Clonal Forestry in India

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Introduction

Because of poor allocations of budgetary support for sustainable development of government owned forest resources for decades and mounting biotic pressures nearly 28.8 million ha. or 42 %, out of 67.8 million ha. of the forest cover in India, constitute open forests with less than 40% crown cover density which have suffered severe degradation. The average growing stock of recorded forest area is very low – nearly 62 m^3/ha with poor mean annual increment less than 1 $m^3.ha^{-1}.yr^{-1}$. (Anon, 2005) Poor increments, extremely low sustainable yields and increasing demand have led to growing shortage of timber and fuel-wood in the country. Fuel-wood needs have been somehow met partly from agricultural residues and largely through unregulated, illicit and unsustainable removals from the forests. However modernization, growth and expansion of wood based industries have suffered for want of sustained supplies of industrial round wood at reasonable price resulting in increasing imports of newsprint / paper and wood based products. Substantial improvement in productivity of forest resources and promotion of large scale agro-forestry plantations, based on genetically improved planting stock, are most essential for meeting the future national needs of fuel-wood, timber and wood based products on sustainable basis. That should also help in achieving 33% good tree cover, conservation of the biodiversity rich natural forest resources and promote environmental amelioration.

As there are statutory ceiling limits on agricultural land holdings in India, wood based industries can not own adequate agricultural land for raising captive industrial plantations for meeting their future raw material requirements. National Forest Policy, revised in 1988, enjoins upon the wood based industrial units to meet their future raw material requirements through developing partnerships with the farmers. However, unfortunately this policy has not addressed the legitimate and genuine concerns of the forest based industries, including their demand for partnership with state governments on mutually agreed basis for time bound reforestation of degraded forest lands. Moreover major disincentives as listed below continue to hamper development and growth of agro-forestry plantations in India. (Lal, 2000):

- Very small and fragmented land holdings because of high population and statutory ceilings on agricultural land holdings.
- Mandatory requirement of felling permission from concerned State Forest Department to harvest farm grown trees and transit permits transport of timber to markets in many states.
- Long gestation period for harvest of planted trees future market price uncertainties and absence of minimum support price guarantees for farm grown timber by Government as for many agricultural crops
- Inadequate supply of genetically improved planting stock and poor extension services for agro-forestry plantations
- Complete ban on export of logs, liberal import of logs and sawn timber and difficult licensing procedures for wood based industries like plywood and saw mills etc.

Plantations of many important species raised from seed have extremely large genetic variation and poor productivity because the all important issue related to development of genetically

improved superior seed sources continue to be neglected. Even for long rotation high value timbers like teak (*Tectona grandis*), shisham (*Dalbergia sissoo*) and many others, most of the seed used for raising nursery seedlings is from unknown poor quality trees. Millions of seedlings are planted in many states every year and yet there is no system in place for certification of seed and genetically improved clonal planting stock or registration of clones and nurseries in India. There are no policy incentives for corporate sector to invest and play a major role in this important area. (Lal, 2000)

It is because of these lacunae that India continues to be deficient in timber and industrial round-wood resources and pay heavy price as the scarce land resources, planted with low cost poor quality seedlings, remain under productive till the harvest of such plantations. More over quality of timber produced from genetically poor seedlings is also inferior further adding to the economic losses. To address these important issues, development of genetically improved seed sources for all important plantation species needs to be taken up with high priority by the institutions of Indian Council of Forestry Research and Education (ICFRE) and State Forest Departments. Initially total quantity of seed required for each species can be collected from carefully selected candidate plus trees with most desirable phenotypic characters, well thinned out seed production areas and the few existing seed orchards. However, very high priority must be given for developing adequate clonal seed orchards and seedlings seed orchards to meet total future seed requirements of important tree species.

Clonal Planting Stock

Genetic improvement of seed through traditional breeding methods, as briefly discussed above, is absolutely essential and important for improving productivity of plantations and quality of timber. However, because of long life cycles of many trees and low genetic gains per generation of breeding, it takes many years to achieve major genetic gains. Clonal plantations exploit existing natural variation for fast and immediate genetic gains taking full advantage of superior genetic qualities of field tested clones. Vegetatively propagated clonal plants, developed from a single mother tree having most desirable genetic qualities, are uniform and true to type with all of the genetic qualities of the mother plant.

There are many advantages of clonal forestry including better utilization of additive genetic variance because differences among tested clones include all the additive variance and complete capture of non additive genetic variance since deployed clones retain their entire genetic value. Another major advantage is possibility of exploiting genotype x environment interaction through deployment of most adapted site specific tested clones (White *et al*, 2007). Likewise, there are also concerns like possible future epidemics of insect pests and pathogens on any particular deployed clone, loss of genetic diversity if the deployed clones are related or very few in number and maturation of clones leading to difficulties in multiplication or loss of productivity etc. Hence development and deployment of a fairly large number of genetically diverse clones in large scale clonal plantations programmes, long term breeding support, sound silvicultural management of plantations and continuous research and development support are amongst the important strategies for minimizing risks and taking full advantage of vast potential of clonal forestry

Candidate plus trees of many species amenable to vegetative propagation, selected based on most desirable phenotypic characters, can be cloned through rooting of juvenile stem cuttings. Use of root promoting hormones and controlled environment may be required for some species like

eucalypts and shisham (*Dalbergia sissoo*). Normally orthotropic shoots from clonal gene banks should be used for cutting production as the clonal plants multiplied from side branches may not grow into straight stems as in case of many conifers. Juvenile coppice shoots are comparatively easier to root for clonal plant production than mature or woody or lignified old branch cuttings (Lal, 1993).

Micro-propagation or tissue culture techniques can be used for many other species which may be difficult to multiply through rooting of stem cuttings. Propagation methods like grafting and air layering etc, are not suitable for production of planting stock for plantations managed for timber production as effect of age and position from where the material is taken for propagation tend to persist in many species. These techniques are fine for multiplication of clonal planting stock for the specific purpose of planting clonal seed orchards where good development of crown, early flowering and excellent fruit formation are the important criteria. It is important to multiply juvenile clonal planting stock for plantations where timber production is the primary objective

Comparative genetic superiority of each clone and adaptability to different agro-climatic and site conditions needs to be confirmed through scientific research trials giving equal conditions for growth and development of all clones. This is a critically important and most essential step for selection and deployment of genetically superior clones because apparent superiority of a good phenotype is the result of interaction between the genetic qualities and environmental factors throughout the age of the candidate plus tree. Field tested genetically superior clones of Eucalyptus and poplars have revolutionized the productivity and profitability of plantations in many countries including India. Moreover, there is substantial improvement in quality of timber produced from selected superior clones. Implementation of scientific improved package of practices, integrated management of pests and diseases, management of soil fertility and nutrient deficiencies, effective protection and optimum irrigation contribute immensely to higher overall productivity of clonal plantations and major improvements in quality of timber. Highest productivity potential of each clone can be achieved through careful matching of most adaptable clones to each category of soils within the climatic regions suitable for the species (Lal *et al* 1997)

Cloning of outstanding natural hybrids or control pollinated hybrids with good heterosis is also a wonderful option to capture of such genetic superiority and take full advantage of same for future plantations. Of course, comparative genetic superiority and adaptability of such hybrid clones to specific sites will also need to be confirmed through scientific research trials. Intra specific hybrids have been developed through reciprocal crosses between some of the promising clones of *Eucalyptus tereticornis* Smith. Likewise, many inter- specific hybrids have also developed through control pollination between selected clones of *Eucalyptus tereticornis* Smith and clones / candidate plus trees of other species of Eucalyptus (Lal, 2001).

Clonal plantations of many conifers including pines and spruce and hardwoods like gamhar (*Gmelina arborea*), casuarinas, poplars, *Acacia mangium* and eucalypts etc. have been raised in many countries with major improvements in productivity and quality of timber. Large scale commercial plantations, based on genetically improved clones of eucalypts, have been developed in many countries including Zaire, Brazil, China, South Africa and Portugal etc. Productivity of many clones developed by Aracruz Florestal in Brazil from *Eucalyptus grandis* Muel x *Eucalyptus uropyhylla* Blake hybrids is around 55 $m^3.ha^{-1}.yr^{-1}$ and some new improved clones planted on ideal sites with intensive management practices have recorded extremely high productivity up to 100 $m^3.ha^{-1}.yr^{-1}$. (Bertolucci *et al*, 1995). China is developing extensive clonal plantations of *Eucalyptus uropyhylla* and many other eucalypts for meeting future demands of

pulp and paper industry and for timber production. However in India, Poplars and clonal Eucalyptus, mainly *Eucalyptus tereticornis* and *Eucalyptus camaldulensis*, plantations are the two most outstanding success stories of clonal plantations. While protocols for vegetative propagation of many species have been developed by Forest Research Institute, Dehradun and other researchers, benefits of such research have not been consolidated through development, field testing and large scale deployment of superior clones in plantations. This weakness needs to be addressed urgently as it is important to improve productivity of plantations and quality of timber of all important tree species that are amenable to cost effective cloning for major gains from research. (Lal, 1993). In a way , the hybrids developed by such institutions will benefit the society when hybrids showing good heterosis are multiplied clonally and clonal planting stock is supplied to the growers on large scale.

Clonal Poplar Plantations

Poplars are normally propagated through stem cuttings taken from one year old nursery plants. 20 – 25 cms. long cuttings, after prophylactic treatment, are directly planted into soil in well prepared nursery beds with assured irrigation during January- February. One year old nursery plants, which are 3 to 4 meters in height, are transplanted during the winter months of January-February in one meter deep pits normally at 5m x 4 m spacing. Irrigated poplar plantations initially raised on State Forest Department's lands in Terai areas of present Uttrakhand State and later adopted by farmers under agro-forestry system represent the first success story of commercial scale clonal plantations in India. Clonal poplar plantations also redefined the productivity standards of plantation forestry for the first time with un-precedented high productivity – more than 25 times the average productivity of our national forests. This together with the second success story of clonal eucalypts plantations have ushered in a new era of high productivity both under production forestry and agro- forestry plantations (Jones and Lal, 1989; Lal *et al* 1997.)

Faced with growing shortage of suitable timber within the country, the safety match industry in northern India imported huge quantities of veneer quality logs of semal (*Bombax ceiba*) and gutel (*Trewia nudiflora*) from Nepal for nearly a decade from mid 1970s onwards for manufacture of match splints. Simultaneously, based on limited successful trials by Forest Research Institute, Dehradun & Uttar Pradesh Forest Department, the industry decided to promote poplars (*Populus deltoides*) plantations on private farm lands to meet their future match-wood requirements. Wimco Limited, the leading safety match manufacturing company, introduced four clones of *Populus deltoides* from Australia out of which two outstanding clones G-3 and G-48 laid the foundations of large scale poplar plantations in India. Commercial scale plantations of poplars under agro- forestry have been expanding since Wimco launched an ambitious agro- forestry project in 1984. Wimco supplied high quality nursery plants and provided technical extension services to farmers and commercial banks provided long term bank loans with refinance assistance of National Bank for Agriculture and Rural Development under this project. Wimco also entered into buy back agreements with the farmers to buy poplar logs on maturity at guaranteed minimum support price (Jones and Lal 1989).

Suitable clones of poplars grown with assured and optimum irrigation facilities by farmers have already changed the skyline in many districts of Punjab, north-western Uttar Pradesh, Terai areas of Uttrakhand and parts of Haryana. Well managed poplars can produce high quality veneer logs at optimum rotation period of 8 years with productivity of 50 $m^3.ha^{-1}.yr^{-1}$. Because poplars are deciduous, winter crops can be grown along-with poplars throughout the rotation period. Fast

growing clones of poplars, supported with improved package of practices, excellent technical extension services, long term bank finance and growing market demand for poplar wood have made poplar plantations on private farms a unique success story (Lal , 1991).

By the year 2000, poplar planting expanded to about 15 million poplar plants under agro-forestry plantations in these states every year, covering roughly 30000 ha. annually. With average 5 years rotation, as many farmers do not wait for 8 years, poplars contributed 1,50,000 ha. green cover and highly productive plantations outside the forests. Similar area of nearly 30,000 ha was harvested annually. Assuming a very safe average yield of 100 tonnes timber / ha at 5 years' rotation, about 3 million tonnes high quality timber harvested annually supported the safety match industry and hundreds of veneer and plywood units in these states. However, most unfortunately market prices of poplar logs crashed from a level of Rs. 4,500/ per tonne to Rs.1000/ to 1500/ per tonne by 2004-05 because of many reasons including licensing issues related to plywood/ veneer factories / saw mills leading to premature harvest of plantations and distress sales by poor farmers.

Assuming average decline of poplar prices by Rs. 1500/ per tonne, poor and marginal farmers lost rupees 450 crores annually and a whopping sum of rupees 1800 crores during the 4 year period of turmoil. Farmers not only resorted to premature harvesting and distress sale of poplar plantations but also virtually stopped planting poplars because of threat arising out of uncertainties and likely closure of plywood factories set up after October 2002 without obtaining licenses . That will be ruinous for the farmers as the market price for poplars may crash again causing a serious set back to the cause of promoting farm forestry and tree cover in the country. Therefore innovate policies for integrated planning and development of agro-forestry plantations and wood based industries is therefore most essential to prevent similar episodes in future. (Lal, 2006) Now that poplar prices have normalized and farmers are showing interest once again in replanting poplars, they should be encouraged and supported through suitable policy initiatives as well as modernization, expansion and growth of processing industries etc.

Clonal Eucalyptus Plantations

With no alternative option open to wood based industries, some of the progressive industrial units have been promoting farm forestry plantations through supply of planting stock, technical extension services and buy back arrangements with varying degrees of success This is despite major constraints and logistics problems like need for motivating very large numbers of farmers and huge costs on collection and transport of wood from scattered small land holdings in far flung areas.

As farmers prefer short rotation fast growing species for obvious reasons like market uncertainties and need for early returns, paper industry promoted mainly eucalypts and to some extent Acacia spp; Casuarina (*Casuarina equisetifolia*) and subabul (*Leucaena leucocephala*) plantations (Saigal *et al* 2002). Large scale Eucalyptus plantations have been raised on forest & farm lands, community lands and road / rail / canal strips in India. These plantations have created very useful resource for timber, poles, pulpwood and fuel-wood. However, most of these past plantations had very large genetic variation, low productivity ranging from 6 to 10 $m^3.ha^{-1}.yr^{-1}$ and poor returns because inferior seed used for raising most of the target oriented plantations (Lal, 1993).

Productivity and profitability of plantations of eucalypts have been revolutionized with the development of genetically improved, fast growing and high yielding clonal planting stock of eucalypts. Visionary management of one of the leading integrated pulp and paper mills, ITC Limited launched a well planned research and development programme in Andhra Pradesh in 1989 for development of genetically improved clonal planting stock of Eucalyptus. 64 candidate plus trees (CPTs) selected, based on most desirable phenotypic characters from seed route plantations of *E. tereticornis*, *E. camaldulensis* and a local derived provenance of *E. tereticornis* called Mysore gum or Eucalyptus hybrid, were cloned during the year 1989 for field testing and future deployment of superior tested clones.

First clonal testing area was planted with 21 clones in September 1989 and five genetically superior fast growing and disease resistant clones number 1, 3, 6, 7, 10 were short-listed based on two years performance and two demonstration plantations were set up during August 1991.The objective was to switch over from seed route plantations to clonal plantations in the shortest possible time with a view to improving productivity and profitability of farm forestry plantations. Meanwhile further evaluation of clones continued and clonal planting stock of 5 most promising clones was released to farmers on selective basis for large scale field trials from 1992 onwards. Most promising Bhadrachalam clones number based on performance in clonal testing area -1 were supplied to the farmers initially @ Rs. 4.50/ per plant Care was taken to ensure that clonal plantations raised by such selected farmers also develop into excellent demonstration plots. Technical extension services about improved package of practices for raising and maintaining clonal *Eucalyptus* plantations were provided free of cost by ITC Limited along-with buy back guarantees for purchase of wood on harvest at declared minimum support price.

Even though, two years time is not sufficient for final selection of superior clones, yet this management decision was taken based on the premise that a beginning must be made with the best available clones and meanwhile search for better ones should continue. Moreover, the major research goal was to achieve high productivity of short rotation clonal *Eucalyptus* plantations for production of pulpwood and poles. This decision has been subsequently vindicated as comparatively disease resistant clones of Eucalyptus with outstanding performance in the first two years have mostly maintained their lead in subsequent years as well. Valuable time was thus saved paving the way for early adoption of clones and expansion of clonal farm forestry plantations.

For ensuring wide and diverse genetic base of clones, more than 1000 CPTs have been cloned and tested in field trials for evaluating their comparative genetic superiority and adaptability to different soil types. More than 50 commercial clones now form the basis of large scale farm forestry plantations. Eucalyptus clones like 3, 6, 7, 10 and 27 developed at Bhadrachalam formed the basis of initial clonal plantations since 1992. These clones are still popular with the farmers. However, clones 72, 105, 286, 288, 316, 407, 411, 413, 498 and 526 and hybrid clones 2004, 2012, 2045, 2070, 2155, 2049 are highly productive commercial clones with excellent bole form which are now being planted on large scale. Out of these clones 413, 411 and 526 have high tolerance and adaptability to alkaline soils followed by clones 316, 288, 72 and 105. Clones 1, 99, 128, 130, 271, 272, 275 and 276 are also fairly tolerant to alkaline soils. Very successful plantations of clone 413 are being raised even on highly alkaline soils with pH 9.5 at village Saleempur near Shahbad Markanda in Kurukshetra district of Haryana and many other places Most of these clones represent *E. tereticornis*, *E.camaldulensis* and Mysore gum. In addition to clones listed above, clones number 265, 266, 274, 284, 290 and 292 and hybrid clones 2011, 2050, 2052, 2120, 2121 , 2149 and 2156 are popular in Andhra Pradesh.((Lal *et al*,1997; Kulkarni , 2006)

Average productivity of commercial *Eucalyptus* clones is around 20 to 25 $m^3.ha^{-1}.yr^{-1}$. under un–irrigated conditions. However, many farmers have achieved record growth rates of 50-58 $m^3.ha^{-1}.yr^{-1}$ making farm forestry an economically attractive land use option with better net returns compared to traditional crops. Significant improvements in quality of produce and reductions in per unit production costs have also been possible with the use of true to type, uniform and genetically improved clonal planting stock of *Eucalyptus* (Lal, 2001).

Development of Hybrid Clones of Eucalyptus

Clonal option exploits existing natural variation for fast and immediate genetic gains taking full advantage of superior genetic qualities of field tested clones. 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. Of course improved package of practices, integrated management of pests and diseases, management of soil fertility and nutrient deficiencies, protection of plantations and optimum irrigation will contribute immensely to the overall productivity improvement.

However, a dead end in highest productivity for each clone will be reached if all optimum conditions are fulfilled. Two pronged strategy are adopted to break such barrier to replace the best available clones with still better clones for future. Further introduction, evaluation and selection of new clones from CPTs selected with more stringent selection criteria is continuing. Selection criteria depend upon species, end use and management objectives. For timber production, large clear bole with straight and cylindrical stem, fast growth, self pruning branches and desirable timber properties are important factors. Reduction of bark and lignin content and improvement of fibre yield and quality are important for pulp production.

Major attention was focused on development of control pollinated hybrids followed by cloning of individual outstanding hybrids showing good heterosis. Intra specific hybrids were developed through reciprocal crosses between some of the promising clones of *Eucalyptus tereticornis* Smith. Inter specific hybrids were also developed through control pollination between selected clones of *Eucalyptus tereticornis* Smith and candidate plus trees of other species of eucalypts (Lal, 2001). A large number of hybrid clones developed from hybrid trees with good heterosis, are under field evaluation both in Andhra Pradesh and Punjab. Early indications at 1 to 3 years age confirm that many of these hybrid clones will redefine productivity standards achieving unprecedented new land marks. Some of the most promising hybrid clones tested at Semi in Punjab are 2070, 2045, 2004, 2012, 2049, 2155, 2023, 2013, 2007, 3012, 3011and 3018. Some of these clones like 2070 and 2045 are already being planted on large scale.

Improved package of practices like site selection , thorough preparation of site by deep ploughing, timely transplanting with the onset of good monsoon rains, deep planting up to 20–30cms depth, prevention of damage by termites with chlorpyriphos and timely weeding and soil working etc. have been developed. Management of soil fertility through application of deficient nutrients, inter- cultivation and green manuring etc. are regularly explained to the farmers by company's promoting clonal plantations. Where assured irrigation is available as in many states of northern India, transplanting of Eucalyptus clones can be carried out throughout the year except the hot summer months of April – June.

Agro-forestry Plantations

Agro-forestry plantations contribute major supplies of timber and pulpwood in India, simultaneously contributing to the green tree cover. In states like Haryana and Punjab, nearly 90% of the timber produced annually is generated outside the forests through sustainably managed plantations. Farmers all over India appreciate the multifarious benefits from trees and they have for decades maintained sporadic naturally grown trees on their farms. Many farmers have been planting a few trees along farm boundaries or roads as shelterbelts and for production of small timber / fuel-wood. Such trees have provided good hedging against risks of crop failures and generated lump-sum incomes in times of need. However, as land holdings are very small and farmers are by and large very poor, they prefer to grow short rotation seasonal or annual crops for their livelihood and regular income for meeting family needs. Even absentee land owners mostly prefer to lease their lands on annual basis instead of growing trees because of uncertainties of market demand and hassles on account of statutory regulations making government permission mandatory for felling of farm grown trees and transport / transit of timber to markets in many states.

Yet farmers have amply demonstrated, as in the case of poplars and clonal eucalyptus plantations that many of them are keen to opt for agro-forestry plantations if there are major benefits and substantially higher returns from this option. Farmers are willing to pay reasonably higher price for genetically improved planting stock. Some of the most important considerations which facilitate farmers to take positive decision in favour of agro- forestry as a preferred land use option are high productivity and far better returns compared to crops, long term market demand, availability of genetically improved planting stock and high quality extension services etc. Availability of long term bank loans with reasonable ease at low interest rates, flow of benefits to farmers treating their agro-forestry plantations as carbon sinks and development of agro- forestry of poplars, clonal eucalypts and other important species integrated with the wood based industries can give a further big boost to growth of high yielding and fast growing clonal plantations. (Lal, 2004 & 1995.)

Adoption of Eucalyptus Clones by Farmers

The pulp and paper mill, which pioneered research & development of these versatile eucalyptus clones, simultaneously promoted large scale clonal eucalyptus plantations on private farm lands in Andhra Pradesh. Lessons learnt from poplar plantations under farm forestry in north India and most of the factors listed above, within the control of the company, were kept in mind while devising and implementing the strategies for rapid expansion of clonal Eucalyptus plantations.

From the very beginning, company adopted a policy to establish long lasting, durable and mutually rewarding relationships with the farmers. Successful clonal demonstration plots convinced the farmers about unique qualities of the clonal planting stock like uniformity, excellent bole form, very fast growth rates and unprecedented high yields with better quality wood. Company entered into buy back agreements with farmers who wanted such commitments and yet provided great flexibility to the farmers permitting them to sell their farm grown eucalyptus to any other parties if they so prefer. Many high yielding clones extremely well adapted for problematic alkaline soils were also identified through replicated trials, which transformed the productivity of such refractory sites. Improved package of practices and silvicultural management techniques were explained and demonstrated to the farmers. These positive and innovative features supported with efficient technical extension services, sincerity,

credibility and commitment of plantation managers of the company helped in better awareness, acceptance and adoption of clonal Eucalyptus plantations by farmers.

Of course, assured long term market demand and prospects of substantially better returns from plantations, compared to returns from traditional agricultural crops on similar sites, played most important role in decision making by farmers for large scale adoption of *Eucalyptus* clones. Most of the clonal plantations in Andhra Pradesh are on un-irrigated rain fed lands. High risks of failure of agricultural crops because of erratic monsoon rains & insect pests and wide fluctuations in prices of commercial agricultural crops have also been very important considerations in favour of planting trees on farm lands.

Status of Clonal Eucalyptus Plantations

ITC Limited, who have pioneered and promoted large scale clonal plantations in Andhra Pradesh have promoted more than 25000 ha. clonal agro-forestry plantations and supplied 51 million genetically improved clonal plants during the period 1992 to 2006. Starting with supply of 0.03 million clonal saplings during 2002-03, this company currently supply nearly 20 million clonal Eucalyptus plants per year to farmers in Andhra Pradesh for their agro-forestry plantations. This stock is sufficient to plant about 8000 ha per year at 3M x 1.5 M spacing including replacement of nominal casualties during the first few months. ITC has now firmed up plans to promote agro-forestry plantations at the rate of 10,000 ha. per year bulk of which will be clonal eucalypts and Subabul (*Lucaena leucocephala*) plantations. (Kulkarni, 2006, Lal *et al* 1997, Lal, 2001) Likewise, Andhra Pradesh Forest Development Corporation and some private entrepreneurs also supply large quantity of clonal *Eucalyptus* plants, estimated at 5 to 10 million annually in Andhra Pradesh.

Ballarpur Industries Limited also promotes clonal Eucalyptus plantations around their paper mills at Ballarshah in Maharashtra, Jeypur in Orissa and Kamlapuram in Andhra Pradesh. During the current year 2008, Ballarpur group plans to supply 9 million clonal plants and 14 million clonal plants during 2009. This group has ambitious plans to achieve planting level of 20 million clonal plants per year by 2010. That will cover 8000 ha. with highly productive clonal plantations in Orissa, Andhra and Maharashtra states annually. J.K. Paper Mills, also promotes clonal plantations with current level of about 1000 ha/ year in Orissa and Gujarat states. Some of the other wood based pulp and paper mills including , Orient Paper Mills , Amlai, M.P. Andhra Pradesh Paper Mills, Rajmundhary, West Coast Paper Mills, Dandeli and TNPL in Tamil Nadu etc. have also started promoting clonal *Eucalyptus* plantations around their paper mills.

A new clonal technology research centre, green houses and modern clonal nurseries have been set up by Pragati Biotechnologies near Jallandhar in Punjab state since 2001 for supply of clonal plants of Eucalyptus and poplars to farmers in north India and to continue the R&D work for development of better clones for replacing the best ones available today. More than 150 clones of Eucalyptus including clones developed from intra and inter specific hybrids are under field evaluation at their research centre. Many farmers have adopted Eucalyptus clones in Punjab and Haryana states quickly because of availability of high yielding clonal planting stock, professional guidance and extension inputs, urgent need for diversification of agriculture, decline in prices of poplar logs and market demand for Eucalyptus logs for rural housing and plywood mills combined with successful demonstration plots. Because of better deep alluvial soils and availability of irrigation facilities productivity of clonal eucalyptus plantations in these states may

exceed the records set in Andhra Pradesh (Lal, 2003). Present capacity of the 1050 sq.m. green houses set up since June 2002 in Punjab is 2 million clonal saplings of *Eucalyptus* sufficient to plant 800 ha annually. Haryana Forest Department, Maharashtra State Forest Development Corporation and some other state forest departments also produce limited stocks of clonal Eucalyptus plants. Current prices of clonal planting stock of *Eucalyptus* in India range form Indian Rupees 700 to 1000 or roughly US $ 17 to 21 per 100 plants delivered at farmer's fields

Thus current level of planting of genetically improved fast growing clones of Eucalyptus is nearly 35 to 40 million plants sufficient to plant 14,000 to 16000 ha. annually at 3 M x 1.5 M spacing including replacement of normal casualties. These plantations with average productivity of 25 $m^3.ha^{-1}.yr^{-1}$ will produce 1.75 to 2 million cubic meters wood annually at 5 years rotation. The demand for genetically superior clonal planting stock of Eucalyptus is continuously growing and extent of area under clonal Eucalyptus plantations is slated to expand very fast. During the next few decades, majority of Eucalyptus plantations in India will be based on genetically improved clonal planting stock. Therefore, the economic stakes in clonal plantations will continue to grow and with that the challenges and opportunities before the research scientists for continuously developing and testing new and still better clones will also multiply.

Mysore Paper Mills, Bhadravathi and West Coast Paper Mills, Dandeli in Karnataka have been successfully promoting clonal plantations of selected hybrids of *Acacia mangium* and *Acacia auriculiformis*. ITC Limited has already deployed tested clones of Subabul (*Leucaena leucocephala)* . Research and development work is in progress in some of the state forest departments and ICFRE institutions for development of genetically superior clones of important species like teak (*Tectona grandis*), gamhar (*Gmelina arborea*) shisham (*Dalbergia sissoo*) and *Melia azadirachta etc.* and hopefully some of these tested clones will be operationally deployed in plantations in due course.

R & D Priorities for Clonal Plantations

Continuous research and development support is most essential for long term development of clonal plantations because of many reasons. Each clone has a specific genetic make up and capacity to tolerate adverse conditions. Because of genetic uniformity of each clone, there can be serious risks of epidemic diseases and insect pest attacks in future if the genetic base of clonal plantations is narrow. Therefore, it is essential to widen the genetic base and diversity of clones by developing a large number of field tested genetically superior clones for commercial scale plantations. (Lal, 2003) Best clones of today will have to be replaced with still better ones in future. A multi-pronged approach is suggested for development of new and better clones with most desirable genetic traits. Selection of new candidate plus trees with stringent criteria with higher benchmarks than the most desirable traits in existing commercial clones should be followed by cloning and field testing of clones. Any clones giving significantly better growth rates, better disease resistance with most desirable timber traits, compared to check clones, should be included as commercial clones for future plantations.

Traditional breeding support is also most essential to development superior future clones. Based on past species cum provenance testing in various states of India, new germ plasm should be introduced by importing seed of most promising provenances and species. Plantations raised from such genetically superior seed will be the source of good candidate plus trees in future for developing and testing new clones. This approach will include development and testing of intra-

specific and inter specific hybrids and cloning of individual hybrids showing excellent heterosis. Resultant hybrid clones should be field tested and compared with the best check clones.

More over, because of specific genetic make up of each clone, all clones are not equally adapted to different planting sites. Refractory sites with problematic soils particularly pose serious problems in respect of choice of suitable clones. Stress conditions caused by salinity, alkalinity, lateritic soils, calcareous black cotton soils or sites subjected to periodical water logging are very important considerations for choice of clones most adaptable to each of such problematic sites. Field testing of all available clones on such sites is essential for identifying specific clones with high adaptability and productivity on each category of such soils within the climatic region suitable for each species of Eucalyptus.

Therefore, new candidate plus trees should also be selected from existing plantations on refractory problematic soils as these may have better adaptability and tolerance to stress conditions caused by problematic soils. Clones developed from such candidate plus trees should be tested on different soil types and compared with the best available check clones already selected for each soil type. Matching of site specific and most adapted clones in future plantations will revolutionize productivity of plantations even on such problematic sites. For example clone 413 grows extremely well on normal soils as well as highly alkaline soils with pH around 9.5 and many clones have already been identified which grow well on alkaline soils with pH 8.5 to 9.

R & D work in progress for development of genetically improved clonal planting stock of important timber species like teak (*Tectona grandis*), gamhar (*Gmelina arborea*) shisham (*Dalbergia sissoo*) and many other species at ICFRE institutes and State Forest Departments should be consolidated and speeded up through deployment of adequate financial and human resources. Excellent progress has been made by Kerala Forest Research Institute, Peechi and Andhra Pradesh Forest Department for developing clones of teak which are now under various stages of testing. Clones developed from natural hybrids of Acacia mangium and Acacia auriculiformis are already being promoted by Mysore Paper Mills , Bhadravathi and West Coast Paper Mills, Dandeli (Sharma et al, 2006). Clones of Casuarinas and subabul (*Leucaena leucocephala*) have been developed by ITC Limited in Andhra Pradesh in addition to eucalypts clones. (Lal *et al*, 1996). Large scale successful clonal eucalypts plantations have provided necessary impetus and confidence for research related to development and deployment of improved clones of many important species in future plantation programmes.

Collaborative research makes eminent sense with major benefits as human and capital resources as well as equipment are scarce and costly. This also ensures multidisciplinary approach and makes research efforts more cost effective. Indian Council of Forestry Research and Education, Indian Council of Agricultural Research, Council for Scientific and Industrial Research and the wood based industries could join hands to promote collaborative research on agreed high priority areas. State Forest Departments and Agriculture Departments should support such research projects, as clonal agro- forestry plantations help conserve biodiversity rich natural forests and promote much needed diversification of agriculture. Collaborative research prevents duplication and enhances benefits of collective wisdom.

Silvicultural and Management Practices

Knowledge and proper implementation of scientific and improved package of practices is most essential for taking full advantage of genetic superiority of clones. Thus research for continuous

improvement of scientific package of planting and management practices should receive high priority. Shortage of major plant nutrients and micro- nutrients not only limit the growth and productivity , but also cause problems like severe chlorosis , reduction in vigour and resistance to diseases. Therefore, research on optimum doses of organic manures and fertilizers during different ages and growth period needs to be strengthened.

Integrated management of pests and diseases in general and prevention of mortality in young plantations because of termites, weedicides, excessive doses or wrong application of fertilizers needs to be strengthened. Development of cheaper, cost effective and environmentally safe products and practices for prevention and control of extensive damage by termites is most desirable to replace chlorpyriphos. Extract of leaves of locally available plant garari (*Cleistanthus collinus*) has been found to be very effective against termites in Andhra Pradesh (Kulkarni, 2006). Many other plants extracts including weeds which are available locally in abundance need to be tested for their efficacy against termites. Leaf spot diseases have caused serious damage to seed route plantations in many states including Andhra Pradesh. Leaf spot fungi like *Alternaria*, *Cylindrocladium* and many others also pose problems in clonal nurseries where the plants are congested particularly during hot and humid weather. We need to develop clones with still better resistance to such leaf spot diseases. Likewise, future clones should have better resistance to other known insect pests and diseases.

Intercropping Research

Area under agro-forestry system of clonal Eucalyptus plantations is expanding fast in many states as farmers are expanding production of timber and pulpwood to meet the growing demand. Therefore, agro- forestry research with Eucalyptus as the principal crop needs to be strengthened. The common myth that nothing grows under Eucalyptus because of so called allelopathic effects has already been nailed clonal eucalyptus based agro–forestry plantations continue to expand in many states like Andhra, Orissa, Maharashtra , Punjab and Haryana. Many intercrops both during the Rabi and Kharif season, like oats, barseem, cowpeas, ginger, turmeric and millets have been successfully raised by Pragati Biotechnologies at their research centre at Semi even during 5th year of clonal Eucalyptus plantations. However, further research on better adapted and more shade tolerant crop varieties will be very helpful to farmers growing Eucalyptus under agro-forestry system.

Because of shortage of labour, most farmers now a days use weedicides to control weeds in their agricultural crops. However, many of the weedicides are highly toxic and very harmful for young Eucalyptus saplings. Therefore, further research for developing safe weedicides, which also do not have any adverse effect on Eucalyptus plants will be very useful.

Processing and Utilization of Fast Grown Timber

Further research on processing and utilization of fast grown timber and poles produced from clonal eucalyptus plantations shall be of great advantage both to the farmers raising agro-forestry plantations and the wood based industries. Because of strong apical dominance and self pruning nature of most Eucalyptus clones, clonal plantations produce poles and timber with large clear, straight and cylindrical bole. Eucalyptus timber has very good strength and many other desirable properties like excellent nail holding capacity making it useful for veneers, plywood, medium density fibre boards, sawn timber etc. Special conversion and sawing techniques developed by Forest Research Institute, Dehradun take care of splitting and end cracks. Likewise, seasoned

timber of Eucalyptus has good dimensional stability and makes useful joinery and furniture. High quality benches made from 4 year old clonal eucalypts timber at Semi is a good example. However, further research on seasoning, preservative timber treatment and processing into various end products shall be very rewarding.

Lops and tops and smaller girth wood of Eucalyptus makes the bulk of pulpwood supplies to the Indian pulp and paper industry. Further research to reduce the bark and lignin content and increase the percentage of useful cellulose with better pulp qualities should also receive high priority. There can be significant advantages and cost savings for the nation through such research.

Research for reduction of per plant cost of producing clonal planting stock, consistent with highest quality standards, is also very important. This will involve improvement of technologies for design of green houses and development of cost effective, energy friendly and efficient equipment for environmental control in green houses. Further refinement of micro propagation and hardening techniques to overcome the present difficulties and high costs will also be an interesting area for research. Further research inputs for efficient and cost effective management of clonal multiplication areas or gene banks for cutting production and green house management are necessary. If we can substantially improve the rooting percentage and production of final plantable clonal stock from present 60- 70 % to 80 or 90 % of cuttings set for rooting, consistent with highest quality standards that will bring down per plant costs significantly.

Policy Research

Our country has not been able to take full advantage of vast potential of clonal technologies and agro-forestry. This is because of major policy flaws and constraints on account of myths associated with eucalypts. As elaborated by the Food and Agriculture Organization in their publication the Eucalypt Dilemma, most of the myths and ill effects attributed to eucalypts do not stand scientific scrutiny. For example, eucalypts are amongst the most efficient plants for utilization of moisture and consume far less water for production of each tonne of biomass compared to species like shisham (*Dalbergia sissoo*), chirpine (*Pinus roxburghii*), Jamun (*Eugenia sp*.) etc. Eucalypts are associated with friendly root mycorrhiza which helps these trees to thrive even on soils with poor nutrients. Eucalyptus plantations provide better soil cover and reduce soil erosion compared to barren tree less sites. Nearly 70 % plant nutrients are recycled back into soil by leaf fall branches and bark shed by eucalypts every year compared to almost 100% outflow of nutrients through agricultural crops.

Current restrictive policies in many states related to felling permits and transit of farm grown timbers and complete absence of planned and integrated development of plantations and wood based industries are hindering growth of agro-forestry as well as growth and modernization of wood based industries. Cumbersome rules and lengthy procedures for granting licenses to new wood based industries and saw mills, even if the units are solely based on agro- forestry plantations have effectively strangulated the growth of industry as well as agro- forestry. Scientific agro-forestry development and planned growth of industries processing plantation grown wood is a win-win situation for all sections of society and forestry. (Lal, 2006, 2004)

While our country imports huge quantities of timber and wood based products, our farmers were denied access to international markets for export of logs of poplars even during the years 2001–04 when domestic prices for poplar logs crashed and assets of farmers growing poplars worth

millions of rupees were eroded. If we do not allow modernization, expansion or establishment of new wood based industries based on agro- forestry produce and keep the export option closed, where will the farmers sell their farm grown timber.

Scientists need to intensify further research on these aspects and place true facts and vast potential of clonal Eucalypts plantations and integrated planned development of agro-forestry and wood based industries before the policy makers and planners. Innovative policy changes can ensure harmonious growth of agro-forestry plantations and wood based industries without any pressures on natural forests. Scientific research often involves high costs and long time spans particularly for long duration trees. Hence it is of vital importance that research projects are evaluated and prioritized based on their comparative future benefits to the nation and society. Research findings must find field applications soonest possible through efficient extension techniques. State governments and wood based industries should strengthen extension services for agro–forestry plantations.

Conclusions

Genetically improved clonal planting stock of eucalypts, poplars and acacias has transformed the productivity and profitability of plantations. Average yields from such clonal plantations are 20 to 25 times higher compared to the average productivity of forests in India. Many farmers have obtained yields exceeding 50 $m^3.ha^{-1}.yr^{-1}$under agro-forestry system. Nearly 3 million tonnes or 3.75 million cubic meters of valuable poplar logs are produced every year by farmers in the four poplar growing states of U.P; Uttrakhand, Haryana and Punjab. At current average price of Rs. 5000/ per tonne , this timber is worth rupees 1500 crores per year. Likewise, yield of poles and pulpwood produced from current planting levels of 14,000 to 16000 ha. Eucalyptus clones, with average productivity of 25 $m^3.ha^{-1}.yr^{-1}$ will produce 1.75 to 2 million cubic meters wood annually at 5 years rotation. This volume equivalent to 2.1 to 2.4 million tonnes of Eucalyptus wood, at current average price of Rs. 2500/ per tonne for poles and pulpwood, will be valued at 5250 to 6000 million rupees per annum. Local value addition through processing by wood based industries will be many times higher. These clonal plantations sustain most of the wood based pulp and paper mills and plywood/ veneer factories in the country saving precious foreign exchange, create ample employment opportunities, provide valuable products like paper and plywood to the society and indirectly conserve our biodiversity rich natural forests. Therefore clonal plantations, both on degraded forest lands and under agro-forestry system, should be encouraged and integrated with planned development of wood based industries through innovative policy changes.

Most of the poplar plantations, with the exception of small areas planted in Terai areas by Uttrakhand Forest Department, are on private lands owned by large number of individual farmers. Likewise, most of the clonal Eucalyptus plantations have been promoted by pulp and paper industry by motivating thousands of farmers to raise agro-forestry plantations on their farm lands. It is a pity that most of the State Forest Departments have not taken full advantage of clonal technology research carried out by private sector. ICFRE institutes and State Forest departments should accord very high priority for genetic improvement of seed of all important planted timber species and for developing suitable clones of timber trees amenable to vegetative propagation including teak , *Gmelina* and pines etc. Substantial gains in productivity and improvement of quality of produce are possible through clonal seed orchard seed. Therefore, State Forest Departments should also accord high priority for developing clonal seed orchards of important timber species planted extensively based on genetically superior clones. Very

favourable cost benefit ratios of high yielding and fast growing clonal plantations need to be appreciated by foresters, scientists, policy makers and farmers for manifold increase in productivity with better quality timber which fetches premium price. Continuous research and development support is most essential for any large scale commercial clonal plantations programme. Extension services must be strengthened for taking the research findings from lab to land and maximizing benefits of vast potential of clonal technology for the society and farmers of our country.

Forests in India can not meet national demand for firewood, timber and wood based products on sustainable basis because of low growing stock, poor increments, inadequate financial and technological inputs, unbearable biotic pressures and serious degradation of forest resources. Growing shortages of industrial round wood have hampered modernization and growth of wood based industries. State Forest Departments, local communities and wood based industries can join hands on mutually agreed basis to transform the productivity of degraded forest lands through technology based clonal plantations. Well managed clonal Eucalyptus plantations covering 1.25 million ha. can meet our country's entire pulp and paper requirements projected at 8.5 million tonnes by 2010-11. Likewise, high yielding, short rotation clonal Eucalyptus plantations on part of the degraded forest lands can meet our country's fuel-wood needs on sustainable basis. That will help conserve our natural forests save valuable timber plantations, generate vast employment opportunities, promote local processing and value addition, and generate much larger and sustainable incomes for local communities.

Summary

Forests in India can not meet national demand for firewood, timber and wood based products on sustainable basis because of low growing stock, poor increments, inadequate financial and technological inputs, unbearable biotic pressures and serious degradation of forest resources. Genetically improved clonal planting stock of eucalypts, poplars and acacias has transformed the productivity and profitability of plantations. Average yields from such clonal plantations are 20 to 25 times higher compared to the average productivity of forests in India. Current levels of clonal Eucalyptus and poplar plantations produce nearly 5 million cubic meters wood valued at 21,000 million rupees annually. Plantations sustain most of the wood based pulp and paper mills and plywood/ veneer factories in the country saving precious foreign exchange.

State Forest Departments, local communities and wood based industries can join hands on mutually agreed basis to transform the productivity of degraded forest lands through technology based clonal plantations. Well managed clonal Eucalyptus plantations covering 1.25 million ha. can meet our country's entire pulp and paper requirements projected at 8.5 million tonnes by 2010-11. Likewise, high yielding, short rotation clonal Eucalyptus plantations on part of the degraded forest lands can meet our country's fuel-wood needs on sustainable basis. That will help conserve our natural forests save valuable timber plantations, generate vast employment opportunities, promote local processing and value addition, and generate much larger and sustainable incomes for local communities.

Therefore clonal plantations, both on degraded forest lands and under agro-forestry system, should be encouraged and integrated with planned development of wood based industries through innovative policy changes. ICFRE institutes and State Forest departments should accord very high priority for genetic improvement of seed of all important planted timber species and for developing suitable high yielding, fast growing clones of timber trees amenable to vegetative

propagation including Teak, Gmelina, and Pines etc. Substantial gains in productivity and improvement of quality of produce are possible through clonal seed orchard seed. Therefore, State Forest Departments should also accord high priority for developing clonal seed orchards of important timber species planted extensively based on genetically superior clones. Continuous research and development support is most essential for any large scale commercial clonal plantations programme. Extension services must be strengthened for taking the research findings from lab to land and maximizing benefits of vast potential of clonal technology for the society and farmers of our country.

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