Clonal Forestry – An ITC Initiative

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Introduction

The ITC Limited - Paperboards & Specialty Papers Division, Bhadrachalam unit uses 800,000 MT/annum of wood from Eucalyptus, Leucaena, Casuarina and Bamboo in it's furnish for manufacturing the pulp and paperboards along with secondary fibre. A plan to grow 100,000 ha plantations before the completion of the decade (2010) was developed to meet the raw material requirements of the mill on a continuous and sustainable basis.

The Company promoted Social and Farm Forestry plantations by distributing nearly 30 million seedlings and covered 9441 ha with Eucalyptus plantations from 1982 to 1995. These plantations showed high genetic variations, poor survival and productivity. At that time the prevailing scene of Eucalyptus seed route plantations was grim as the foliar blight disease caused by *Cylindrocladium* spp. was quite prevalent in plantations. Apart from that, termites caused large-scale seedling mortality in plantations of young age. The out come was that the survival of trees in plantations at harvest stage was 30 to 50 per cent and productivity of 4 to 6 MT/ha/yr. Due to low yields, the plantations were not economical to the farmers as an alternative farming option. The other reasons for poor productivity were hybrid breaking, non availability of quality seeds, primitive nursery practices, mismatch of species and provenances to site, close spacing, lack of follow up of correct package of practices (Kulkarni, 2001). Because of Eucalyptus controversy (Rajan, 1987), farmers were scared to take up plantations. Leucaena had Psyllid problem and Casuarina with stem fungal disease.

Therefore, a decade ago, Farm Forestry plantations were becoming unpopular in spite of the incentives, subsidies and National Bank for Agriculture and Rural Development (NABARD) loans to the farmers. This adverse scenario changed over a period of 4 to 5 years from 1989 year when the Company decided to launch Tree Improvement Programme and promoted Clonal Technology based plantations (Kulkarni and Lal, 1995).

Materials and Methods

The experimental site and Clonal Research Station is located at 17^{o} 40' N latitude and 81^{o} E longitude. The altitude of the place is 100 m above mean sea level. The climate is sub tropical with annual rainfall of 1033 mm, mostly from southwest monsoon. The maximum temperature recorded is 49 ^{o}C and minimum 10 ^{o}C. The predominant soils are red sandy and black cotton. Soils are either normal or alkaline. Saline soils are also found.

For Eucalyptus, the seeds were imported from CSIRO (Australia) in the years 1986, 1990, 1994 and 1995 to raise provenance trials. Candidate Plus Trees of *E.tereticornis* Smith. and *E.camaldulensis* Dehnh. were mainly selected from Government and Farm Forestry plantations. Selected plus trees were propagated vegetatively from coppice cuttings in mist chambers. Root Trainer Technology was adopted for the production of plants. The successful ramets were planted in Gene Banks known as Clonal Multiplication Areas (CMA) at a spacing of 1 x 1 m. The Clonal

Testing Areas (CTA) were planted at 3 x 2 m spacing in RBD with 3 replications. Ploughing of the plots was carried out annually. No fertilizers and irrigation was provided to the trial plots. Periodic measurements were recorded for girth, height and occurrence of pests and diseases and promising clones were short-listed. Clonal Seed Orchards (CSO) adopting the permutated neighborhood design (Sekar, *et. al*. 1984) were established in 3 ha area. Clonal Demonstration Plots (CDP) were raised under the extension scheme. Inter and Intra-specific hybridization was carried out between selected best clones and other species of Eucalyptus. Half and full-sib progeny trials were laid out. Promising hybrids were cloned and planted in multi-location trials. Genotype x Site interaction studies for various clones were carried out on normal and refractory sites. A gene repository was also established for conserving clonal material. The proximate analysis and strength properties of CPT wood for pulp and paper were carried out at the Central Laboratory of the mill. For Leucaena, seeds were imported from USAID, Hawaii and for Casuarina from CSIRO, Australia.

Results and Discussion

At the beginning of the programme, the main handicap faced was the non-availability of a wide genetic base for the improvement of Eucalyptus. Therefore, "breed the best with the available best" strategy was followed.

Gene Resource: The genetic base deployed for improvement of Eucalyptus is based on the species *E. tereticornis* as it is most suited to this zone. However, other species of Eucalyptus were also involved for selection and hybridisation. For Leucaena, *L. Leucocephala (k-8, k-28, k-636, k-156, k-784 & hybrids- k x 2 & L x L), L. diversifolia* and their hybids formed the gene resource. *Casuarina equisitifolia* and *C.junguniana* were the two species involved in the improvement programme.

Candidate Plus Tree Selection: The selection of the most desirable tree with characteristics such as straightness of stem, annual growth rate, disease resistance, crown structure, wood density, fibre morphology, cellulose / lignin balance, bark to solid wood, under bark relationships etc. were considered. Starting with the cloning of 64 CPTs during 1989, more than 1000 CPTs and 500 full sib CPTs have been selected and cloned by now. Out of 107 promising clones qualified so far 63 per cent have come from the provenance seeds source obtained from CSIRO (Australia) and 37 per cent from local Mysore gum source. The provenance's that gave maximum clones are 8 KM NW Black Mountain and 1 KM N of Laura. More than 241 CPTs for Leucaena and 240 CPTs for Casuarina were selected.

Vegetative Propagation: For most of the clones, the percentage of rooting of juvenile coppice shoots under mist conditions was more than 70 except for clone 6 which was less than 40 per cent for Eucalyptus. Cladodes were used for rooting Casuarina CPTs while, stem cuttings with bark were used for Leucaena.

Clonal Testing and Promising Clones: Clones were evaluated from CTAs for comparative genetic superiority and G x E interactions. Nearly 159 trial plots in a 36 ha area have been established since 1989 in various soil types. 107 promising clones were short-listed from the above trials. In the beginning of the programme, clones were planted without due regard to site. After a gap of 3 to 4 years, it was discovered that some clones were doing well and some were not in a given site. In general, black soils (normal, alkaline and saline) require specific clones 1, 10 and 130 which adapt well. But clone 10 doesn't tolerate saline sandy soils as a result it led to high mortality (up to 90) in a 2

year old plot at Tangutur in Prakasam District of A.P. However, in the same plot clone 411 and 413 were performing well with high productivity and survival. Normally, CPTs selected from black soil are to be tested first on black soil itself and later on other soil types as clones exhibit a strong affinity to the site of their origin. For example, clone 351 that was selected from black soil gave a yield of 22 m^3/ha/yr on similar site compared to 6 m^3/ha yr on red soil (Table 1).

Table 1. Performance of Two Clones 3 & 351 on Red and Black Soils

CAI / MAI Vol/ha (ub, m^3)	Red Soil		Black Soil	
	Clone 3	Clone 351	Clone 3	Clone 351
CAI at Age				
1	14.2	7.9	4.6	4.0
2	24.7	4.9	9.0	13.3
3	11.7	5.7	25.2	33.2
4	14.8	5.4	37.0	37.4
MAI at 4 years	16.3	6.0	18.9	22.0

Clone 3 - origin from red soil. **Clone 351 - origin from black soil.**

There has been a slight change in clonal testing method now as clonal testing is now directly taken-up in the farmer's field for obtaining higher yields with short rotation of 2 to 3 years. By providing irrigation, fertilization and close spacing, the wood volume production was high by 10 to 40 per cent. Furthermore, to develop future clones with higher productivity, check clones as benchmarks were introduced apart from seedling control in CTA 21 and 83.

The most important commercial clones are - 3, 6, 7, 10, 27, 71, 72, 99, 105, 115, 122, 128, 130, 223, 265, 266, 271, 272, 273, 274, 175, 277, 284, 285, 286, 288, 290, 292, 316, 319, 405, 411, 412, 413, 417, 439 and 470.

The most adaptable clones for alkaline soils are - 1, 10, 27, 71, 99, 105, 115, 116, 122, 128, 130, 158, 223, 266, 271, 272, 273, 274, 277, 290, 316, 318, 328, 410, 411, 412, 413 and 417.

The plastic clones are - 27, 71, 83, 99, 105, 116, 128, 130, 147, 271 and 285.

Disease Resistance: The outbreak of diseases caused by various fungi on Eucalyptus in nursery and field revealed main pathogens as *Cylindrocladium* spp. and *Alternaria* spp. The disease resistant clones short-listed are 1, 3, 6, 7, 288 and 316.

For Leucaena 12 clones and 15 clones for Casuarina were shortlisted as promising clones.

Productivity of clones: The survival percentage for majority of clonal plantations is more than 95 (Kulkarni and Lal, 1995). The productivity of "ITC-Bhadrachalam" clone's ranges from 20 to 58 MT/ha/yr compared to 6 to 10 MT/ha/yr from seedling origin plantations (Fig.2 to 4). Apart from increase in productivity by 4 to 6 times the rotation period is reduced by half (Fig.5). Therefore, farmers are now harvesting plantations at 4 years instead of 7 years.

Clonal Multiplication Areas (Gene Bank): Since 1989, 33 ha gene bank is raised with 0.22 million ramets in blocks at 1 x 1 m spacing in the mill premises. The CPT material was first planted in the Gene Banks. Gene banks are regularly coppiced at 2 years age for obtaining the propagule for multiplication. Each stump has given 180 to 200 ramets with 3 harvests and annually nearly 10 million plants are produced for planting. Modern technique of "mini cutting" is now employed to produce plants.

Clonal Demonstration Plots (CDP): Clonal demonstration plantations raised by the Company resulted in large-scale adoption of genetically superior "ITC-Bhadrachalam" clones of Eucalyptus by the farmers and State Forest Departments / Forest Development Corporations. Since 1989, nearly 24 ha of CDP have been established at various places in Andhra Pradesh. As "seeing is beleieving", farmers meetings were regularly held in these plots which enabled them to pick and choose the clones most suited for their land.

Clonal Seed Orchards (CSO): CSO with the best clones covering an area of 3 ha have been established. Fresh CPTs are now being selected from the CSO based plantations as selections with new recombinations are giving next generation clones. The major problem encountered in raising CSO was that the neighbouring fast growing clones suppressed the slow growing clones. Thus, planting in a mosaic design did not serve the purpose. Another problem encountered was non-synchrony in flowering resulting in restricted gene exchange.

Hybridization: The Hybridization programme was initiated in 1994. A breeding orchard was set-up with cleft grafted plants of *E. tereticornis, E. camaldulensis, E. alba, E. urophylla* and *E. grandis*. The selected material was multiplied in large numbers by cleft grafting. The graft union was successful between *E. tereticornis* Smith. root stock and scion material derived from *E. alba, E. camaldulensis* and *E. urophylla*. Graft incompatibility, however, was noticed in the case of *E. torelliana (Corymbia torelliana)* At 7 years of age, the grafts in the breeding orchard have attained a maximum GBH of 58 cm and height of 10 m. The best results of grafting were obtained in the months of August to November. Almost all the grafts flowered at 2 to 3 year's age.

Inter-specific hybridization was attempted to combine desirable complementary attributes of promising clones and eliminate defects keeping in view the customers (grower / mill) view point *viz.* high yields (volumetric productivity), felling cycle of 3 to 5 years economic rotation), adaptability to sites, superior wood quality and uniformity of raw material. The clones with well-defined traits (Table 2) were included in the breeding programme.

Table 2. Clonal Characters for Hybridization

Characters	Clone Numbers
Clear Bole	1, 4, 6, 7, 27, 122, 223, 265, 266, 272, 274, 275, 284, 286, 288, 290, 292, 316 and 319.
High Productivity	3, 6, 7, 10, 105, 130, 265, 266, 272, 274, 284, 290, 292, 316 and 319.
Adaptable to Refractory Sites	1, 10, 71, 105, 115, 116, 128, 130, 223, 266, 271, 272, 274, 285, 290, 316, 405, 411 and 413.
Disease Resistance	1, 3, 6, 7, 288 and 316.

Development of inter-specific hybrids such as *E. tereticornis* Smith x *E. urophylla* Blake.; *E. tereticornis* Smith. x *E. grandis* Muell.; *E. tereticornis* Smith. x *E. camaldulensis* Dehnh.; *E. tereticornis* Smith. x *E. alba* Reinw. and *E. tereticornis* Smith. x *E. torelliana* Muelli; *E. urophylla* Blake x *E. grandis* Muell was attempted. One of the major problems encountered in breeding *E. urophylla* is that the flowering coincides with the rainy season (August) leading to flower drop (before and after fertilization). Therefore, *E. urophylla* is considered to be the male donor parent as the pollen is collected in the month of August and is stored and used for pollination in the months from October to January on other Eucalyptus species. Teretigrandis and Urograndis hybrids have adapted well to drought conditions and producing maximum volume of wood. These hybrids are now planted on large scale. Recently, *E. tereticornis* x *E. globulus* and *E. grandis* x *E. globulus* hybrids have been successfully grown in the plots and are under evaluation.

By controlled pollination between the best 32 clones of *E. tereticornis,* the derived full-sib hybrids have shown good heterosis at 2 years age. The full-sib progeny trial showed a maximum of 33 per cent improvement over the parents for production of wood volume. Based on the performance of full-sibs, elite full-sib trees were selected and cloned. Nearly 358 full-sib hybrid trees have been cloned. These hybrid clones have been tested on various sites. Heterobeltioisis studies on 18 hybrid clones showed 82 per cent improvement in wood volume production over the best parent. A few hybrid clones from the crossing of clone 6, 10 & 27 gave hybrid clones 2011, 2014, 2045, 2050, 2052, 2053, 2120, 2121, 2149, 2155 and 2156 which are totally devoid of the defects and surpassed in growth. In addition, some of the clones showed a narrow crown which is required for closer planting at a spacing 3x1.5 m enabling harvesting of trees at 3 to 4 years age.

Improvement for Pulp and Paper quality: As soon as the CPT was selected it was first tested for proximate chemical analysis and strength properties. A few clones have given 52.8 per cent screened yield compared to 42 per cent from seed route plantations (Table 3). Over the last two years much emphasis has been laid on improving the fiber quality by hybridizing clones with the best fibre properties. The best fibre for papermaking is derived from species like *E. globulus, E. grandis, E. deglupta, E. urophylla* etc. Therefore, Teretigrandis and Urograndis hybrids with strength index above 70 have been developed.

Table 3. Pulp and Paper Quality of Eucalyptus Clones

Parameter	Unit	Clone Nos			
		3	**2261**	**643**	**2259**
Screen Yield	%	50	42.4	52.8	45.6
Rejects	%	0.82	3.82	1.16	1.10
Kappa No.		24.2	23.9	22.2	21
UBV		16.9	15.2	20.66	15.5
Bulk	cc/g	1.9	1.8	1.62	1.65
Burst		28	26	44.1	33
Tear		65	60	72	61
Breaking Length	m	4668	4350	5621	4235
Strength Index		40	30	72	36
Ash	%	1.26	0.69	1.79	1.38
AB Extract	%	2.16	2.48	3.79	1.62
Lignin	%	28.5	31.2	28.9	27.1
Holocellulose	%	67.1	62.4	64.1	64.3
Pentosans	%	14.14	14.02	15.79	15.3

No hybridization programme was taken up in case of Leucaena and Casuarina but this programme may start from 2010 onwards.

Clonal Nursery Infrastructure: For a successful clonal forestry programme, a good nursery is a pre-requisite. A modern clonal nursery with an annual production capacity of 20 million Eucalyptus and 20 million Leucaena ramets was established with indigenous technological know-how. Presently, the infrastructure for clonal propagation includes 120 mist chambers covering an area of 12000 m^2, hardening area of 5000 m^2 and 1,00,000 m^2 for open nursery. The Clonal Technology with Root Trainers has given considerable improvement in the production of quality planting stock. The root development is better than seedlings raised in polypots as multiple roots seldom form in the Root Trainers and root coiling is totally avoided. The out planting results were quite high thereby increasing survival and productivity.

Package of practices: Apart from the superior genetic quality of the planting stock, site quality, adaptability of the clones to specific sites, implementation of the improved package of practices and effective protection of plantations from damage by pests, diseases and cattle are also important factors which determine the overall productivity of the plantations. Therefore, the Company developed an improved package of practices for raising and maintenance of clonal Eucalyptus plantations and demonstrated the benefits of the same to the farmers. Study of soil profiles and analysis of soil samples was carried out to match adaptable clones to the planting sites. Deep ploughing of the soil with disk ploughs or mould-board ploughs in both directions is recommended for preparing the fields for transplanting of clonal saplings. Spacing of 3 x 2 m is recommended for the production of poles and pulpwood, and larger spacing is desirable for production of timber. Transplanting in 30 cm^3 pits is carried out during the early parts 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. Application of botanical pesticides like kodesa (*Clistanthus collinus*) for controlling termites was introduced as an eco-friendly replacement to chemical pesticides.

Cultural practices recommended include timely weeding and soil working, protection against damage by insect pests and cattle and raising of leguminous crops in between the 3 m wide planting rows for green manuring. In addition, inter-cultivation with cotton, chili, tobacco, pulses, vegetables, and horticulture plants was encouraged during the first year of planting which gives additional earnings to the farmers. As most of the soils in India are deficient in nitrogen and phosphorous, application of fertilizers to supplement availability of these deficient plant nutrients is recommended. Soil and water conservation measures like raised field boundaries and staggered trenches are recommended in well-drained planting sites for holding the rainwater. However, in low-lying areas or poorly drained heavy black cotton soils, drainage has to be improved during the rainy season.

Of late, new pests *Leptocybe invasa* is causing gall on young shoots of Eucalyptus in nursery and plantations. Psyllid on Eucalyptus is causing little leaf (witches broom) disease. For the above two new pest and diseases on Eucalyptus there is no remedy available.

Clonal Plantations: The Company distributed more than 332 million saplings to growers from 1992 to 2008. Morethan, 80,115 ha of plantations have emerged over a period of 17 years under Farm Forestry programme promoted by ITC, which has created wood asset worth Rs.1827 million (US$ 457 million). These Farm Forestry plantations are acting also as carbon sinks sequestering 12 million tonnes of carbon, reducing 43 million tonnes of Carbon dioxide from the atmosphere. The carbon credit value works out to more than Rs.6880 million (US$ 172 million). These plantations have generated vast employment opportunities (35 million person days) to the rural mass bringing in socio-economic prosperity (Kulkarni, 2008; Paroma Basu, 2009).

Yield Assessment: One hundred plantations were felled in different districts to assess wood production for authenticating the CTA trial results. The farmers obtained the MAI (MT/ha) of 23 in Khammam, 28 in Prakasam, 21 in Guntur, 24 in Krishna and 39 in West Godavari was obtained. The average MAI (MT/ha) works out to 27. Further, the farm forestry plantation average IRR per acre in different districts worked out to 40 in West Godavari, 48 in Khammam, 32 in Prakasam, 26 in Guntur and 30 in Krishna. (Manage Report, 2003)

In India clonal plantations covering 1.25 million hectares of the degraded forest areas can yield 25 million tonnes of pulpwood annually. That would be sufficient for meeting India's entire pulp and paper requirements projected at 8.5 million tonnes by 2010-2011. Likewise, high yielding short rotation clonal plantations on 20 million ha of wastelands / degraded forestlands could meet country's current firewood requirements on a sustainable basis. That would minimize biotic pressures on remaining natural forests and conserve their rich bio-diversity. In addition to restoring marginal lands to high sustainable productivity, clonal plantations will generate vast employment opportunities for the rural poor, contribute to environmental amelioration and help conservation of precious soil and water resources. Such plantations will also create opportunities for significant value addition through local processing of plantation wood and save large amounts of scarce foreign exchange used to import of wood based products. Therefore, clonal forestry can bring in "Brown revolution" in our country.

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