam (2665), Ethiopia (29343), Chile (9292), Malaysia (65883), Thailand (19344), Brazil (75783), Bolivia (4341), Uganda (5564), Peru (48689), Paraguay (1523), Albania (22964), Colombia (37783), fifteen in China (1521876) & and four in India(72982)}. Values in parentheses indicate the potential reduction. (www.unfccc.org)
32	Approved A/R – CDM project		Project / Reduction $mtCO_2$ equiv. / Area (ha) / Involvement (farmers) 1. The internationa small Group and tree planting prog. (TN) / 3594 / 106 / 1200 2. Small scale cooperative Afforestation CDM project (Haryana) / 11596 / 370 / 227 3. Reforestation of severely Degraded landmass (ITC project, AP) / 57792 / 3070 / 3398 4. Saber Papr Ltd., Una (HP) / 74692 / - / - (www.cdmindia.in)
33	Basic Data on CDM Projects -India		Project / No. / Total CER 2012 ($mtCO_2$) / CERs issued ($mtCO_2$) Biomass / 144 / 34.7 / 6.60 Wind power / 102 / 26.9 / 7.29 Waste gas/heat utilization / 66 / 35.3 / 9.49 Hydropower / 64 / 16.8 / 1.75 Energy efficiency / 54 / 8.48 / 1.02 Cement / 17 / 16.8 / 1.25 Biogas / 14 / 2.47 / 0.57 Fuel switch / 14 / 24.58 / 1.42 Methane avoidance / 11 / 2.17 / 0.00 HFC reduction / 6 / 82.7 / 49.3 N2O reduction / 4 / 5.84 / 0.00 Afforest./reforestation / 4 / 0.72 / 0.00 Other renew. energies / 3 / 0.28 / 0.00 PFC reduction / 1 / 1.30 / 0.00 Methane recovery & utilization / 1 / 1.17 / 0.07 Transportation / 1 / 0.24 / 0.003 Total / 506 / 260.4 / 78.8 (www.iges.or.je/en/cdm)

34	Any other additional information		India has generated approximately 30 million carbon credits and approximately 140 million in run, India's carbon market is growing faster than even information technology, bio-technology and BPO sectors as 850 projects with a huge investment of Rs. 650,000 million are in pipeline. As per the Prime Minister's Council on Climate Change, the revenue from 200 projects is estimated at Rs. 97 billion till 2012. Carbon, like any other commodity, is traded on India's Multi. In addition, stakeholders have been using voluntary markets for carbon trading to avoid CDM complications. Commodity Exchange, Mumbai (first exchange in Asia to trade carbon credits).

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I, A.K. Dhawan, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Sd/ A.K. Dhawan

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