

## Private sector forestry research: a success story from India

The author discusses the success story of development and commercial-scale deployment of high-yielding, fast-growing and disease-resistant eucalyptus and *Casuarina* clones and the promotion of technology-based clonal farm forestry plantations in India.

Piare LAL

### INTRODUCTION

In India, almost the entire recorded 76 million ha forest area is owned and managed by the State Governments. Unfortunately, the forests are under intense biotic pressures, leading to degradation of forest resources. Nearly, 32 million ha of forest area has less than 40% crown cover density (ANON, 1998). This is a great paradox and tragedy for a densely populated country. And yet forest-based industries and the corporate sector continue to be denied participation in the reforestation of degraded forestlands.

The Government provides most of the funds for forestry research to the State Forest Departments and various Forest Research Institutes under the Indian Council of Forestry Research and Education (ICFRE). Legislation for *sui generis* protection of breeder's rights is still pending and no mechanism is currently available for the certification of seed of forestry species, registration of clones or certification of clonal planting stock. The Government also funds agroforestry research undertaken by universities and the Indian Council of Agricultural Research (ICAR).

There are statutory ceilings limiting agricultural landholdings both for individual farmers and the corporate sector to extremely low levels in all states, e.g. up to 22 ha of the worst category of land in Andhra Pradesh (REDDY, REDDY, 1995). It is therefore, not possible for any wood-based industrial unit or private sector company to own adequate land to develop intensively managed technology-based captive plantations. It is no wonder, therefore, that there is very little incentive for private sector investments in forestry research.

A very few NGOs such as Tata Energy Research Institute (TERI), New Delhi, are engaged in research in limited areas related to forestry.

Some of the wood-based integrated pulp and paper mills are promoting farm forestry plantations by supplying eucalyptus, *Casuarina* and *Leucaena* seedlings for pulpwood production. The two well known examples of significant forestry research and promotion of technology-based plantations by the private sector in India are:

- Wimco Seedlings Limited, well known for promotion of poplar (*Populus deltoides* Bartr.) plantations;
- ITC Bhadrachalam Paperboards Limited ("the Company") pioneers in clonal technology research and promotion of large-scale eucalyptus plantations on marginal farmlands owned by farmers (JONES, LAL, 1991; NAIR *et al.*, 1996).

### FARM FORESTRY PLANTATIONS

An integrated pulp and paper mill with 40 000 t/year capacity was established by the Company, at Sarapaka, near the temple town of Bhadrachalam in a remote tribal belt of Khammam District of Andhra Pradesh State during 1979. The geographical location of Bhadrachalam and data on climatic conditions are given in Figure 1 and Table I. The mill presently has a capacity of 65 700 t pulp and 210 000 t high quality paperboards and paper annually. For pulp production, 40 000 t bamboo from Government owned forests and 124 000 t hardwoods from the farm forestry plantations are procured annually. However, the Government has not allocated bamboos since 1997-1998 because of disagreement on the royalty to be charged. The Company is keen to invest in captive industrial plantations to secure future supplies of high quality pulpwood on a cost-effective and sustainable basis to facilitate modernization and expansion of the pulp mill.



Figure 1. Sketch map of India and location of Bhadrachalam where the Company's pulp and paper mill and clonal technology research station are located in Khammam district of Andhra Pradesh State.

*Carte de l'Inde, avec la localisation de Bhadrachalam où sont situées l'usine de fabrication de pâte et de papier appartenant à la compagnie ITC ainsi que la station de recherche sur les biotechnologies, dans le district de Khammam et dans l'État d'Andhra Pradesh.*

**TABLE I**  
**GEOGRAPHICAL LOCATION**  
**OF THE CLONAL TECHNOLOGY**  
**RESEARCH STATION OF ITC**  
**BHADRACHALAM**  
**PAPERBOARDS LIMITED.**

Place	Bhadrachalam
District	Khammam
State	Andhra Pradesh
Latitude	17° 40' N
Longitude	81° 00' E
Altitude	100 m
Average annual rainfall	1 033 mm
Rainy days	57 (June to September)
Average annual temperature	35°C
Maximum temperature	49°C
Minimum temperature	10°C
Type of forest	Dry subtropical forest
Soil types	Red sandy soils, black cotton soils, alluvial soils and red soils

However, it has not been possible for the Company to develop captive industrial plantations because of statutory ceilings on agricultural landholdings and current Government policy of not involving industries in the reforestation of degraded forestlands.

The visionary Company management therefore opted for the only alternative to promote farm forestry plantations on marginal agricultural lands by providing high quality

seedlings, technical extension services and buy-back guarantees at remunerative prices to farmers. From 1987 to 1995, 6 185 farmers in 1 138 villages were assisted to promote 7 441 ha of eucalyptus plantations with 17.4 million seedlings. Unfortunately, genetically improved planting stock of short-rotation pulpwood species like eucalyptus, *Casuarina* and *Leucaena*, which are popular with the farmers, was not available. Therefore, plantations es-

tablished with nursery seedlings from available seed sources showed very high genetic variation and poor productivity, ranging from 6 to 10 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup>.

## CLONAL TECHNOLOGY RESEARCH AND DEVELOPMENT

With a view to improving the productivity and profitability of plantations and making farm forestry an attractive land-use option, the Company has been implementing a major research and development project since 1989, focused on genetic improvement of planting stock and improvement of practices in silvicultural. Major gains in eucalyptus



Figure 2. Gene banks of eucalyptus clones.  
*Banque de gènes d'eucalyptus.*

plantation productivity have been achieved within a short timespan of 11 years through the application of vegetative propagation and cloning techniques for gainful exploitation of existing useful variation. Large-scale commercial plantations based on genetically improved eucalyptus clonal planting stock have been developed in many countries such as Zaire, Brazil and Portugal, with substantial gains in productivity and improvement of wood quality. Productivity of hybrid clones of *E. grandis* Muell. × *E. urophylla* Blake, developed by Aracruz Florestal in Brazil, is around  $55 \text{ m}^3 \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$ . Some new clones developed by Aracruz on ideal sites with intensive management practices have recorded extremely high productivity of  $100 \text{ m}^3 \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$  (BERTOLUCCI *et al.*, 1995). Development and commercial-scale deployment of locality-specific, high-yielding, fast-growing and disease-resistant eucalyptus clones, traditionally propagated through seed, has been successfully achieved for the first time in India by the Company.

The methodology adopted by the Company for the development and commercial-scale deployment of high-yielding and disease-resistant

*Eucalyptus tereticornis* Smith. and *Eucalyptus camaldulensis* Dehnh. clones has been as follows.

- Selection of candidate plus trees (CPTs), with the most desirable phenotypic qualities, such as high volume, large clear and cylindrical bole, dominant height and disease resistance, etc.
- Clonal multiplication of CPTs through rooting of leafy stem cuttings from 50 to 60 days old juvenile coppice shoots treated with 6 000 ppm indole butyric acid under a controlled environment in greenhouses.
- Evaluation of the comparative genetic superiority of resulting clones through replicated field trials and selection of genetically superior high-yielding and disease-resistant clones for commercial multiplication.
- Trials for genotype × environment interaction studies were carried out to identify specific groups of genetically superior clones most adaptable

Volume ( $\text{m}^3/\text{ha}$ )

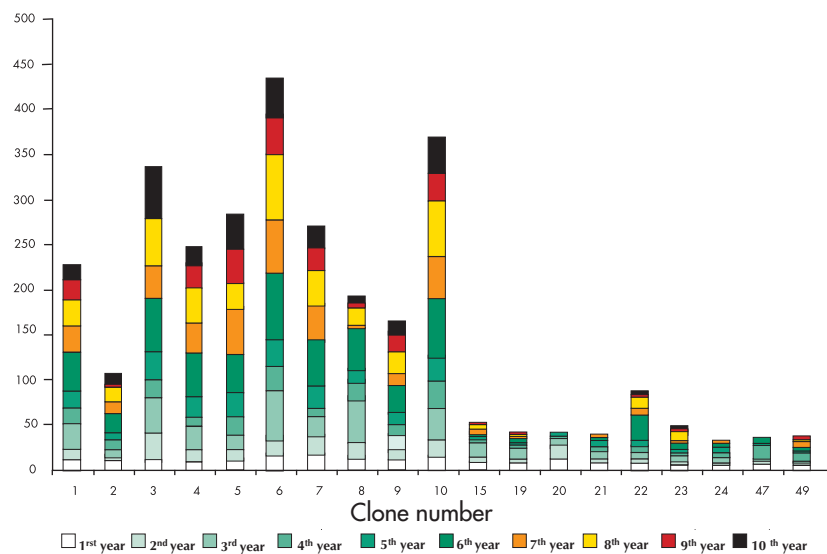


Figure 3. Bar chart showing CAI of various clones in the first clonal testing area (CTA1) from year 1 to year 10.

*Histogramme de l'accroissement annuel cumulé (CAI) pour divers clones d'eucalyptus sur la première zone de tests clonaux (CTA1), de la 1<sup>re</sup> à la 10<sup>e</sup> année.*

to problematic sites, such as alkaline and calcareous black cotton soils.

Clonal demonstration plantations developed by the Company resulted in large-scale adoption of genetically superior Bhadrachalam eucalyptus clones by farmers and State Forest Departments/Forest Development Corporations.

Starting with the cloning of 64 CPTs in 1989, more than 613 CPTs of *E. tereticornis* Smith., *E. camaldulensis* Dehnh. and Mysore gum—a local derived provenance close to *E. tereticornis* Smith. from Karnataka State in India, have been cloned. Progeny of all clones have been planted in gene banks or clonal multiplication areas for production of propagules for future clonal multiplication (Figure 2). The area covered by gene banks had increased to 17 ha by end of 1999. Replicated field trials for the evaluation of comparative genetic superiority for the selection of superior commercial clones have been set up. Clonal test plots have been planted since 1989, covering 20 ha area at 82 different locations. Comparative growth data on various clones, in three clonal testing areas, is given in Tables II to IV and Figures 3 to 5.

Based on the performance of individual clones in the field trials, 89 promising, fast-growing and disease-resistant clones have been identified. These clones are known as Bhadrachalam clones, with productivity ranging from 12 to 58 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup> under nonirrigated conditions, compared to 6 to 10 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup> productivity from normal seedling origin plantations. Further research work to identify still better clones is continuing. Two plots of clonal seed orchards covering 1 ha have been planted with the best Bhadrachalam clones for production of genetically improved seed.

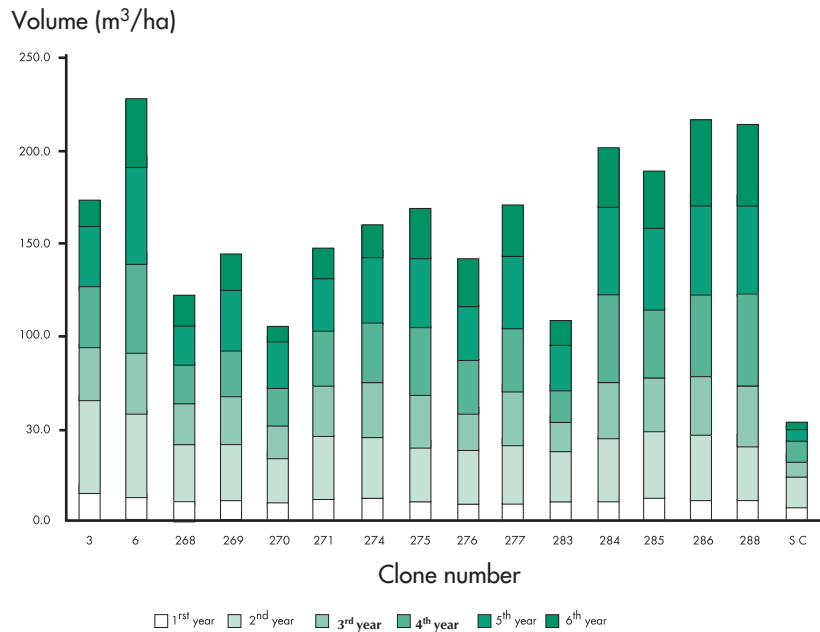


Figure 4. Bar chart showing CAI of various clones in CTA 21 from year 1 to year 6. *Histogramme de l'accroissement annuel cumulé (CAI) pour divers clones d'eucalyptus sur la zone de tests clonaux (CTA21), de la 1<sup>re</sup> à la 6<sup>e</sup> année.*

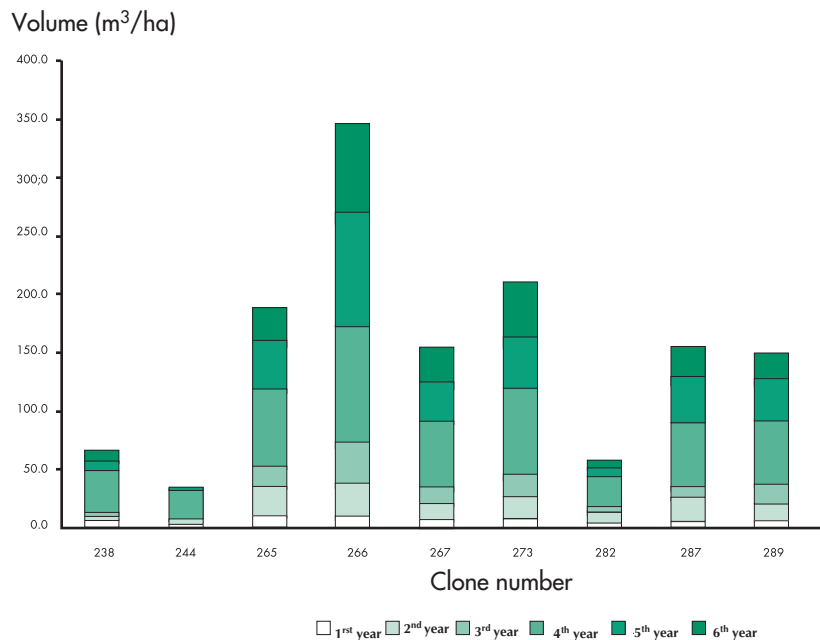


Figure 5. Bar chart showing CAI of various clones in CTA 23 from year 1 to year 6. *Histogramme de l'accroissement annuel cumulé (CAI) pour divers clones d'eucalyptus sur la zone de tests clonaux (CTA 23), de la 1<sup>re</sup> à la 6<sup>e</sup> année.*

**TABLE II**  
**YEAR-WISE GROWTH DATA FOR CURRENT ANNUAL INCREMENT (CAI) AND MEAN ANNUAL INCREMENT (MAI),**  
**CLONAL TESTING AREA 1 LOCATED AT BHADRACHALAM.**

SI N°	Clone N°	Current annual increment under bark (m <sup>3</sup> /ha/year)									Mean annual increment under bark (m <sup>3</sup> /ha/year)									10 <sup>th</sup> year data				
		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	GBH (cm)	HT (m)	CAI	MAI	Survival (%)
1	6	12	27	47	29	75	48	75	35	12	20	29	29	29	29	36	39	44	43	58	27	46	43	100
2	10	10	18	38	32	69	45	65	28	10	14	22	25	24	24	32	34	38	37	56	26	40	37	96
3	3	12	18	48	24	62	34	55	22	12	15	26	26	26	26	32	32	35	34	55	25	33	33	96
4	5	6	10	20	17	49	45	41	38	6	8	12	13	14	20	23	26	27	100	50	23	39	28	100
5	7	10	15	32	11	22	55	35	43	10	13	19	17	18	24	26	28	27	89	50	25	25	27	89
6	4	7	13	26	12	21	50	32	41	7	10	15	14	16	22	23	25	25	96	47	25	22	25	96
7	1	9	13	28	17	16	45	30	31	9	11	16	17	16	21	22	24	23	81	49	24	20	22	81
8	8	9	22	44	21	12	52	21	6	9	16	25	24	22	27	22	22	20	74	48	25	7	19	74
9	9	9	12	19	10	9	30	14	27	9	11	13	12	12	15	15	16	17	90	43	20	15	16	90
10	2	6	5	4	10	7	8	18	5	6	6	7	8	8	10	10	11	11	100	35	18	9	10	100
11	22	5	4	10	7	8	18	8	16	5	4	6	6	7	9	8	9	9	93	36	15	8	9	93
12	15	6	6	10	5	12	10	7	7	6	6	7	7	6	7	6	6	5	90	28	14	1	5	90
13	23	5	2	8	3	10	2	9	6	5	3	5	4	4	5	5	5	5	100	27	13	2	5	100
14	19	5	3	6	6	7	3	5	2	5	4	5	5	4	5	5	5	4	85	26	13	1	4	85
15	21	6	5	10	2	8	2	4	4	6	5	7	6	5	6	5	5	4	81	25	13	3	3	81
16	24	5	2	6	2	7	4	5	5	5	4	4	4	3	4	4	4	3	81	24	13	3	3	81
17	49	6	5	7	2	4	9	6	6	6	5	6	5	5	5	5	5	3	81	25	13	3	3	81
18	47	7	8	12	3	6	6	6	6	7	7	9	7	7	7	7	7	5	81	25	13	3	3	81
19	20	10	15	8	4	5	10	13	11	10	13	11	9	8	8	8	8	8	90	40	19	19	17	90
Mean		8	11	20	11	12	34	23	28	17	8	9	13	12	16	17	18	17		40	19	19	17	90
S.D. +/-		2	7	15	9	9	24	19	23	12	2	5	8	8	11	12	13	13		13	6	16	13	8
C.V.		31	68	73	83	78	70	82	82	71	31	52	61	65	66	67	71	72		31	29	81	77	9

Notes

1. Volume in cubic meters (without bark) calculated based on regression equation  $V = 0.00258 + 0.0281 \text{ (GBH)}$
2. Data arranged in descending order of MAI as per last assessment
3. Spacing  $3 \times 2 \text{ m}$
4. Number of saplings planted per treatment is 9 with 3 replications
5. Species: *Eucalyptus tereticornis* clone numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
6. Mysore gun clone numbers 15, 19, 20, 21, 22, 23, 24, 47, 49
7. Clone numbers 47 and 20 were highly diseased and were uprooted during the 6th year
8. Shortlisted promising Bhadrachalam clones numbers 1, 3, 4, 5, 6, 7, 8, 10
8. Blank spaces in 7, 8, 9 & 10 years CAI column explain the non-increment during those years.

Abbreviations

- CAI : current annual increment/ha in cubic meters under bark
- MAI : mean annual increment/ha in cubic meters under bark
- GBH: girth at breast height in cm
- HT: height in meters
- VOI/HA : volume per hectare in cubic meters under bark
- UB: under bark



**TABLE III**  
**YEAR-WISE GROWTH DATA FOR CURRENT ANNUAL INCREMENT (CAI) AND MEAN ANNUAL INCREMENT (MAI), CLONAL TESTING AREA 21 LOCATED AT BHADRACHALAM.**

		Current annual increment under bark (m <sup>3</sup> /ha/year)					Mean annual increment under bark (m <sup>3</sup> /ha/year)					6 <sup>th</sup> year data				
SI N°	Clone N°	1	2	3	4	5	1	2	3	4	5	GBH (cm)	HT (m)	CAI	MAI	Survival (%)
1	6	14	44	33	47	51	14	29	30	34	38	53	18	38.1	37.8	93
2	286	11	35	31	44	49	11	23	26	30	34	50	18	45.1	35.9	100
3	288	11	30	32	50	49	11	20	24	31	34	50	18	40.8	35.3	100
4	284	11	35	28	48	45	11	23	25	31	33	48	18	33.2	33.4	100
5	285	13	35	28	38	44	13	24	26	29	32	48	17	20.7	31.3	100
6	3	20	46	26	35	29	20	33	31	32	31	45	18	16.8	28.8	100
7	277	10	32	28	34	39	10	21	23	26	29	47	15	26.7	28.3	100
8	275	10	29	28	38	36	10	20	23	26	28	45	17	26.4	28.1	100
9	274	13	34	27	32	35	13	23	25	27	28	44	17	18.1	26.5	100
10	271	13	34	25	32	26	13	23	24	26	26	43	17	17.3	24.5	96
11	269	11	32	23	25	29	11	21	22	23	24	43	16	22.1	23.8	100
12	276	9	30	18	30	30	9	19	19	22	23	43	16	23.9	23.5	96
13	268	11	29	23	22	22	11	20	21	21	21	40	16	14.8	20.3	96
14	283	10	27	16	18	24	10	19	18	18	19	38	15	11.7	17.9	100
15	270	10	24	18	22	21	10	17	17	18	19	37	15	10.8	17.5	100
16	SC	7	15	9	12	7	7	11	10	11	10	31	13	3.2	8.9	85
Mean		12	32	25	33	34	12	22	23	25	27	44	16	24	26	98
S.D. +/-		3	7	6	11	12	3	5	5	6	7	5	2	12	8	4
C.V.		23	23	26	34	36	23	22	22	25	27	12	9	49	29	4

## Notes

1. Volume in cubic meters (without bark) calculated based on regression equation  $V = 0.00258 + 0.0281 (GBH)$
2. Data arranged in descending order of MAI as per last assessment
3. Spacing 3 × 2 m
4. Number of saplings planted per treatment is 9 with 3 replications

5. Species: *Eucalyptus tereticornis* clone numbers 3, 6, 269, 270, 271, 274, 268, 275, 276, 277, 283, 284, 285, 286, 288
6. Shortlisted promising Bhadrachalam clones numbers 288, 286, 284, 285, 277, 275, 274, 271, 269, 276, 268
7. Soil type is red soil

## Abbreviations

- CAI: current annual increment/ha in cubic meters under bark  
 MAI: mean annual increment/ha in cubic meters under bark  
 GBH: girth at breast height in cm  
 HT: height in meters  
 SC: seedlings control treatment  
 VOL/HA: volume per hectare in cubic meters under bark  
 UB: under bark

## CURRENT RESEARCH AND DEVELOPMENT FOCUS

Vegetative propagation and cloning techniques tap the full productivity potential of superior genotypes. However, no further enhancement of productivity or improvement of the genetic qualities of selected clones is possible through vegetative

propagation, which replicates genotypes. In order to develop still better clones than the best presently available and to widen the genetic base of clonal plantations, the following research and development priorities have been identified and are being implemented.

- Selection of additional candidate plus trees for cloning and field evaluation continues as a regular feature of the strategy for the development

and deployment of new superior clones—to widen the genetic base of clonal eucalyptus plantations and safeguard against future risk of epidemic pests and diseases.

- Field testing and selection of highly productive site-specific clones for refractory sites, including saline and alkaline soils, through genotype × environment interaction studies is a high priority research focus. Sixteen out of 89 selected Bhadrachalam

**TABLE IV**  
YEAR-WISE GROWTH DATA FOR CURRENT ANNUAL INCREMENT (CAI) AND MEAN ANNUAL INCREMENT (MAI), CLONAL TESTING AREA 23 LOCATED AT BHADRACHALAM.

SI N°	Clone N°	Current annual increment under bark (m <sup>3</sup> /ha/year)					Mean annual increment under bark (m <sup>3</sup> /ha/year)					6 <sup>th</sup> year data				
		1	2	Year			1	2	Year			GBH (cm)	HT (m)	CAI	MAI	Survival (%)
1	266	10	34	29	100	94	10	22	24	43	53	61	19	80	58	93
2	273	9	20	17	75	45	9	15	15	30	33	47	18	45	35	93
3	265	11	25	16	68	38	11	18	17	30	32	49	18	30	31	80
4	287	6	21	9	57	36	6	13	12	23	26	44	17	27	26	80
5	267	8	15	12	58	35	8	11	12	23	26	44	17	27	26	80
6	289	8	18	13	57	34	8	13	13	24	26	44	15	23	25	80
7	238	5	4	3	37	8	5	4	4	12	11	25	11	9	11	80
8	282	5	8	5	28	5	5	7	6	12	10	30	11	8	10	80
9	244	3	2	1	26	1	3	3	2	8	7	15	6	0	3	40
Mean		7	16	12	56	33	7	12	12	23	25	40	15	28	25	76
S.D. +/-		3	10	9	24	28	3	6	7	11	14	14	4	24	16	17
C.V.		36	62	74	42	86	36	54	60	49	58	35	29	86	65	22

## Notes

- Volume in cubic meters (without bark) calculated based on regression equation  $V = 0.00258 + 0.0281 (\text{GBH})$
- Data arranged in descending order of MAI as per last assessment
- Spacing 3 × 2 m
- Number of saplings planted per treatment is 9 with 3 replications

- Species: *Eucalyptus tereticornis* clone numbers 244, 265, 266, 267, 273, 282, 287, 289
- Mysore gum clone number 238
- Shortlisted promising Bhadrachalam clones numbers 266, 273, 265, 289, 267, 287
- Soil type is red soil

## Abbreviations

- CAI: current annual increment/ha in cubic meters under bark  
 MAI: mean annual increment/ha in cubic meters under bark  
 GBH: girth at breast height in cm  
 HT: height in meters  
 VOL/HA: volume per hectare in cubic meters under bark  
 UB: under bark

clones have already demonstrated good tolerance to calcareous/alkaline soils with fairly high productivity.

- Development of intra-specific hybrids through control-pollination between the best Bhadrachalam clones of *E. tereticornis* Smith and inter-specific hybrids through control-pollination of these clones with CPTs of appropriate eucalyptus species and their reciprocal crosses. F<sub>1</sub> hybrids showing good heterosis have been cloned for field evaluation (Figure 6).

- Development of clonal seed orchards for the production of improved genetically superior seed for future seed-based plantations and selection of CPTs from such planta-



Figure 6. Hybrid clone n° 2128 (centre) with male parent clone n° 6 (left) and female parent clone n° 122 (right) of *E. tereticornis* (Smith).  
 Clone hybride n° 2128 (au centre) obtenu du croisement du parent mâle clone n° 6 (à gauche) avec le parent femelle clone n° 122 (à droite) de *E. tereticornis* (Smith).



Figure 7. Hybrid clone n° 2 069 under field evaluation at Bhadrachalam. Age 10 months.

Clone hybride n° 2 069 âgé de 10 mois évalué au champ à Bhadrachalam (État d'Andhra Pradesh).

tions for the development of new future clones.

- Further improvement of technical practices for field plantations and clonal nurseries.

Several intra-specific hybrids have been developed through controlled pollination between selected best Bhadrachalam clones of *E. tereticornis* Smith. Development of inter-specific hybrids such as *E. tereticornis* Smith. × *E. urophylla* Blake.; *E. tereticornis* Smith. × *E. grandis* Muell.; *E. tereticornis* Smith. × *E. camaldulensis* Dehnh.; and *E. tereticornis* Smith. × *E. alba* Reinw. is progressing well (LAL *et al.*, 1997). Some control-pollinated hybrids have shown good heterosis at 1 to 2 years of age, and such plants have been cloned for field trials to select superior hybrid clones for commercial-scale multiplication for future plantations. Nearly 157 hybrid clones are presently under field evaluation (Figure 7).

*Casuarina* is a popular species for farm forestry plantations on coastal sandy soils. Commercial-scale clonal plantations based on genetically

superior *Casuarina* clones are being developed in some countries such as China and Thailand (BOLAND *et al.*, 1996; KHA, 1996). Encouraged by the success of Bhadrachalam eucalyptus clones, similar research work for the development and deployment of genetically superior *Casuarina* clones has been making



Figure 8. Gene banks of *Casuarina equisetifolia* Forst.  
Banque de gènes de *Casuarina equisetifolia* Forst.

rapid progress since 1994. More than 175 *Casuarina* CPTs have been successfully cloned and gene banks have been established. Field trials are under way for the evaluation of the comparative genetic superiority of these clones, with a view to selecting disease-resistant clones with high productivity (LAL *et al.*, 1996). Based on field trials, 10 *Casuarina* clones with a productivity range of 8.6 to 13.9 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup> have been selected to supply farmers with clonal planting stock (Figure 8).

## IMPROVEMENT OF NURSERY PRACTICES

Eucalyptus and *Casuarina* clonal planting stock is being grown in modern nurseries using vermiculite as growing medium. Moulded plastic trays with 20 to 40 built-in cavities are used as containers for growing clonal nursery plants (Figure 9). There are vertical ribs inside each of the container cavities to prevent root coiling. These containers are supported on suitable benches in the





Figure 9. Clonal saplings in moulded plastic trays in the open nursery with greenhouses in the background.

*Jeunes arbres clonaux dans des emballages en plastique moulé dans la nurserie à l'air libre. En arrière-plan, la serre.*

nurseries to facilitate self-pruning of roots, good aeration, easy handling and sprinkler irrigation. These containers also facilitate multi-tier loading arrangements in trucks for transport of clonal planting stock for cost-effective delivery to farmers' fields.

Improved practices for ensuring the best possible results with respect to rooting of cuttings in greenhouses under controlled environment, and subsequent maintenance and nursing of plants in shadehouses and open nurseries have been standardized through intensive research. Schedules for fertilizer and micronutrient applications have been refined and perfected for large-scale commercial production of clonal planting stock. Prophylactic and control measures against common leaf-spot disease of eucalyptus at the nursery stage have been identified. Bavistin was found to be the most effective product for controlling *Cylindrocladium* spp. and Dithane M-45 as well as Blitox are quite effective against leaf-blight disease.

## IMPROVED PRACTICES

Apart from the superior genetic quality of the planting stock, site

land quality, clone adaptability to specific sites, implementation of improved practices and effective protection of plantations from damage by pests, diseases and cattle are important factors which determine the overall productivity of plantations. Therefore, the Company developed improved silvicultural practices for the development and maintenance of clonal eucalyptus plantations and demonstrated their benefits to farmers (Figure 10). Studies of soil profiles and analysis of soil samples were 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 to prepare fields for transplanting of clonal saplings. Plant spacing of 3 × 2 m is recommended for the production of poles and pulpwood, and wider spacing is desirable for timber production from clonal eucalyptus plantations. Transplanting in 30 × 30 × 30 cm pits is carried out during the early parts of the monsoon rains so that plants will be established and grow well, benefiting



Figure 10. Clonal demonstration plantation at Cherupally village, Khammam district. Clone n° 7 and 10. *E. tereticornis* Smith age 4 years.

*Plantation clonale de démonstration au village de Cherupally, district de Khammam. Clones n° 7 et 10 d'*E. tereticornis* Smith âgés de 4 ans.*

from the good moisture availability throughout the monsoon rains. Soil in and around the planting pit is treated with 2 ml of Chloropyrifos diluted in 1 l of water to prevent termite damage to young clonal saplings 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 crops between the 3-m wide planting rows for green manuring. As most soils in India are deficient in nitrogen and phosphorus, application of supplement fertilizers is recommended. Soil and water conservation measures such as raised field boundaries and staggered trenches are recommended in well-drained planting sites to retain rainwater. In low lying areas or poorly drained heavy black cotton soils, drainage has to be improved during the rainy season.

## APPLICATION AND TRANSFER OF RESEARCH FINDINGS

Planting stock of selected Bhadrachalam clones was supplied to Forest Development Corporations/Forest Departments of many states and Forest Research Institutes in India to enable them to plant clonal seed orchards and maintain their own gene banks for future multiplication of these clones. The Andhra Pradesh Forest Development Corporation (APFDC) is implementing a World Bank funded Industrial Plantations Project to reforest degraded forest lands with Bhadrachalam clones of eucalyptus. More than 7 000 ha of clonal eucalyptus plantations had already been established successfully by APFDC by 1999.

Clonal planting stock of Bhadrachalam eucalyptus clones was supplied to Forest Departments/Forest Development Corporations of Tamil

Nadu, Kerala, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Uttar Pradesh, Orissa, West Bengal and Haryana states of India. Likewise, Bhadrachalam clones have been supplied to the Institute of Forest Genetics and Tree Breeding, Coimbatore, Institute of Wood Sciences and Technology, Bangalore, Kerala Forest Research Institute, Peechi, State Forest Research Institute, Jabalapur, many wood based industrial units and NGOs.

Clonal saplings of 42 of the best clones, with productivity of 20 to 58 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup> under nonirrigated conditions are being supplied to farmers for developing clonal farm forestry plantations with technical extension services and buy-back guarantees provided by the Company. Two Clonal Demonstration Plantations (CDPs) were established in August 1991, based on five short-listed clones with outstanding performance in the first clonal testing area (CTA), planted in September 1989 at 2 years of age. Eight additional CDPs have been established in three districts of Andhra Pradesh, covering 24 ha area.

Clonal planting stock of the most promising Bhadrachalam clones was released to farmers on a selective basis from 1992 onwards. As "seeing is believing" for farmers, these demonstration plantations and successful extension campaigns by the field staff of the Company have been instrumental in large-scale acceptance and adoption of Bhadrachalam clones for farm forestry plantations and reforestation projects.

Ever growing demand for planting stock of Bhadrachalam clones is a testimony of their popularity and genetic superiority. The present production capacity is 3 million clonal saplings per year. The current selling price is 8 Indian rupees/plant or US\$ 18/100 plants.

Eucalyptus clonal plantations promoted by the Company between 1992-1999 benefitted 1914 farmers who planted 5.64 million saplings on 3 217 ha (Figures 11 to 13). In addition, 1.64 million saplings of Bhadrachalam clones were supplied to State Forest Departments/Forest Development Corporations during the 1992-1999 period, which now form the basis of clonal eucalyptus plantations in those states (LAL *et al.*, 1997).

Yearwise details of clonal saplings supplied for farm forestry plantations and Forest Department/Corporations since 1992 are given in Table V.

Findings of clonal technology research and experience gained in the promotion of clonal eucalyptus plantations have been published by the Company's scientists in the form



Figure 11. Clonal farm forestry plantation in Nallaturu village, Prakasam district, Bhadrachalam. Clone n° 27 *E. tereticornis* Smith age 2 years. *Plantation forestière clonale chez un exploitant dans le village de Nallaturu, district de Prakasam. Clone Bhadrachalam n° 27 d'*E. tereticornis* Smith âgé de 2 ans.*





Figure 12. Clonal farm forestry plantation in Venagamukkapalem village, Prakasam district. Bhadrachalam clone n° 7 *E. tereticornis* Smith age 5 years.  
*Plantation forestière clonale chez un exploitant dans le village de Venagamukkapalem, district de Prakasam. Clone Bhadrachalam n° 7 d'E. tereticornis Smith âgé de 5 ans.*



Figure 13. Clonal farm forestry plantation in Boyapalem village, Guntur district, Bhadrachalam. Clone n° 7 *E. tereticornis* Smith age 4 years.  
*Plantation forestière clonale chez un exploitant dans le village de Boyapalem, district de Guntur. Clone Bhadrachalam n° 7 d'E. tereticornis Smith âgé de 5 ans.*

**TABLE V**  
**YEAR-WISE DETAILS OF CLONAL SAPPLINGS SUPPLIED TO FARMERS FOR FARM FORESTRY PLANTATIONS AND TO STATE FOREST DEPARTMENTS/FOREST CORPORATIONS.**

Year	Clonal plants (millions)	Area planted (ha)
1992-93	0.03	17
1993-94	0.06	40
1994-95	0.23	161
1995-96	0.42	239
1996-97	1.02	791
1997-98	1.29	759
1998-99	2.07	1 204
1999-2000	2.17	1 356
Total	7.29	4 567

of research papers in the journal *Indian Forester*, and papers presented in various national and international seminars/conferences. Printed copies of the improved practices for clonal plantations have also been supplied to the Forest Departments and farmers developing clonal plantations.

## RESEARCH COORDINATION AND LINKAGES

After the visit of top executives of the Company to Aracruz in Brazil in 1987, the Company solicited transfer of technology and consultancy services from Aracruz Florestal S.A. and some renowned international consultants. However, the arrangements could not be finalized because of the exorbitant price tag, which the Company just could not afford. The Company thus decided to be self-reliant and make earnest efforts to succeed through in-house efforts. A separate Plantation Department was created and Vice President-Plantations with supporting research and extension managers were recruited in 1989.

Collaborative arrangements, initially for 2 years, were finalized with Tata Energy Research Institute (TERI), and then extended for another 4-year term. It was a learning process for both organizations. The vast experience of Mr. A. N. CHATURVEDI, a retired and well-known forester, and Mr. Sujan SINGH, plant pathologist of TERI, was of immense help. Initial selection of candidate plus trees was carried out jointly by the Company scientists and Mr. A. N. CHATURVEDI. Mr. Sujan SINGH provided very useful help in the identification of fungal pathogens and finding appropriate preventive and control measures against these pests at the greenhouse and open nursery stages, as well as field plantations. Even now, need-based assistance, in areas such as plant pathology, entomology and soil science, etc., is sought from scientists of Agricultural Universities and Forest Research Institutes.

The pioneering and painstaking efforts of the Company for the development and deployment of genetically superior eucalyptus clones would not have been successful but

for the generous help provided by APFDC and the farmers of Andhra Pradesh. They were kind to permit the Company scientists to select CPTs for cloning from their seed-based eucalyptus plantations. As the Company did not have any breeding populations or extensive plantations, CPTs selected from APFDC and farmer's plantations contributed to the vital foundations of the Company's clonal technology research and development programme. Later, some clones were also received on an exchange basis from the Institute of Forest Genetics and Tree Breeding and from Wimco Seedlings Limited, Rudrapur, Uttar Pradesh for trials in Andhra Pradesh. Unfortunately, none of the clones received from these two sources performed well enough to qualify for large-scale commercial multiplication.

The Company also recently finalized arrangements with Mysore Paper Mills Limited for collaboration regarding domestication of CPTs from their extensive *E. camaldulensis* Dehnh. plantations for cloning and field evaluation. It will be extremely useful if all State Forest Departments with large-scale eucalyptus and *Casuarina* plantations could join hands to select CPTs for cloning and planting of multi-locational trials in all States for simultaneous field evaluation of clones. Simultaneously, shortlisted Bhadrachalam clones and all new clones to be developed as above, can be planted on problematic sites such as saline/alkaline and other refractory sites to study genotype  $\times$  environmental interactions to select promising future clones most adapted to each specific site in various states promoting eucalyptus plantations.

The Company has also announced a policy decision concerning their willingness to supply genetically improved clonal planting stock of

Bhadrachalam clones to any wood-based industrial unit in the country, all State Forest Departments and research institutes.

The Company is also willing to provide technical consultancy services for transfer of clonal technology to any organization in the public or private sector on a mutually agreed basis. In fact, the Company has already provided technical support as local consultants to the Forest Development Corporation of Maharashtra to upgrade root trainer nurseries and clonal technology under a World Bank-supported Forestry Development Project.

Collaborative research is of considerable interest because of the tremendous cost savings through minimizing duplication of equipment, manpower and expenses on repetitive research. Likewise, there is great benefit in terms of saving valuable time and developmental costs by arranging transfer of already developed technology, which may suit the requirements of other interested clients. For example, the Company is keen to collaborate with any reputed research laboratory for collaborative research with respect to molecular marker techniques and DNA fingerprinting of Bhadrachalam clones, with a view to developing suitable techniques for the early identification of future promising and genetically superior clones. The Company is in touch with the Centre for Cellular and Molecular Biology, Hyderabad, Andhra Pradesh, for developing DNA fingerprinting protocols for eucalyptus.

The Company is keen to develop links for mutual cooperation with other research institutes. The Company is a member of the Asia Pacific Association of Forestry Research Institutions (APAFRI) and International Union of Forestry Research Organizations (IUFRO). Unfortunately, there are administrative and procedural difficulties for developing meaning-

ful collaborative research programmes between the private sector and public-funded research institutes of ICFRE and ICAR. These constraints must be overcome in the best national interests. Forestry research in government sector institutions suffers from incessantly frequent changes in personnel and research priorities, lack of accountability and procedural delays. The private sector has been able to address most of these negative bottlenecks and achieve extremely successful results in a short timespan at minimum cost.

However, this project has been implemented under the following major constraints:

- inadequate genetic resources;
- absence of breeding populations;
- non-availability of adequate land for field trials;
- shortage of sophisticated equipment;
- limited staff and shoestring budgets for research and development.

Without these constraints, the achievements would have been far more commendable and faster.

## RESEARCH FUNDING AND EXTENSION COSTS

All clonal technology research and farm forestry extension programmes are funded internally by the Company. The proceeds of selling clonal planting stock until 1996-1997 met only part of the production, research and development, staff and administration, depreciation and the interest costs. However, the Company continued to support this activity, which is vital for securing future pulpwood supplies.

During the 1986-1987 to 1997-1998 period, the Company spent US\$ 0.71 million (Rs. 31.9 million) on the promotion of farm forestry



plantations and providing technical extension services. Likewise, during the 1989-1990 to 1997-1998 period, the Company spent US\$ 0.64 million (Rs. 28.8 million) towards operating expenses and administration costs for clonal technology research, development and production of clonal planting stock. Capital expenditure incurred during the 1989-1990 to 1997-1998 period, mainly for greenhouses, shadehouses, modern root trainer nurseries, lab equipment and vehicles, etc., was US\$ 0.33 million (Rs. 15 million). A sum of US\$ 0.52 million (Rs. 23.6 million) was recovered from the sale of seedlings and clonal planting stock up to 1997-1998. (Current exchange rate of Rs. 45 = US\$ 1 was applied).

The demand for clonal planting stock is growing very fast and the production capacity was expanded to 3 million clonal saplings per year during 1998-1999. Research and development expenses and fixed overhead costs will be spread over larger volumes. The Plantation Department is now self-sufficient in funds through sales of clonal planting stock, achieving net profits since 1997-1998. Profits generated by this activity over the last 3 years, up to March 2000, amount to US\$ 0.38 million (Rs. 17.10 million). Simultaneously, the primary objective of securing future pulpwood supplies through clonal farm forestry plantations has been successfully met.

## PLANTATION DEPARTMENT ORGANIZATION

The Plantation Department of the Company, headed by the Vice President-Plantations, has complete freedom to decide on research priorities, technical issues and implement research and clonal produc-

tion and marketing plans subject to the approval of financial expenses by the Managing Director. Vice President-Plantations is assisted by Chief Manager-Plantations Research and Clonal Plant Production, supported by eight managers. Likewise, Chief Manager-Plantations, supported by twelve managers, assists the Vice President-Plantations in farm forestry extension, promotion of technology-based plantations and marketing of clonal planting stock. Four managers provide secretarial and office support services.

Key factors leading to the emergence of the Company as a respected pioneer in the field of clonal technology and technology-based clonal plantations in India have been:

- extremely well-defined research objectives;
- competent and committed scientific personnel;
- continuity of research plans and personnel;
- adequate delegation with accountability;
- wholehearted support at the upper level of the Company.

Company's efforts and contributions for promoting forestry research and clonal farm forestry plantations have been recognized with four prestigious awards:

- Indira Priyadarshini Vrikshamitra Award-1997 from the Ministry of Environment and Forests, Government of India;
- Rajiv Gandhi Parti Bhoomi Mitra Award-1994-1996, from the Ministry of Rural Areas and Employment, Government of India;
- The Vantech Industry Rolling Trophy for Research and Development-1995, Award from the Confederation of Indian Industry, Southern Region;

- FAPCCI Award for "The Best Technological Development in Research and Development for 1991-1992" from the Federation of Andhra Pradesh Chambers of Commerce and Industry.

Company scientists have been associated with technical consultancy assignments for World Bank-supported Forestry Development Projects in Maharashtra State and evaluation of Forestry Development Project in Madhya Pradesh State.

## CONTRIBUTION OF CLONAL TECHNOLOGY RESEARCH

Extremely fast-growing, high-yield and disease-resistant eucalyptus clones have been developed for the first time in India by the Company. The productivity of Bhadrachalam eucalyptus clones is 3- to 4-times higher than the productivity of normal seed-based plantations. Clonal eucalyptus plantations, promoted by the Company, are the first successful examples in India of commercial-scale clonal plantations of any forestry species traditionally propagated through seedlings. More than 1 900 farmers have benefited and a large number of Forest Departments/Forest Development Corporations in many states have already planted these clones.

Clonal plantations covering 1.25 million ha, or 33% of the degraded forest areas in Andhra Pradesh alone, could yield 25 million t of pulpwood annually. That would be sufficient to meet India's entire pulp and paper requirements, forecast at 8.5 million t by 2010-2011, based on 70% wood-based fibre furnish. Likewise, high-yield short-rotation clonal plantations on 20 million ha wastelands/degraded forest lands can meet the country's current firewood requirements on a sustainable

basis. This would minimize biotic pressures on remaining natural forests and conserve their rich biodiversity. In addition to the restoration of marginal lands to achieve high sustainable productivity, clonal plantations will generate vast employment opportunities for the rural poor, contribute to environmental improvement and promote conservation of precious soil and water resources. Such plantations will also create opportunities for significant added value through local processing of plantation wood, while saving large amounts of scarce foreign currency expended for importing wood-based products.

The Company has now released 10 genetically improved *Casuarina* clones for commercial-scale farm forestry and reforestation projects. Immense gains in productivity and

improvement of produce quality are possible through the application of similar cloning techniques for many important indigenous species amenable to vegetative propagation, e.g. *Tectona grandis* Linn., *Gmelina arborea* Linn., *Pinus roxburghii* Sarg., *Dalbergia sissoo* Roxb., *Anthocephalus chinensis* Lam. and Dipterocarps etc. Unfortunately, forestry research organizations of the State Forest Departments and ICFRE institutions have not accorded richly deserved high research priority for the development and large-scale deployment of genetically improved clones of important indigenous species. No wonder the country pays a very high price for continuing large-scale use of nonimproved seed for most tree species in the farm forestry and reforestation programmes.

**Acknowledgements:** The author conveys sincere and grateful thanks to his dedicated research and extension team for their untiring efforts, and the present and past Managing Directors and Chairmen of the Company for their support and encouragement, without which this success story would not have been possible. I also express my sincere gratitude to all the farmers and State Forest Departments/Forest Development Corporations who have adopted Bhadrachalam clones. Grateful thanks to Ms. Lorraine White for her competent secretarial support for completing this paper.

► Piare LAL  
ITC Bhadrachalam Paperboards Limited  
106, Sardar Patel Road  
SECUNDERABAD 500 003  
Andhra Pradesh  
India

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## R É S U M É

## LA RECHERCHE FORESTIÈRE DANS LE SECTEUR PRIVÉ : LE RÉCIT D'UNE RÉUSSITE EN INDE

La quasi-totalité des 76 millions d'hectares de la surface forestière recensée en Inde appartiennent aux États qui les gèrent. Il n'est donc pas étonnant que le secteur privé soit peu motivé pour investir dans la recherche forestière. Cependant, une société papetière, ITC Bhadrachalam Paperboards Limited, a mené avec succès un projet majeur engagé en 1989 pour améliorer la productivité et la rentabilité des plantations et pour rendre attractives les exploitations forestières. Dans les plantations commerciales et sans irrigation, la productivité des clones se situe entre 20 et 58 m<sup>3</sup>.ha<sup>-1</sup>.an<sup>-1</sup>, alors que la productivité des plantations d'eucalyptus obtenues à partir de semences est de l'ordre de 6 à 10 m<sup>3</sup>.ha<sup>-1</sup>.an<sup>-1</sup>. Plusieurs hybrides intra- et interspécifiques d'eucalyptus ont été produits par une pollinisation contrôlée. Les hybrides F<sub>1</sub> intéressants ont été clonés et ces clones sont en cours d'évaluation au champ. Des recherches comparables ont débuté, en 1994, pour la production de clones d'élite de *Casuarina*. La diffusion de clones d'élite a permis, rapidement et à grande échelle, de mettre en place des plantations clonales d'eucalyptus. Entre 1992 et 1994, 7,3 millions de jeunes arbres clonaux ont été fournis aux exploitants et aux départements forestiers pour couvrir 4 567 ha. La capacité actuelle de production est de 3 millions de jeunes arbres par an.

**Mots-clés :** eucalyptus, *Casuarina*, clone, génotype, productivité.

## A B S T R A C T

## PRIVATE SECTOR FORESTRY RESEARCH: A SUCCESS STORY FROM INDIA

In India, almost the entire recorded 76 million ha forest area is owned and managed by the State Governments. It is no wonder, therefore, that there is little incentive for private sector investments in forestry research. ITC Bhadrachalam Paperboards Limited has successfully implemented a major research and development project since 1989 with a view to improving the productivity and profitability of plantations and making farm forestry an attractive land-use option. The productivity of these clones, released for commercial plantations, ranges from 20 to 58 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup> under non-irrigated conditions compared to 6 to 10 m<sup>3</sup>.ha<sup>-1</sup>.yr<sup>-1</sup> productivity of eucalyptus plantations raised from available seed sources. Several intra-specific and interspecific eucalyptus hybrids have been developed through controlled pollination. F<sub>1</sub> hybrids with good heterosis have been cloned and the resulting hybrid clones are currently under field evaluation. Similar research was started in 1994 for development of superior *Casuarina* clones. The development of elite clones has been followed by rapid adoption and development of large-scale commercial clonal eucalyptus plantations. Between 1992-1999, nearly 7.3 million clonal saplings were supplied to farmers and Forest Departments and grown on a plantation area of 4 567 ha. Current production capacity is 3 million saplings per year.

**Key words:** eucalyptus, *Casuarina*, clone, genotype, productivity.

## R E S U M E N

## LA INVESTIGACIÓN FORESTAL EN EL SECTOR PRIVADO: RELATO DE UN ÉXITO EN LA INDIA

Los 76 millones de hectáreas de la superficie forestal inventariada en la India pertenecen casi totalmente a los estados que se ocupan de su manejo. Esto explica la falta de interés del sector privado para invertir en la investigación forestal. No obstante, una sociedad papelera, ITC Bhadrachalam Paperboards Limited, ha conseguido realizar un importante proyecto, comenzado en 1989, para mejorar la productividad y rentabilidad de las plantaciones y hacer atractivas las explotaciones forestales. En las plantaciones comerciales sin riego, la productividad de los clones se sitúa entre 20 y 58 m<sup>3</sup>.ha<sup>-1</sup>.año<sup>-1</sup> mientras que la productividad de las plantaciones de eucaliptos procedentes de semillas está entre 6 y 10 m<sup>3</sup>.ha<sup>-1</sup>.año<sup>-1</sup>. Se produjeron varios híbridos inter o intraespecíficos mediante polinización controlada. Los híbridos F<sub>1</sub> interesantes fueron clonados y estos clones están evaluándose en campo. En 1994, se iniciaron investigaciones análogas para la producción de clones de élite de *Casuarina*. La difusión de clones de élite permitió, rápidamente y a gran escala, sembrar plantaciones clonales de eucalipto. Entre 1992 y 1994, se suministraron 7,3 millones de árboles jóvenes clonales a los silvicultores y a los departamentos forestales para cubrir 4 567 ha. La capacidad de producción actual es de 3 millones de árboles jóvenes por año.

**Palabras clave:** eucalipto, *Casuarina*, clon, genotipo, productividad.

## SYNOPSIS

## LA RECHERCHE FORESTIÈRE DANS LE SECTEUR PRIVÉ : LE RÉCIT D'UNE RÉUSSITE EN INDE

PIARE LAL

En Inde, les gouvernements des États possèdent et gèrent pratiquement toutes les zones forestières recensées, soit 76 millions d'hectares. Les recherches forestières menées par les administrations forestières et par différents instituts forestiers sont financées par le gouvernement. De nouveaux textes législatifs qui prévoient la protection *sui generis* des droits des obtenteurs sont encore en suspens, et il n'existe aucun mécanisme pour la certification des semences d'essences forestières, ni pour l'inscription de clones ou la certification de plants clonés. Il n'est donc pas étonnant qu'il existe peu d'incitations à l'investissement privé dans la recherche forestière.

Malgré de nombreuses contraintes, la société ITC Bhadrachalam Paperboards Limited mène, depuis 1989, un grand projet de recherche qui vise à améliorer la productivité et la rentabilité des plantations et à valoriser, ainsi, la sylviculture. Les plus gros efforts en recherche-développement portent sur l'amélioration génétique des végétaux et sur celle des itinéraires techniques. Des gains significatifs de productivité sur l'eucalyptus ont été obtenus grâce à l'exploitation de variétés existantes et au développement de clones d'essences locales à croissance rapide, à haut rendement et résistantes aux maladies.

La méthodologie utilisée par la société comprend :

- une sélection d'arbres candidats améliorés (*Candidate Plus Trees*, CPT) qui proviennent de plantations appartenant à des agriculteurs ou à des sociétés ;
- le clonage de CPT par enracinement de boutures de tiges prélevées sur des pousses juvéniles ;
- des essais de terrain sur les clones et des études sur les interactions génotype-environnement ;
- la multiplication commerciale des clones sélectionnés pour leur supériorité génétique, pour promouvoir des plantations clonales.

### AMÉLIORATION GÉNÉTIQUE ET OPTIMISATION DES ITINÉRAIRES TECHNIQUES

Par le clonage de 64 CPT d'*Eucalyptus tereticornis* Smith et *E. camaldulensis* Dehnh depuis 1989, plus de 613 CPT ont été clonés à ce jour. Les performances de clones individuels sur le terrain ont permis d'identifier 89 clones prometteurs pour la croissance et la résistance aux maladies. Ces clones Bhadrachalam, développés pour la première fois en Inde, produisent sans irrigation de 12 à 58 m<sup>3</sup>.ha<sup>-1</sup>.an<sup>-1</sup>, à comparer au rendement des plantations obtenues à partir de semences : 6-10 m<sup>3</sup>.ha<sup>-1</sup>.an<sup>-1</sup>.

Dans la descendance d'hybridations intraspécifiques, produites par une pollinisation entre les meilleurs clones d'*E. tereticornis* Smith, de nombreux hybrides sont très prometteurs. Des hybrides interspécifiques entre les meilleurs clones d'*E. tereticornis* Smith et d'*E. urophylla* Blake/*E. grandis* Muell/*E. camaldulensis* Dehnh. et d'*E. alba* Reinw. ont été développés. Des études sur les interactions génotype-environnement ont permis d'identifier des clones spécifiques au terrain, bien adaptés aux sols calcaires.

L'utilisation continue de nouveaux clones assure une large base génétique. L'amélioration des itinéraires techniques et leur diffusion auprès des agriculteurs assortie de modalités de rachat et d'un soutien à long terme pour l'obtention et le développement sont des aspects stratégiques essentiels de la société. Des recherches similaires ont été lancées en 1994 pour produire des clones améliorés de *Casuarina equisetifolia* Forst. La productivité de ces clones varie de 8,6 à 13,9 m<sup>3</sup>.ha<sup>-1</sup>.an<sup>-1</sup>.

Des plantations de démonstration ont convaincu les agriculteurs et les administrations forestières de plusieurs gouvernements indiens que les gains en productivité et en rentabilité apportés par les plantations clonales d'eucalyptus peuvent être importants. Ainsi, les clones Bhadrachalam ont été plantés à grande échelle. Les fournitures de plants clonés ont été lancées en 1992, avec 27 000 jeunes arbres. La promotion des plantations clonales d'eucalyptus assurée par la

société, entre 1992 et 1999, a bénéficié à 1 914 agriculteurs, qui ont planté 5,64 millions de jeunes arbres sur 3 217 ha. De plus, 1,64 million de ces clones ont été fournis aux administrations forestières et aux sociétés de développement forestier de différents États, entre 1992 et 1999 ; ils constituent aujourd'hui la base des plantations clonales. La société de développement forestier d'Andhra Pradesh a monté son propre centre de multiplication clonale et a boisé 7 000 ha de forêts dégradées avec des clones d'eucalyptus, entre 1993 et 1999.

### SATISFAIRE LA DEMANDE EN BOIS DE TRITURATION

La capacité annuelle du centre de production clonale de la société, à Bhadrachalam, dans le district de Khammam, est actuellement de 3 millions de plants, suffisamment pour boiser environ 1 800 ha. Le bois de trituration produit par ces 1 800 ha de plantation, qui arrive à maturité au bout de rotations de 7 ans, suffira pour satisfaire la totalité de la demande de pâte à papier par l'usine de la société, dont la capacité est de 65 700 tonnes par an. Ainsi, l'approvisionnement futur en bois de trituration sera entièrement assuré par des plantations sylvicoles clonales. Le service des plantations assure désormais son autofinancement grâce à la vente des plants clonés, activité qui dégage des bénéfices nets depuis 1997-1998 : 0,38 million US\$ (17,10 millions de roupies) générés en 3 ans.

Des objectifs de recherche bien définis, un personnel scientifique compétent et motivé, la continuité des plans de recherche et du personnel, une délégation suffisante avec une bonne transparence, et le soutien constant de la société sont autant de facteurs clés du succès de l'entreprise. ITC Bhadrachalam fait aujourd'hui figure de pionnier respecté, aussi bien dans la recherche sur la technologie du clonage que dans la promotion de boisements productifs d'arbres clonés dans les terres agricoles privées, en Inde. Les efforts et les contributions de la société ont été reconnus par l'attribution de quatre prix prestigieux, dont deux au niveau national.