KFRI Research Report No.230 ISSN 0970-8103

# IDENTIFICATION OF PROMISING PROVENANCES OF NEW FAST GROWING SPECIES AND DEVELOPMENT OF NEW EUCALYPT AND ACACIA CLONES FOR ESTABLISHMENT OF CLONAL MULTIPLICATION AREA (CMA)

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# IDENTIFICATION OF PROMISING PROVENANCES OF NEW FAST GROWING SPECIES AND DEVELOPMENT OF NEW EUCALYPT AND ACACIA CLONES FOR ESTABLISHMENT OF CLONAL MULTIPLICATION AREA (CMA)

(Final Report of the Project KFRI 342/2000)

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## ABSTRACT OF PROJECT PROPOSAL

1. Project No. : KFRI 342/2000

2. Title of the project : Identification of promising provenances of new fast growing species and development of new eucalypt and acacia clones for establishment of Clonal Multiplication Area (CMA)

3. Objectives :

i. Identification of new candidate plus trees (CPTs) of *E. tereticornis, E. camaldulensis, E. urophylla* and *E. grandis,* and *Acacia auriculiformis, A. crassicarpa, A. peregrina* and *A. mangium.*

ii. Vegetative multiplication of the candidate plus trees of *Eucalyptus* and *Acacia* spp. and their evaluation for growth and disease resistance for selection of new clones.

iii. Supply of new clones of *Eucalyptus* spp. and *Acacia* spp. to the Kerala Forest Department for establishing clonal multiplication area and clonal plantation.

iv. Evaluation of clones already supplied to the forest Department.

v. Establishment of provenance trial plots of *E. nitens, E.globulus, Paulownia* and Poplar.

vi. Training of Forest Department staff on vegetative multiplication of eucalypts and acacia.

4. Expected outcome :

i. Development of new high yielding disease resistant eucalypt and acacia clones

ii. Standardization of techniques for clonal propagation of *Acacia* spp.

iii. Extension of Clonal Multiplication Area (CMA) and establishment of clonal plantation for Kerala Forest Department

iv. Establishment of provenance trial plots of *E. nitens, E. globulus, Paulownia* and Poplar.

v. Package of practices in the form of brochure and extension bulletin.

5. Date of commencement : April 2000

6. Date of completion : March 2002

7. Funding agency : Kerala Forestry project (World bank Aided)
Kerala Forest Department

8. Project team
Principal Investigator : Dr. M. Balasundaran

Associate Dr. E. J. Maria Florence

Research Fellow : Mrs. Binu C. Nair

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## ABSTRACT

A study was carried out to identify new clones and provenances of pulpwood species adapted to Kerala with emphasis on eucalypts and acacias. Twenty one new candidate plus trees (CPTs) of *Eucalyptus tereticornis* (11), *E. camaldulenis* (2) and *E. urophylla* (8) were identified from the provenance trial plots and their half sib progenies maintained in the KFRI experimental plots at Kottappara in Kodanad range. Of these, 10 superior clones were identified and planted for field screening for productivity and resistance against Cylindrocladium leaf blight (CLB) and pink disease in clonal testing area (CTA). Forty five CPTs of *E. grandis* were identified, from which 25 clones were planted in clonal multiplication area (CMA) established at Devikolam, for multiplication and field screening for fast growth and disease resistance. A clonal propagation facility was established at Devikolam for vegetative multiplication of *E. grandis* and *E. globulus*, grown only at high elevations.

Initial attempts to multiply vegetatively 4-year-old CPTs identified in *Acacia auriculiformis, A. crassicarpa, A. peregrina* and *A. mangium* provenance trial plots at Kodanad were not a success probably due to increased age of trees and absence of irrigation facilities; the stumps failed to produce coppice shoots. However, *A. mangium* was successfully cloned through coppice shoots produced on pruned branches of older trees and 6- to18-month-old plants of *A. mangium* and mangium hybrid clones. Development of hedge garden by pruning acacia plants initially at 90 cm height at 6-18 month growth was the most efficient method of obtaining assured supply of juvenile coppice shoots for vegetative multiplication. Red soil and washed coir pith and their mixtures were the best rooting media for acacia cuttings.

About 74,000 ramets of 20 KFRI clones of *E. tereticornis* (9 clones), *E. camaladulensis* (8 clones) and *E. urophylla* (3 clones) and three Bhadrachalam clones, and 5000 ramets of 10 mangium hybrid clones were supplied to the Kerala Forest Department for raising plantations. In addition, 50 ramets each of three new *E. urophylla* clones, two *E. tereticornis* clones, and one *Acacia mangium* clone, and 1000 ramets of 10 mangium hybrid clones of West Coast Paper Mills, Dandeli were also supplied to the central nurseries of the Forest Department for expanding CMA and testing the clones. Field performance of 3-year-old clones of *E. tereticornis*, and *E. camaldulensis* showed that MAI of more than 20 $m^3$ $ha^{-1}$ $yr^{-1}$ has already been achieved for a few clones. No pink disease infection was observed in any of the field-planted clones except a few plants of Bhadrachalam clones, BCM 7, BCM 83 and KFRI 7. CLB of low to medium intensity was observed on several clones such as KFRI 10, KFRI 14, KFRI 49, BCM 10, BCM 130, BCM 83, BCM 7 and BCM 119 during squally weather. However, infected plants recovered after cessation of heavy rainfall.

Growth of *Paulownia fortunei* and *P. coreana* was not encouraging when the growth was recorded up to 6 months. Clones of *Populus deltoides* attained a height of about 25 cm within 40 days at Kodanad and Devikulam.

As part of extension work, two training programmes, a one-day programme in 2001 and a 3-day-programme in 2002 were organized for the benefit of staff of central nurseries, and other KFD staff. Central nurseries were visited periodically to provide technical assistance for clonal propagation of eucalypt and acacia, and for discussion with officers on this topic.

# 1. INTRODUCTION

## 1.1. Productivity of eucalypt plantation in Kerala

The average productivity of eucalypt plantations in Kerala was recorded to be considerably low as indicated by a study conducted by KFRI in 1997 (Nair *et al.*, 1997). The mean annual increment (MAI) of seedling crop of *Eucalyptus* 'hybrid' was 7.65 $m^3$ $ha^{-1}$ at 8 year rotation and for the first coppice crop 2.54 $m^3$ $ha^{-1}$. The MAI for seedling crop of *E. grandis* at 10 year rotation was 10 $m^3$ $ha^{-1}$. The main reason for the low yield was severe infection of leaf blight caused by *Cylindrocladium* spp. and pink disease caused by *Corticium salmonicolor*. Besides, low density of the growing stock in the plantations and wide variation among the growth of trees were the other reasons.

## 1.2. Strategy adopted by KFRI for productivity improvement

The reason for high incidence of diseases and wide variation among the growing stock was the inferior quality of seeds collected from highly inbred populations with very narrow genetic base. To overcome this situation, Kerala Forest Research Institute (KFRI) initiated a tree improvement programme under which several Australian provenances of eucalypts were introduced into Kerala to identify disease resistant planting stock and to develop superior, genetically improved, disease resistant clones from these provenances.

### 1.2.1. Eucalypt and Acacia provenance trials

As a short-term strategy to identify seed sources of improved quality, four multi-location provenance trial plots comprising 83 provenances of *E. tereticornis, E. camaldulensis, E. urophylla, E. pellita and E. grandis* were established during 1990, 1992 and 1993 in approximately 28 ha area using provenance seeds obtained from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia.

Considering the increasing importance of *Acacia* spp. as raw material for pulpwood industries, multi-location trials were established in 1997 for 38 provenances of *A. mangium, A. auriculiformis, A. crassicarpa* and *A. aulacocarpa (A. peregrina)* with the seeds obtained from CSIRO, Australia.

Based on the observations on growth and disease resistance in the field, some of the promising provenances of eucalypts with fast growth and disease resistance were identified and recommended to the Kerala Forest Department for raising plantations under the Kerala Forestry Project.

### 1.2.2. Development of Eucalypt and Acacia clones

As the next step towards a long-term strategy for improving the eucalypt planting stock for higher yield, the technology of clonal forestry was adopted. The technology consisted of mass multiplication and planting of superior clones of eucalypts. In KFRI, this programme was initiated during 1996 with the identification of candidate plus trees from provenances adapted to Kerala and mass multiplying them vegetatively in semi-permanent field clonal propagation unit established at Kottappara in Malayattoor Forest Division. A clonal gene bank (CGB) using ramets from 85 clones of *E. tereticornis, E. camaldulensis, E. pellitta* and *E. urophylla*, and Clonal Multiplication Area (CMA) comprising 42 potential clones were also established. The clones developed from the CMA were given to the Central Nurseries of the Kerala Forest Department for establishing their CMA for further multiplication of these clones for raising clonal plantations for the Kerala Forest Department.

## 1.3. Gains through clonal forestry

Exploitation of the potentials of clonal forestry has resulted in increased productivity of eucalypt in countries such as Brazil, Congo and South Africa, and in the state of Andhra Pradesh in India. The MAI of *E. grandis* plantations in Brazil prior to embarking on genetic improvement and clonal forestry in 1967 was 15 $m^3$ $ha^{-1}$ at 7 year rotation. But, when selected clones were introduced, the yield increased to 70 $m^3$ $ha^{-1}$ in industrial plantations. With use of improved clones under intensive management, the yield reached

even up to 100 $m^3$ $ha^{-1}$ in moderately good sites. Such growth is not so far obtained from seedlings (Zobel, 1993). These achievements were possible primarily through continuous genetic improvement of planting stock, especially selection and use of disease resistant and high yielding clones.

In India, clonal forestry through vegetative propagation on an industrial scale was pioneered by ITC Paper Boards Ltd., Bhadrachalam in Andhra Pradesh. The ITC Company selected plus trees from plantations of Mysore gum commonly known as *Eucalyptus* 'hybrid' and distributed ramets (vegetatively propagated plants from clones) on a large scale among farmers as farm forestry crop and also to the Andhra Pradesh Forest Department. Clones from 35 fast growing disease resistant trees are being multiplied on a large scale through rooting of cuttings. Productivity is expected to be 20 to 25 $m^3$ $ha^{-1}$ $yr^{-1}$ by 7th year which is nearly four-fold increase in yield over eucalypt plantations raised to study their adaptability in order to utilize them in future (Lal, 1993).

Even though, the productivity of eucalypts and Acacia can be increased to several fold, one of the disadvantages of clonal forestry is the increased vulnerability of the uniform genotype of the trees to outbreak of pest and disease problems. The risk is more serious in Kerala where warm humid weather, conducive for pest and disease epidemic, prevails. Promising clones may become suddenly susceptible to disease and pest attack after a few rotations of satisfactory performance. Hence, new clones have to be developed to match emerging situations and local soil conditions by widening the genetic base of the clones. Trial plantations of alternative pulpwood species also have to be raised to utilize them if needed in special situations.

## 1.4. Introduction of new provenances

*Eucalyptus globulus* and *E. nitens* are supposed to be suitable for planting in high altitude areas of Kerala. An adaptability trial of these species using new provenance seeds from Australia can identify the most suitable provenances for introduction to Kerala. Poplar and *Paulownia* are the two fast growing agroforestry species commonly cultivated in the

subtropics. Poplar is cultivated in Northern India in large scale while *Paulownia* is being introduced from China and other countries. An adaptability trial of these two species will also provide an indication of their potential for raising plantations in Kerala.

## 1.5. Objectives

The specific objectives of this project were:

1. Identification of new candidate plus trees (CPTs) of *E. tereticornis, E. camaldulensis, E. urophylla* and *E. grandis, E. globulus* and *Acacia auriculiformis, A. crassicarpa, A. aulacocarpa* and *A. mangium.*
2. Vegetative multiplication of the candidate plus trees of eucalypts and *Acacia* spp. and their evaluation for growth and disease resistance for selection of new clones.
3. Supply of new clones of *Eucalyptus* and *Acacia* spp. to the Kerala Forest Department for establishing clonal multiplication area and clonal plantation.
4. Evaluation of clones already supplied to the Forest Department
5. Establishment of provenance trial of *E. nitens, E. globulus, Paulownia* and Poplar.
6. Training of project staff on vegetative multiplication of eucalypts and acacia.

# 2. MATERIALS AND METHODS

## 2.1. Identification of new candidate plus trees (CPTs)

### 2.1.1. Identification of CPTs of eucalypts

New candidate plus trees of *E. tereticornis*, *E. camaldulensis* and *E. urophylla* were identified from the provenance trees of the KFRI provenance trial plots established at Kottappara in Kodanad range during 1990, 1992 and 1993. CPTs were also selected from 4-year-old half-sib progenies of *E. urophylla* CPTs, identified earlier in the same provenance trial plots. *E. grandis* trees were identified in a 7-year-old plantation (32 ha) at Kacheriland near Devikulam, marked for felling during the year 2000-2001. The trees were selected according to the methods suggested in Balasundaran (1997) and Sharma and Balasundaran (2001). The main emphasis was given to the following characters.

- Better growth in terms of height and diameter at breast height (DBH) than the surrounding trees
- Clear bole and less branching
- Tolerance against Cylindrocladium leaf blight and pink disease
- Light conical crown and balanced canopies

### 2.1.2. Identification of CPTs of Acacias

CPTs of the *Acacia* spp. were identified from the 4-year-old provenance trial plot comprising, *A. auriculiformis* (11 provenances), *A. crassicarpa* (6 provenances), *A. aulacocarpa (A. peregrina)* (8 provenances) and *A. mangium* (2 provenances) planted in 1997 at Kottappara. The criteria of selection were superior height, girth and girth, straightness, less branching and with no disease and pest problem.

*2.1.2.1. Mangium hybrid clones*

The following mangium hybrid clones, procured from the West Coast Paper Mills, Dandeli, Karnataka State were also used for coppicing. Fifty ramets of each clone were obtained as shown below. The details of the parents of the clones are not known.

1. SU 3
2. SU 4
3. SU 5
4. SU 38
5. SU 40
6. SU 47
7. HT 7
8. HT 10
9. BC 65
10. FC 6

## 2.2. Vegetative multiplication of CPTs of eucalypts and acacias

### 2.2.1. Vegetative multiplication of CPTs of *E. tereticornis* and *E. urophylla*

Vegetative multiplication of the two lowland species of eucalypts viz. *E. tereticornis*, and *E. urophylla* was carried out at the field clonal propagation unit (FCPU) established at Kottappara (Sharma *et. al*., 2000). The identified CPTs were felled using sharp saw, with a gentle slanting cut, about 20-30 cm above ground level during December 2000 and 2001. The sawing was done without injuring the bark. The cut surface was protected applying a solution of copper oxychloride (0.1%), a fungicide. The sprouts started to appear within 10-15 days of felling the trees (Fig. 1). Each stump produced varying number of shoots. Watering the stumps produced healthier coppice shoots. The stumps and the coppice shoots were protected from cattle browsing and trampling by providing a protective fence around them. Forty five- to 60-day-old coppice shoots were harvested, immediately kept in a bucket containing clean water and brought to mist chamber facility for processing. Two-leafed cuttings were prepared from healthy coppice shoots and leaves cut to about quarter to half length to reduce loss of water due to transpiration. The coppice shoots and cuttings were always kept in water, and water sprayed on the leaf

surface when shoots were brought to the mist chamber. The cuttings were kept in 0.1% Carbendazim (fungicide) solution for 10 minutes for protection from fungal infection. The lower portions of cuttings were treated with 4000 ppm indole butyric acid (IBA), the rooting hormone, mixed with talcum powder, and then planted in block type root trainers (24-celled) containing wet horticultural grade vermiculite (Keltech Energies Limited, Perlite Division, No.2, 2nd Floor, Unity Building, Tower Block, Mission Road, Bangalore). The root trainers (5 each) were kept on a root trainer stand, and then transferred to trenches (Fig. 2). Misting was provided for about half to one minute duration with an interval of 30-60 min depending upon the weather conditions so as to maintain a temperature of 30-35$^0$C and relative humidity of 65 to 90 per cent (Fig. 3). Carbendazim (0.1% a.i.) was sprayed on the cuttings once in 10 days. Ten ml Hoagland's nutrient solution was applied to each cutting in the root trainer after ten days.

### 2.2.2. Vegetative multiplication of *E. grandis* CPTs

*2.2.2.1. Construction of mist chamber and store cum work area at Devikulam*

As there was no clonal nursery for vegetative multiplication of *E. grandis*, the high range species, a mist chamber and a store/office cum potting shed was constructed at Devikulam. The facility is established at about 1.5 km away from Munnar Forest Division Office in the 1994-Kacheriland *E. grandis* plantation. For vegetative multiplication, the method adopted for *E. tereticornis* and *E. urophylla* was followed (para 2.2.1).

### 2.2.3. Vegetative multiplication of *A. mangium, A. auriculiformis, A. crassicarpa, A. aulacocarpa (A. peregrina)* CPTs and mangium hybrid clones

*2.2.3.1. Method of coppice shoot induction*

The following experiments were carried out in order to find out the appropriate time and method of felling the plants to obtain the maximum number of coppice shoots.

i. 4-year-old acacia provenance trees at Kottappara

Three treatments viz. a. Felling at a height of 60 cm from ground level
b. Felling at a height of 90 cm from ground level
c. Coppicing branches of >10 cm girth

For treatments (a) and (b), 80 trees were cut. For treatment (c), two trees from each provenance for each treatment (list not provided) were cut.

ie. 2 trees x 27 provenances x 3 treatments = 162 trees

The experiments (a) and (b) were done during 2000 while (c) were done during 2001 only.

ii. 18-month-old *A. mangium* plants and mangium hybrid clones of West Coast Paper Mills, Dandeli.

Two treatments viz. a. Felling at a height of 90 cm from ground level
b. Coppicing branches of >10 cm girth

Five trees from each clone for each treatment

ie. 5 trees x 10 clones x 2 treatments = 100 trees

The experiments were done during 2001.

iii. 6-month-old mangium hybrid plants

One treatment viz. Coppicing at a height of 90 cm to produce hedge garden

5 plants x 10 clones = 50 plants

*2.2.3.2. Processing of coppice shoots for rooting*

The apical portion of coppice shoots was used for rooting by retaining the apical bud intact. For this, coppice shoots were cut to a length of 12-15 cm with at least 4-5 leaves.

Side branches were avoided. All other procedures, except the type of rooting medium used, were exactly the same as done for eucalypts (para 2.2.1).

### 2.2.4. Standardization of rooting medium

Rooting experiment was conducted by filling the root trainers with 12 types of potting medium as provided below.

| Sl. No. | Componenets of potting mixture taken in trays and kept in mist chamber for rooting |
|---|---|
| 1 | Red soil |
| 2 | Compost |
| 3 | Sand |
| 4 | Vermiculite |
| 5 | Normal soil |
| 6 | Washed coir pith |
| 7 | Compost:soil (1:1) |
| 8 | Compost:vermiculite (1:1) |
| 9 | Compost:sand(1:1) |
| 10 | Compost:soil:vermiculite(2:1:1) |
| 11 | Compost:soil:vermiculite(3:1:1) |
| 12 | Compost:soil:vermiculite(1:1.5:1.5) |

For large scale multiplication, the cuttings, after hormone treatment, were planted in red soil taken in metal or plastic trays and then placed in trench type mist chambers.

## 2.3. Supply of clones to the Kerala Forest Department

### 2.3.1. Supply of new clones

The following new clones identified during the project period are being hardened for supply to the central nurseries of the forest department for expanding the CMA of forest department.

*E. tereticornis* : Clone No. KFRI 86, KFRI 98

*E. urophylla* : Clone Nos. KFRI 99, KFRI 100, KFRI 101, KFRI 102, KFRI 103, KFRI 104, KFRI 105, KFRI 106

*A. mangium* : KFRI M-1

### 2.3.2. Supply of clones developed earlier

As eucalypts and acacia clones were required by the forest department for raising clonal plantations, the following KFRI clones developed earlier, and Bhadrachalam clones were multiplied in the clonal multiplication facility at Kottappara adopting the method developed for vegetative multiplication (Balasundaran *et al*., 2000). The clones were supplied to the forest department.

*2.3.2.1. Eucalypts clones*

***E. tereticornis***

KFRI 14, KFRI 16, KFRI 28, KFRI 43, KFRI 49, KFRI 56, KFRI 65

*E. camaldulensis*

KFRI 10, KFRI 23, KFRI 25, KFRI 54, KFRI 55, KFRI 68

Bhadrachalam clones

BCM 7, BCM 130

*2.3.2.2. Mangium hybrid clones* (West Coast Paper Mills, Dandeli)

SU 3, SU 4 , SU 5, SU 38, SU 40, SU 47, HT 7, HT 10, BC 65, FC 6

## 2.4. Evaluation of clones for growth and disease resistance

### 2.4.1. Evaluation of new eucalypts clones

Twenty five ramets of each eucalypt clone produced during 2000 and 2001 were planted in 2.5 m x 2.5 m spacing. The plants were evaluated for growth (height) and resistance/tolerance against incidence of cylindrocladium leaf blight and pink disease.

Growth of *E. grandis* clones was evaluated at Devikulam and *E. tereticornis, E. urophylla* and acacia clones at Kottappara.

### 2.4.2. Evaluation of clones supplied to the forest department earlier

*2.4.2.1. Evaluation of clones planted in CMA at Central Nurseries for disease resistance.*

Each tree of each clone planted in CMA at Kulathupuzaha and Nilambur was examined for incidence of cylindrocladium leaf blight during the season of heavy rainfall in July – August and for pink disease during September – October in year 2000 and 2001. The severity of infection was scored on a scale ranging from Nil to severe as shown below.

*2.4.2.2. Cylindrocladium infection*

| | |
|---|---|
| Low infection (L) | = if leaf spots are confined to lower branches |
| Medium infection (M) | = if leaf spots are spread to the upper branches with heavy defoliation of lower branches |
| Severe infection (S) | = if entire tree is infected including apical portion. The tree will show a blighted appearance with heavy defoliation reaching up to the apical branches. |
| No infection (Nil) | = if the tree is free from leaf spots |

2.4.2.3. *Pink disease*

| | |
|---|---|
| Low infection (L) | = if infection is confined to branches |
| Medium infection (M) | = if main stem is infected showing canker but without any die-back symptom |
| Severe infection (S) | = if main stem is infected with die-back |

symptom and coppice shoot formation below the point of infection

No infection (Nil) = if the tree is free from any infection

### 2.4.3. Evaluation of clonal plantations raised by the forest department using KFRI clones

The performance of the field–planted clones supplied by KFRI at the Central Nurseries was assessed. The data collected by KFRI and also by the forest department staff were utilized for this purpose. The GBH and height measurement of plants were recorded by the forest department staff systematically by demarcating sample plots for each clone. These data were utilized in respect of plantations raised during year 2000 and 2001. However, disease incidences were assessed by the investigators after visiting the plantations and discussions with the local forest staff.

Growth measurements in respect of 3-year-old plantations (planted in 1999) were either taken by the investigators or the same sample plot measurements recorded by the department staff were used after confirming the accuracy of the data by visiting the sample plots. The volume of wood produced at the close of third year of planting, mean height and GBH of a 2-year-old and two 3-year-old plantations were recorded. The height attained by various clones within 9 months was measured. Disease incidence was recorded by the investigators after visiting the CMA (Table 9) and plantations. The conical volume ($m^3$) of 3-year-old trees was estimated using the following formula (Cameron *et al*., 1989).

$$Vc = \Pi [Hr/(H-h)]^2 H/3$$

Where, Vc = Conical volume of stem

r = Main stem radius measured at height h

H = Total Height

h = height at which radius was measured

## 2. 5. Establishment of provenance trial of *E. nitens, E. globulus,* poplar and *Paulownia*

### 2.5.1. *E. nitens and E. globulus*

In order to obtain provenance seeds of *E. globulus* and *E. nitens*, we requested Dr. Chris Harwood of Australian Tree Seed Centre, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia to supply us 10 g seeds of each provenance.

### 2.5.2. Poplar

Three hundred cuttings of three clones of *P. deltoides* viz. L 200/84, L 34/82 and S7C2, were obtained from the Silviculture Division of FRI, Dehra Dun for trial at KFRI clonal nursery at Kottappara and Devikulam. The following methods were followed for planting.

The lower and upper (waxed) ends of cuttings were cut off with secateurs giving flat cut. The cuttings were immediately submerged in water taken at least for 24 hr or until they were planted. The nursery site was fertile open area (deep loamy soil or sandy loam, free from water logging is appropriate for poplar). Adequate quantities of farm yard manure, single super phosphate and muriate of potash were also mixed with the soil; just before planting, the cuttings were submerged in carbendazim solution (0.05%) for 30 minutes. The cuttings were planted vertically maintaining correct polarity. The spacing in nursery was 45 cm x 45 cm. Only one bud was left above the ground level. The nursery was irrigated by flooding it once a week during the summer season.

### *2.5.3. Paulownia*

Two species viz., *P. fortunei* and *P. coreana* were obtained for adaptability trial in Kerala. Two hundred and fifty numbers of tissue culture-raised, 2-month-old plantlets of *P. fortunei* were obtained from Tata Energy Research Institute (TERI), New Delhi by

paying Rs.15 per plantlet. Half the number of plantlets were brought to KFRI, Peechi in polybags filled with soil and the other half as bare-rooted seedlings. These plantlets were transferred to polybags filled with potting mixture containing soil, cow dung and sand in the ratio 2:1:1. Another set of 250 tissue-culture raised plantlets of *P. fortunei* were brought from a progressive nursery man from Kozhikkode by paying Rs.25 per seedling. The plantlets were originally obtained from Australia. The plantlets obtained from TERI were about 15 cm in height while those from Kozhikkode were 3-month-old and about 30 cm in height. The plants were out-planted in 30 cm x 30 cm x 30 cm pits in 2.5 m x 2.5 m spacing at Kodanad, Devikulam and Nilambur during September 2001.

The seeds of *P. coreana* were received from Prof. Don Koo Lee, Department of Forest Resources, CALS, SNU, Suwon, Korea. The seeds were germinated over wet polyurethane pad floating over water. The seeds germinated within 5 days. Two-leafed seedlings were transplanted to poly bags of size 10 cm x 15 cm filled with a mixture of soil, sand and cow dung (2:1:1), and 24-celled root trainer block of cell capacity 150 ml filled with a mixture of compost, soil, sand and vermiculite (1:1:1:1). Two-month-old seedlings of about 30 cm height were out planted in 30 cm x 30 cm x 30 cm pits in 2.5 m x 2.5 m spacing at Kodanad during February 2002. The plants were watered every day.

# 3. RESULTS

## 3.1. Identification of new CPTs of eucalypts

Twenty one CPTs belonging to *E. tereticornis* (11), *E. camaldulensis* (2) and *E. urophylla* (8) were identified and felled during the year 2000 and 2001. The details of the CPTs are provided in Table 1. Of these, five stumps of CPTs did not produce coppice shoots. The CPTs were vegetatively multiplied at the field clonal propagation unit at Kottappara. Cuttings from coppice shoots of a large number of mother trees showed poor rooting and a few of them showed severe cylindrocladium infection. Clones were prepared from mother trees vegetatively and only those clones which showed satisfactory rooting (around 25%) and which were free from cylindrocladium infection or with low infection were accepted as a clone for further trial.

Forty five CPTs of *E. grandis* were identified from the 32 ha-final felling area of 1994-Kacheriland plantation near Devikulam during the month of November – December 2000. The GBH of these trees ranged between 55 and 80.5 cm and height between 18.75 and 25.90 m. These trees were felled during March 2001 to induce coppice shoot production (Table 2).

## 3.2. Identification of CPTs of *Acacia* spp.

Eighty CPTs representing all the provenances of *A. auriculiformis, A. crassicarpa* and *A. aulacocarpa* and Morehead provenance of *A. mangium* were selected for felling (Table 3). The GBH of *A. auriculiformis, A. crassicarpa and A. aulacocarpa* ranged between 29 and 48 cm, 33 and 55 cm and 23 and 49 cm respectively. The range of height was 7.6 - 15.5 m, 8.7-17.6 m and 8.0-12.7 m respectively for these species. The highest GBH and height of *A. mangium* were 53 cm and 13.5 m respectively.

Table 1. CPTs of *E. tereticornis* and *E. urophylla* identified during 2000 and 2001

| Sl. No. | CPT Serial No. (Clone No.) | Year of selection | Age of mother tree (Yrs) | GBH (cm) | Height (m) | Remark/ Success in rooting (%) | Susceptibi-lity to CLB** |
|---|---|---|---|---|---|---|---|
| *E. tereticornis* | | | | | | | |
| 1. | 86 | 2000 | 10 | 83 | 24.7 | 45 | Low |
| 2 | 87 | 2000 | 10 | 71 | 24.2 | NC* | - |
| 3. | 88 | 2000 | 10 | 91 | 24.4 | NC | - |
| 4. | 89 | 2000 | 10 | 70 | 25.3 | 20 | Medium |
| 5. | 90 | 2000 | 8 | 57 | 22.0 | NC | - |
| 6. | 91 | 2000 | 8 | 88 | 18.2 | 40 | Severe |
| 7. | 92 | 2000 | 8 | 74 | 26.0 | 36 | Severe |
| 8. | 93 | 2000 | 8 | 66 | 21.2 | NC | - |
| 9. | 94 | 2000 | 7 | 71 | 15.0 | 27 | Severe |
| 10. | 95 | 2000 | 7 | 56 | 16.3 | 15 | Medium |
| 11. | 98 | 2000 | 7 | 65 | 23.7 | 34 | Low |
| *E. camaldulensis* | | | | | | | |
| 12. | 96 | 2000 | 8 | 54 | 18.7 | 32 | Severe |
| 13. | 97 | 2000 | 8 | 72 | 21.3 | NC | - |
| *E. urophylla* half sib progeny | | | | | | | |
| 14. | 99 | 2001 | 4 | 68 | 21.7 | 60 | Screening |
| 15 | 100 | 2001 | 4 | 75 | 20.8 | 48 | Screening |
| 16 | 101 | 2001 | 4 | 62 | 21.65 | 52 | Screening |
| 17 | 102 | 2001 | 4 | 53 | 18.30 | 59 | Screening |
| 18 | 103 | 2001 | 4 | 48 | 19.00 | 32 | Screening |
| 19 | 104 | 2001 | 4 | 98 | 22.60 | 37 | Screening |
| 20 | 105 | 2001 | 4 | 84 | 19.80 | 43 | Screening |
| 21 | 106 | 2001 | 4 | 86 | 21.20 | 49 | Screening |

*NC: No coppice shoot was available; **CLB: Cylindrocladium leaf blight;

- Stump dried.

Table 2. CPTs of *E. grandis* identified and felled for producing clones during 2001

| **Sl. No. (Clo-one No.)** | GBH of CPTs( cm) | Height of CPTs (m) | Root-ability of CPTs (%) | CLB Infe-ction of clone | Mean clone height (cm) | **Sl. No. (Clo-one No.)** | GBH of CPTs (cm) | Height of CPTs (m) | Root-ability of CPTs (%) | CLB Infe-ction of clone | Mean Clone height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 71.0 | 24.25 | 24.5 | M | 133 | **24** | 66.0 | 23.60 | 7.3 | L | 161 |
| **2** | 80.5 | 22.40 | 15.6 | - | - | **25** | 61.5 | 21.30 | 34.3 | - | - |
| **3** | 63.5 | 21.70 | 16.2 | - | - | **26** | 60.0 | 22.70 | 28.8 | M | 133 |
| **4** | 55.5 | 21.20 | 23.4 | - | - | **27** | 66.0 | 21.40 | 11.2 | - | - |
| **5** | 57.0 | 23.40 | 18.2 | - | - | **28** | 56.0 | 23.20 | 7.8 | - | - |
| **6** | 55.5 | 21.60 | 9.0 | - | - | **29** | 55.0 | 21.70 | 16.2 | - | - |
| **7** | 67.0 | 21.30 | 43.6 | M | 175 | **30** | 58.0 | 21.70 | 50.2 | M | 119 |
| **8** | 65.0 | 20.60 | 37.2 | M | 185 | **31** | 57.2 | 21.25 | 26.3 | M | 151 |
| **9** | 65.0 | 22.70 | 6.2 | - | - | **32** | 62.0 | 22.50 | 28.5 | M | 141 |
| **10** | 64.5 | 23.80 | 29.0 | L | 161 | **33** | 56.0 | 23.00 | 2.8 | - | - |
| **11** | 58.5 | 23.30 | 11.9 | - | - | **34** | 72.0 | 25.50 | 37.5 | M | 137 |
| **12** | 62.0 | 22.00 | 41.0 | L | 156 | **35** | 62.0 | 21.00 | 6.5 | - | - |
| **13** | 64.0 | 22.20 | 29.7 | M | 160 | **36** | 66.5 | 22.00 | 25.4 | L | 127 |
| **14** | 58.0 | 21.00 | 4.5 | - | - | **37** | 55.0 | 22.60 | 19.8 | - | - |
| **15** | 58.0 | 21.30 | 16.0 | - | - | **38** | 55.0 | 21.30 | 27.5 | - | - |
| **16** | 57.0 | 21.10 | 37.7 | L | 163 | **39** | 58.4 | 23.20 | 28.5 | L | 123 |
| **17** | 61.0 | 22.40 | 26.0 | L | 122 | **40** | 58.5 | 22.00 | 25.4 | M | 99 |
| **18** | 63.0 | 21.40 | 3.5 | - | - | **41** | 59.0 | 21.20 | 25.9 | M | 107 |
| **19** | 60.0 | 21.40 | 27.5 | L | 136 | **42** | 57.5 | 22.30 | 7.8 | - | - |
| **20** | 60.0 | 20.15 | 43.4 | M | 143 | **43** | 68.0 | 24.00 | 35.5 | M | 134 |
| **21** | 60.0 | 21.00 | 31.4 | M | 202 | **44** | 58.0 | 23.00 | 1.2 | - | - |
| **22** | 58.0 | 18.75 | 29.0 | L | 154 | **45** | 58.5 | 22.60 | 25.0 | M | 118 |
| **23** | 55.0 | 22.40 | 30.1 | L | 138 | | | | | | |

- Insufficient coppice shoot or rejected due to severe disease problem.

L = Low intensity; M= Medium intensity; NIL = No disease

Table 3. CPTs of *A. auriculiformis, A. crassicarpa* and *A. aulacocarpa (A. peregrina)* and *A. mangium* identified and felled for producing clones during 2000 and 2001

| **Sl. No**. | Provenance | GBH of CPT (cm) | Hei-ght of CPT (m) | Copp-iced height (cm) | **Sl. No**. | Provenance name | GBH of CPT (cm) | Hei-ght of CPT (m) | Copp-iced height (cm) |
|---|---|---|---|---|---|---|---|---|---|
| ***A. auriculiformis*** | | | | | ***A. crassicarpa*** | | | | |
| **1** | SAI THONG | 33 | 12.2 | 90 | **1** | MOREHEAD | 42 | 10.2 | 60 |
| **2** | SAI THONG | 33 | 10.4 | 90 | **2** | MOREHEAD | 45 | 12.2 | 90 |
| **3** | SAI THONG | 46 | 11.9 | 60 | **3** | MOREHEAD | 51 | 13.8 | 90 |
| **4** | SAI THONG | 38 | 11.6 | 90 | **4** | BENSBACH | 45 | 13.2 | 90 |
| **5** | MOREHEAD R ROOKU | 36 | 11.8 | 90 | **5** | BENSBACH | 45 | 11.4 | 90 |
| **6** | MOREHEAD R ROOKU | 29 | 8.2 | 90 | **6** | PONGAKIE MOREHEAD | 55 | 11.6 | 90 |
| **7** | MOREHEAD R ROOKU | 36 | 12.1 | 90 | **7** | PONGAKIE MOREHEAD | 50 | 13.0 | 90 |
| **8** | S. OF COEN CAPE YORK | 45 | 15.5 | 90 | **8** | PONGAKIE MOREHEAD | 55 | 11.6 | 90 |
| **9** | S. OF COEN CAPE YORK | 41 | 12.0 | 90 | **9** | PONGAKIE MOREHEAD | 34 | 12.7 | 60 |
| **10** | S. OF COEN CAPE YORK | 44 | 15.4 | 60 | **10** | JARDINE R | 35 | 8.7 | 90 |
| **11** | S. OF COEN CAPE YORK | 41 | 12.8 | 60 | **11** | JARDINE R | 33 | 11.5 | 90 |
| **12** | BENSBACH R | 46 | 13.9 | 90 | **12** | DIMISSI VILLAGE | 46 | 11.6 | 90 |
| **13** | BENSBACH R | 37 | 11.5 | 90 | **13** | DIMISSI VILLAGE | 46 | 12.3 | 90 |
| **14** | BENSBACH | 48 | 7.6 | 90 | **14** | DIMISSI VILLAGE | 45 | 13.6 | 60 |
| **15** | OLIVE RIVER | 39 | 12.7 | 90 | **15** | DIMISSI VILLAGE | 42 | 12.7 | 60 |
| **16** | OLIVE RIVER | 39 | 11.5 | 90 | **16** | LIMAL MALAM | 41 | 11.3 | 90 |
| **17** | OLIVE RIVER | 33 | 12.5 | 90 | **17** | LIMAL MALAM | 48 | 17.6 | 90 |
| **18** | POHATURI RIVER | 41 | 12.5 | 90 | **18** | LIMAL MALAM | 46 | 13.0 | 60 |
| **19** | POHATURI RIVER | 38 | 13.7 | 60 | ***A. aulacocarpa*** | | | | |
| **20** | POHATURI | 44 | 13.1 | 90 | **1** | WASUA | 43 | 10 | 90 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RIVER | | | | | PEDEYA | | | |
| **21** | MELVILLE ISLAND | 37 | 14.2 | 90 | **2** | WASUA PEDEYA | 30 | 8.8 | 60 |
| **22** | MELVILLE ISLAND | 40 | 11.8 | 90 | **3** | WASUA PEDEYA | 46 | 12.1 | 90 |
| **23** | MELVILLE ISLAND | 36 | 11.4 | 60 | **4** | W OF WIPIM | 41 | 9.8 | 90 |
| **24** | ORIOMO | 35 | 10.2 | 90 | **5** | W OF WIPIM | 40 | 11.1 | 90 |
| **25** | ORIOMO | 38 | 12.3 | 90 | **6** | W OF WIPIM | 40 | 9.1 | 90 |
| **26** | ORIOMO | 40 | 13. 0 | 90 | **7** | W OF WIPIM | 33 | 9.7 | 60 |
| **27** | ORIOMO | 36 | 12.8 | 90 | **8** | PONGAKIE MOREHEAD | 48 | 11.7 | 90 |
| **28** | BINATURI R | 38 | 12.8 | 90 | **9** | PONGAKIE MOREHEAD | 44 | 9.5 | 90 |
| **29** | BINATURI R | 33 | 10.4 | 90 | **10** | PONGAKIE MOREHEAD | 40 | 9.8 | 90 |
| **30** | BINATURI R | 35 | 14.6 | 90 | **11** | PONGAKIE MOREHEAD | 37 | 12.7 | 60 |
| **31** | DO OSOSO | 36 | 11.1 | 90 | **12** | BENSBACH BALAMUKH | 37 | 10.6 | 90 |
| **31** | DO OSOSO | 39 | 13.2 | 90 | **13** | BENSBACH BALAMUKH | 36 | 12.6 | 90 |
| **32** | SPRINGVALE | 41 | 12.3 | 60 | **14** | 3 KS MT LARSKOM | 34 | 9.7 | 90 |
| **33** | SPRINGVALE | 41 | 13.2 | 90 | **15** | 3 KS MT LARSKOM | 23 | 8.0 | 90 |
| **34** | SPRINGVALE | 33 | 10.4 | 90 | **16** | 3 KS MT LARSKOM | 30 | 8.5 | 60 |
| **35** | SPRINGVALE | 41 | 14.8 | 60 | **17** | SAMFORD | 26 | 10.1 | 90 |
| ***A. mangium*** | | | | | **18** | SAMFORD | 42 | 9.7 | 90 |
| **1** | MOREHEAD | 41 | 12.5 | 60 | **19** | OLD LOCKART AIR-STRIP | 36 | 9.4 | 90 |
| **2** | MOREHEAD | 53 | 13.5 | 60 | **20** | OLD LOCKART AIR-STRIP | 33 | 9.8 | 90 |
| **3** | MOREHEAD | 51 | 12.9 | 60 | **21** | OLD LOCKART AIR-STRIP | 36 | 12.6 | 60 |
| | | | | | **22** | PROV.SEED ORCHARD | 37 | 12.2 | 90 |
| | | | | | **23** | PROV.SEED ORCHARD | 51 | 9.4 | 90 |
| | | | | | **24** | PROV.SEED ORCHARD | 49 | 13.0 | 90 |

## 3.3. Vegetative multiplication of CPTs of Eucalypts

### 3.3.1. *E. tereticornis and E. urophylla*

The cuttings rooted and sprouted within 3-4 weeks. The percentage of success ranged between 20 and 90 per cent. After initiation of rooting and sprouting (after 25 days), all the cuttings were transferred to a hardening unit provided with shade net to reduce sunlight and temperature. Water was sprayed frequently using sprinkler or fine sprayer for the first few days. Di-ammonium phosphate (DAP) and micronutrient mix such as Multiplex were applied as foliar spray once in five days or as and when required. After two weeks of hardening, the root trainers along with stands were transferred to the second hardening unit provided with UV stabilized polythene sheets, where the frequency of watering was reduced step by step. After one month, the ramets were kept directly under the sun with watering as required (Fig. 4). Fertilizer (NPK mixture) was also supplied to the growing ramets if required. The plants attained plantable height (30-40 cm) within four months. The identity of each clone was maintained by proper labeling. Coppice shoots were harvested 2-3 times from each stump at periodical intervals for production of ramets.

### *3.3.2. E. grandis*

#### *3.3.2.1. Construction of mist chamber at Devikulam*

The building consisted of an office room and a store room, each of 2.9 m x 2.9 m and an attached potting shed of 5.9 m x 5.9 m size (Fig. 5). The total plinth area is 55.51 $m^2$. The roof is provided with GI sheet supported by purlins. The clonal multiplication facility consisted of two mist chambers, erected using GI pipes and GI flats and covered by UV stabilized polythene sheets and shade net. One mist chamber accommodated two trench type propagation chambers and in the other, provision for two poly tunnels with misting facilities was provided. The clonal nursery consisted of clonal multiplication area, provenance trial plot of poplar and *Paulownia* and a eucalypts progeny trial plot, all

accommodated in one ha area protected by chain link fence. Irrigation facilities supported by two water pumps, one for lifting water from a pond, 35 m away from the nursery and another pump for working the misting system, were provided. The construction was completed during February 2002.

*3.3.2.2. Vegetative multiplication*

The coppice shoots produced by the stumps (Fig. 6) were harvested during May 2001 and processed as mentioned in para 2.2.1. for *E. tereticornis.* Generally, the rootability of cuttings from CPTs was poor and the percentage of rooting varied between 1.2 and 50.2.. Twenty CPTs were rejected either due to insufficient coppice shoot production or poor rootability. Fifty per cent of the clones were used to raise clonal multiplication area and planted in 1.5 m x 1.5 m spacing and the rest were used for planting in clonal testing area at Devikulam.

## 3.4. Vegetative multiplication of CPTs of *Acacia* spp.

### 3.4.1. Coppice shoot production

None of the stumps of the 4-year-old CPTs *ie*. those CPTs which were cut at 60 cm and 90 cm height produced coppice shoots suitable for vegetative multiplication. All the stumps dried gradually (Fig. 7). Even though, a few of the 90 cm-height stumps showed initiation of coppice shoots, none of them produced healthy shoots. Such unhealthy shoots failed to produce roots when kept in mist chamber for rooting.

The main reason for not producing healthy shoots is that all the four species are poor coppicers, especially after 3 years of age. As water source was far away, it was not possible to irrigate the mother trees. Absence of watering also might be a reason for absence of sprouting of stumps. Pruned branches of more than 10 cm girth produced new shoots after pre-monsoon rain in 2002.

The 18-month-old mangium hybrid and *A. mangium* clones produced satisfactory number of coppice shoots at 90 cm height, and on branches even without irrigation. But irrigation greatly enhanced the shoot production. The most vigorous coppice shoot production was shown by 6-month-old mangium hybrid and *A. mangium* clones (Fig. 8). It was easy to make a hedge garden when the plants were cut at 6-month-old stage at 90 cm height.

The highest rooting percentage was shown in red soil (Fig. 9 and 10) while no rooting and sprouting was observed when compost alone was used as the potting medium. It was encouraging to note that coir pith supported rooting with (Fig. 11) 90 per cent success (Table 4).

Table. 4. Rooting percentage of mangium clones in various potting media in mist chamber

| Sl. No. | Componenets of potting mixture taken in trays and kept in mist chamber for rooting | Percentage of rooting and sprouting |
|---|---|---|
| 1 | Red soil | 95 |
| 2 | Compost | Nil |
| 3 | Sand | 90 |
| 4 | Vermiculite | 90 |
| 5 | Normal soil | 80 |
| 6 | Washed coir pith | 90 |
| 7 | Compost:soil (1:1) | 60 |
| 8 | Compost:vermiculite (1:1) | 40 |
| 9 | Compost:sand(1:1) | 20 |
| 10 | Compost:soil:vermiculite(2:1:1) | 80 |
| 11 | Compost:soil:vermiculite(3:1:1) | 40 |
| 12 | Compost:soil:vermiculite(1:1.5:1.5) | 90 |

## 3.5. Supply of clones to the forest department

### *3.5.1. Supply of new clones*

Fifty ramets each of clone No. KFRI 86 of *E. tereticornis*, KFRI 99, KFRI 100 and KFRI 101 of *E. urophylla* and KFRI M-1 of *A. mangium* have been supplied to the Central Nurseries at Chettikulam and Nilambur for raising CMA and CTA. These clones have also been planted at Kottappara for continued monitoring of growth and disease resistance. Clones of *A. auriculiformis, A. crassicarpa, A. peregrina* and *A mangium* are being multiplied for supply in sufficient number to the Central Nurseries.

A total of 68,450 ramets of 18 Clones of *E. tereticornis* and *E. camaldulensis* were supplied to the Kerala Forest Department during the planting season of 2000 and 2001 (Table 5), and 5000 ramets of 10 mangium hybrid clones (para 2.3.2.2.) of West Coast Paper Mills, Dandeli during 2001. Also, about 10000 ramets of eight eucalypts clones developed prior to year 2000 and 1200 ramets of mangium hybrid clones of West Coast Paper Mills, Dandeli have been supplied to the Central Circle this year. Two kg of half-sib seeds of Australian provenance (Morehead) of *Acacia mangium* were also supplied to the Central Nursery, Kulathupuzha during 2001.

Table 5. List of eucalypt clones supplied to the Kerala Forest Department during 2000 to 2002

| Sl. No. | Clone No. | Provenance/origin of clone | 2000* | 2001** | 2002@ |
|---|---|---|---|---|---|
| *E. tereticornis* | | | | | |
| 1 | KFRI 14 | Kennedy River, Qld[1] | 800 | - | 750 |
| 2 | KFRI 16 | Morehead River, Qld | 2400 | 3700 | 2000 |
| 3 | KFRI 28 | 80 Km NNW Cook town, Qld | 800 | - | - |
| 4 | KFRI 38 | East of Kupiano | 400 | - | - |

| | | | | | |
|---|---|---|---|---|---|
| 5 | KFRI 43 | Ravenshoe, Qld | 1600 | 2900 | 500 |
| 6 | KFRI 49 | Morehead River, Qld | 1600 | - | 750 |
| 7 | KFRI 56 | Ravenshoe, Qld | 1600 | 2700 | 750 |
| 8 | KFRI 65 | Kennedy Creek Pen Dev Road, Qld | 800 | - | 750 |
| *E. camaldulensis* | | | | | |
| 9 | KFRI10 | Cape River, Qld | 400 | - | - |
| 10 | KFRI 23 | West of Normanton, Qld | 3200 | 1400 | - |
| 11 | KFRI 25 | Katherine, NT | 11200 | 17000 | 4000 |
| 12 | KFRI 54 | Cape River, Qld | 3600 | 6150 | - |
| 13 | KFRI 55 | Victoria River, Nt | 800 | - | - |
| 14 | KFRI 68 | Cape River, Qld | 800 | 400 | - |
| *ITC BHADRACHALAM CLONES* | | | | | |
| 15 | BCM | ITC, BHADRACHALAM | - | - | 500 |
| 16 | BCM 7 | ITC, BHADRACHALAM | 800 | - | - |
| 17 | BCM 130 | ITC, BHADRACHALAM | 2400 | 1000 | - |
| New clones | | | | | |
| 18 | KFRI 86 | *E. tereticornis* | - | - | 100 |
| 19 | KFRI 99 | *E. urophylla* | - | - | 100 |
| 20 | KFRI 100 | *E. urophylla* | - | - | 100 |
| 21 | KFRI 101 | *E. urophylla* | - | - | 100 |
| | | Total | 33200 | 35250 | 10400 |
| | | Grand total | | | 78850 |

*All the clones were supplied to Palode Range

**Supplied to Kodanad and Wadakkancherry Ranges and Central Nursery, Kulathupuzha

@Ready for supply to Central Circle.

## 3.6. Evaluation of eucalypt clones supplied to the forest department

### 3.6.1. Evaluation of growth

Table 6 gives an indication of the growth in terms of mean GBH and height of KFRI clones and Bhadrachalam clones up to 3 years in approximately 50 ha area. KFRI 23, KFRI 25 and KFRI 43 have shown the highest GBH of 30 cm in 20-month-old plantation

Table. 6. Growth of eucalypt clones planted in various forest ranges

| Sl. No. | Clone | 20-month-old plantation (planted in 2000) | | | 2-year-old plantation (planted in 2000) | | | 3-year-old plantation (planted in 1999) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Palode* | | | Anchal** | | | Kodanad* | | | Arienkavu* | | |
| | | Total ramets | Maxi-mum GBH (cm) | Max-mum heig-ht (m) | Total ramets | Mean GBH (cm) | Mean hei-ght (m) | Total ramets | Mean GBH (cm) | Mean hei-ght (m) | Total ramets | Mean GBH (cm) | Mean hei-ght (m) |
| ***E. tereticornis*** | | | | | | | | | | | | | |
| 1 | KFRI 14 | 800 | 28 | 7.7 | - | - | - | 160 | 19.0 | 7.9 | 540 | 27.3 | 12.7 |
| 2 | KFRI 16 | 2400 | 22 | 7.0 | - | - | - | 3460 | 24.5 | 10.1 | 2060 | 26.7 | 12.8 |
| 3 | KFRI 28 | 800 | 29 | 8.9 | - | - | - | - | - | - | 200 | 26.1 | 12.5 |
| 4 | KFRI 35 | | | | - | - | - | - | - | - | - | 24.1 | 11.0 |
| 5 | KFRI 38 | 400 | 27 | 7.4 | - | - | - | 200 | 27.5 | 10.3 | 280 | 24.3 | 12.0 |
| 6 | KFRI 43 | 1600 | 30 | 8.0 | | | | | | | | | |
| 7 | KFRI 49 | 1600 | 27 | 7.6 | - | - | - | 400 | 30.4 | 11.2 | 320 | 28.0 | 12.8 |
| 8 | KFRI 56 | 1600 | 28 | 7.8 | - | - | - | 100 | 23.2 | 11.1 | - | | |
| 9 | KFRI 58 | | | | - | - | - | - | - | - | 140 | 27.2 | 12.3 |
| 10 | KFRI 62 | | | | - | - | - | - | - | - | 200 | 26.0 | 11.6 |
| 11 | KFRI 65 | 800 | 26 | 7.2 | - | - | - | 600 | 27.8 | 11.9 | 780 | 26.3 | 12.6 |
| ***E. camaldulensis*** | | | | | | | | | | | | | |
| 12 | KFRI 10 | 400 | 27 | 7.5 | 1450 | 10.0 | 4.3 | 560 | 22.3 | 10.5 | 300 | 24.3 | 11.5 |
| 13 | KFRI 23 | 3200 | 30 | 7.5 | - | - | - | 300 | 27.7 | 11.8 | 1040 | 27.9 | 13.4 |
| 14 | KFRI 24 | | | | - | - | - | 200 | 24.9 | 11.7 | 100 | 26.2 | 11.5 |
| 15 | KFRI 25 | 11200 | 30 | 8.0 | 4000 | 8.0 | 3.9 | 7100 | 29.6 | 12.3 | 3400 | 29.0 | 13.5 |
| 16 | KFRI 54 | 3600 | 24 | 7.0 | - | - | - | 1200 | 24.0 | 10.5 | 760 | 23.2 | 12.4 |
| 17 | KFRI 55 | 800 | 28 | 7.6 | - | - | - | 200 | 25.2 | 9.7 | 390 | 29.2 | 13.9 |
| 18 | KFRI 59 | | | | - | - | - | - | - | - | 190 | 24.3 | 12.5 |
| 19 | KFRI 68 | 800 | 28 | 7.6 | - | - | - | 540 | 21.2 | 9.2 | 200 | 29.3 | 13.5 |
| ***E. pellitta*** | | | | | | | | | | | | | |
| 20 | KFRI 26 | | | | 2100 | 14.0 | 4.3 | - | - | - | - | - | |
| **Bhadrachalam clones** | | | | | | | | | | | | | |
| 21 | BCM 3 | | | | 3450 | 22.0 | 9.5 | 200 | 26.8 | 13.3 | 80 | 28.7 | 14.1 |
| 22 | BCM 6 | | | | - | - | - | - | 25.7 | 9.7 | - | - | - |
| 23 | BCM 7 | 800 | 22 | 6.0 | - | - | - | 200 | 21.3 | 9.7 | - | 25.2 | 11.8 |
| 24 | BCM 10 | | | | 500 | 18.0 | 6.7 | - | - | - | - | - | - |
| 24 | BCM 83 | | | | 3500 | 11.0 | 4.4 | 200 | 23.0 | 9.5 | 600 | - | - |
| 25 | BCM119 | | | | 1300 | 8.0 | 3.8 | - | - | - | - | - | - |
| 26 | BCM 128 | | | | 1650 | 9.0 | 3.8 | - | - | - | - | - | - |
| 27 | BCM 130 | 2400 | 21 | 6.0 | 2400 | 19.5 | 7.7 | 400 | 18.8 | 8.4 | 320 | - | - |
| Total | | 33200 | | | 20350 | | | 16020 | | | 11900 | | |

*Supplied by KFRI

**Supplied by Central Nursery, Kulathupuzha

raised at Palode. KFRI 28 showed the maximum height of 8.9 m. In the 2-year-old plantation at Anchal, highest GBH of 22 cm and height of 9.5 m were shown by the Bhadrachalam clone BCM 3. At Kodanad, in the 3-year-old plantation, the highest GBH was shown by KFRI 49 (30.4 cm) and maximum height by the Bhadracahalam clone

BCM 3 (13.3 m), while at Arienkavu, KFRI 68 gave the highest GBH of 29.3 cm and BCM 3 the maximum height of 14.1 m. In general, among the KFRI clones, KFRI 23, KFRI 25, KFRI 28, KFRI 43, KFRI 49, KFRI 65 and KFRI 68, and among Bhadrachalam clones BCM 3 are the best clones in terms of growth.

When volume of timber was estimated in the 3-year-old plantation (Table 7), wide variation in productivity of the same clone was observed between Kodanad and Arienkavu. KFRI 25 showed the highest mean annual increment (MAI) (19.31 $m^3$ $ha^{-1}$ $yr^{-1}$) followed by KFRI 49 (19.01 $m^3$ $ha^1$ $yr^1$ ) at Kodanad (Chart 1). At Arienkavu (Chart 2), KFRI 55 (20.63 $m^3$ $ha^{-1}$ $yr^{-1}$) gave the highest MAI followed by KFRI 68 (20.31 $m^3$ $ha^{-1}$ $yr^{-1}$) and Bhadrachalam clone BCM 3 (20.16 $m^3$ $ha^{-1}$ $yr^{-1}$). Among Bhadrachalam clones, only BCM 3 is at par with the best KFRI clones.

Table 7. Productivity of 3-year-old (approximately) KFRI- and Bhadrachalam eucalypt clones planted in Kodanad and Arienkavu forest ranges during 1999

| Sl. No. | Clone No. | Mean annual increment $m^3 ha^{-1} yr^{-1*}$ | |
|---|---|---|---|
| | | Kodanad | Arienkavu |
| ***E. tereticornis*** | | | |
| 1 | KFRI 14 | 5.91 | 16.82 |
| 2 | KFRI 16 | 11.48 | 16.19 |
| 3 | KFRI 28 | - | 15.19 |
| 4 | KFRI 38 | 14.67 | 12.78 |
| 5 | KFRI 49 | 19.01 | 17.80 |
| 6 | KFRI 56 | 11.00 | - |
| 7 | KFRI 58 | - | 16.30 |
| 8 | KFRI 62 | - | 14.26 |
| 9 | KFRI 65 | 16.62 | 15.52 |
| ***E. camaldulensis*** | | | |
| 10 | KFRI 10 | 9.77 | 12.38 |
| 11 | KFRI 23 | 16.39 | 18.31 |
| 12 | KFRI 24 | 13.17 | 14.39 |
| 13 | KFRI 25 | 19.31 | 19.89 |
| 14 | KFRI 54 | 11.31 | 11.93 |
| 15 | KFRI 55 | 11.81 | 20.63 |
| 16 | KFRI 59 | - | 13.17 |
| 17 | KFRI 68 | 8.08 | 20.31 |
| **Bhadrachalam clones** | | | |
| 18 | BCM 3 | 16.80 | 20.16 |
| 19 | BCM 6 | 12.29 | - |
| 20 | BCM 7 | 8.44 | 13.57 |
| 21 | BCM 83 | 9.71 | - |
| 22 | BCM 130 | 6.00 | - |

* 1600 trees $ha^{-1}$ in 2.5 x 2.5 m spacing.

Chart 1. Mean annual increment (MAI) in estimated volume ($m^3$ $ha^{-1}$ $year^{-1}$ ) of 3-year-old KFRI and Bhadrachalam (BCM) clones at Kodanad

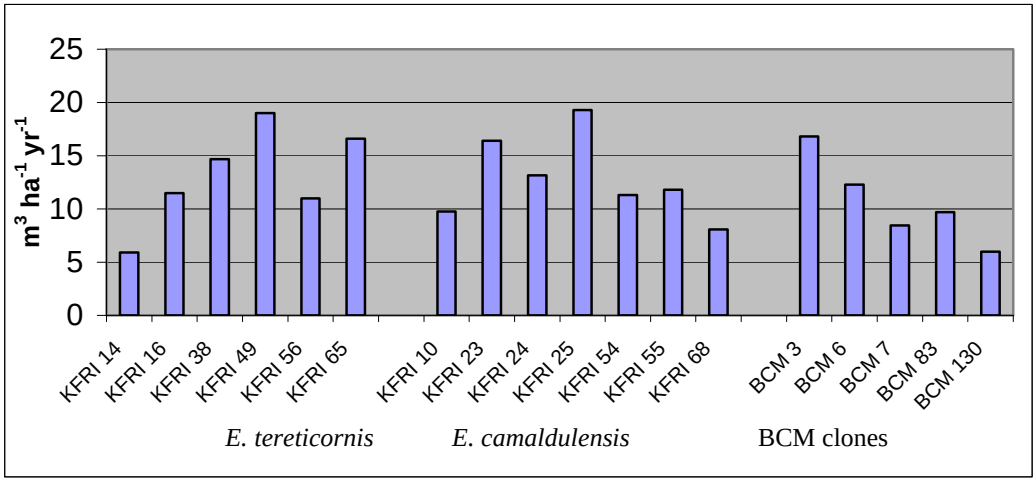
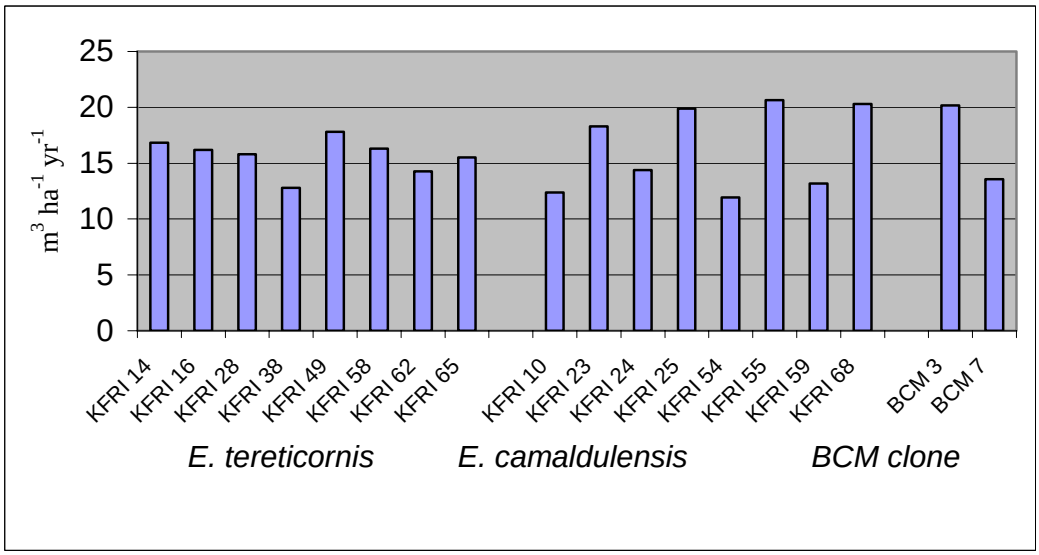



Chart 2. Mean annual increment (MAI) in estimated volume ($m^3$ $ha^{-1}$ $yr^{-1}$ ) of 3-year-old KFRI and Bhadrachalam (BCM) clones at Arienkavu



Among the younger plantations also (Table 8), KFRI 25, KFRI 43 and BCM 3 have shown the superiority in height throughout Kerala from Vazhikkadavu in Nilambur North Division to Arienkavu in Thenmala Division.

Table 8. Mean height (m) of 9-month-old KFRI and Bhadrachalam clones planted in 2001 in various forest ranges

| Sl. No. | Clone No. | Forest Range | | | | |
|---|---|---|---|---|---|---|
| | | Vazhikk-adavu* | Wadakk-ancherry** | Kodanad** | Arienkavu*** Section | |
| | | | | | Karayala-rmethu | Thalappara |
| ***E. tereticornis*** | | | | | | |
| 1 | KFRI 14 | - | - | - | - | 1.80 |
| 2 | KFRI 16 | - | 0.70 | - | - | - |
| 3 | KFRI 43 | 4.43 | 0.90 | - | - | - |
| 4 | KFRI 56 | 4.12 | 0.72 | - | 1.55 | 1.38 |
| 5 | KFRI 65 | 3.19 | - | - | - | - |
| ***E. camaldulensis*** | | | | | | |
| 6 | KFRI 23 | - | - | - | - | - |
| 7 | KFRI 25 | 4.41 | - | 2.19 | 1.56 | 2.11 |
| 8 | KFRI 54 | 4.01 | - | 1.32 | - | - |
| **Bhadrachalam clones** | | | | | | |
| 9 | BCM 3 | 4.52 | - | - | 1.43 | - |
| 10 | BCM 10 | 4.06 | - | - | - | - |
| 11 | BCM 83 | - | - | - | 1.10 | - |

*Supplied by Central Nursery, Nilambur

**Supplied by KFRI

***Supplied by Central Nursery, Kulathupuzha

### 3.6.2. Disease susceptibility of clones planted in Kodanad, Arienkavu and Palode ranges

The clones planted in clonal multiplication area (CMA) in Central nurseries of Nilambur and Kulathupuzha and CMA of KFRI at Kottappara were more vulnerable to infection

Table 9. Incidence of Cylindrocladium leaf blight and pink disease in clones raised in Central Nurseries of Kerala Forest Department and in clonal nursery of KFRI

| Sl. No. | Clone No. | Disease incidence | | | | | |
|---|---|---|---|---|---|---|---|
| | | Central Nursery Nilambur | | Central nursery Kulathupuzha | | KFRI nursery Kottappara | |
| | | CLB | Pink disease | CLB | Pink disease | CLB | Pink disease |
| *E. tereticornis* | | | | | | | |
| 1 | KFRI 14 | L-M | NIL | M | NIL | L | NIL |
| 2 | KFRI 15 | - | - | - | - | L | NIL |
| 3 | KFRI 16 | M | NIL | L | L | L | L |
| 4 | KFRI 20 | - | - | - | - | L | NIL |
| 5 | KFRI 21 | - | - | L | - | M | M |
| 6 | KFRI 28 | M | NIL | - | - | L | M |
| 7 | KFRI 33 | - | - | L | NIL | L | L |
| 8 | KFRI 43 | L-M | L | M | NIL | L | NIL |
| 9 | KFRI 44 | - | - | - | - | L | NIL |
| 10 | KFRI 49 | S | NIL | - | - | M | L |
| 11 | KFRI 56 | M | NIL | M | NIL | M | L |
| 12 | KFRI 65 | L-M | M | - | - | L | NIL |
| *E. camaldulensis* | | | | | | | |
| 13 | KFRI 7 | - | - | - | - | S | S |
| 14 | KFRI 8 | - | - | - | - | S | S |
| 15 | KFRI10 | M | NIL | S | L | M | L |
| 16 | KFRI 22 | - | - | - | - | L | L |
| 17 | KFRI 23 | M | NIL | M | NIL | L | NIL |
| 18 | KFRI 24 | M | NIL | - | - | L | NIL |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 19 | KFRI 25 | L-M | L | L | L | L | NIL |
| 20 | KFRI 39 | - | - | - | - | M | M |
| 21 | KFRI 45 | - | - | - | - | M | L |
| 22 | KFRI 54 | L-M | M | - | - | M | L |
| 23 | KFRI 59 | M | L | - | | L | L |
| 24 | KFRI 68 | - | - | - | - | L | NIL |
| 25 | KFRI 70 | - | - | - | - | M | L |
| *E. urophylla* | | | | | | | |
| 20 | KFRI 26 | NIL | NIL | NIL | NIL | NIL | NIL |
| 21 | KFRI 63 | - | - | - | - | L | L |
| Eucalyptus hybrid | | | | | | | |
| 22 | Control | S | S | S | S | S | S |
| Bhadrachalam clones | | | | | | | |
| 23 | BCM 3 | M | NIL | L | L | L | NIL |
| 24 | BCM 6 | L-M | NIL | L | L | L | L |
| 25 | BCM 10 | L-M | NIL | M | NIL | L | L |
| 26 | BCM130 | L | NIL | S | NIL | S | L |

caused by Cylindrocladium leaf blight (Fig. 12) and pink disease (Fig. 13) probably because of the close spacing of plants ie. 1m x 1m or 1.5 m x 1.5 m compared to 2.5m x 2.5 m in the plantations. While pink disease was found almost absent in plantation (monitored up to 3 years age), cylindrocladium leaf blight was found affecting clones such as KFRI 10, KFRI 14, KFRI 54 and Bhadrachalam Clones BCM 7, BCM 83, BCM 119 and BCM 130. Compared to other tolerant clones, the growth of these clones was better. Hence, it was advised to avoid deploying these clones in high rainfall localities.

## 3.7. Establishment of provenance trial plots of *Eucalyptus nitens, E. globulus, Paulownia* and Poplar

Provenance trial plots of *E. nitens* and *E. globulus* could not be established as the seeds of new provenances were not readily available with CSIRO, Australia. We are awaiting for the supply of the provenance seeds.

### 3.7.1. Survival of *Paulownia* in nursery

About 40 per cent of the seedlings brought from TERI (Fig. 14) and about 10 per cent of the plants brought from Kozhikkode wilted and dried in the nursery itself. The main reason for the wilting was found to be root and collar infection caused by *Fusarium* spp. Root infection was found in *P. corena* also but to a lesser extent.

The out-planted seedlings also showed wilting and drying at Kodanad. When observed, the roots showed scar of grub attack. Such roots also showed *Fusarium* infection. Disease incidence was very high during rainy season. *P. coreana* seedlings (Fig. 15) which were out-planted and watered also showed grub damage. Healthy plants of both the species showed initial large leaves and fast growth (Fig. 16) which slowed when the seedlings reached a height of 50-75 cm. Subsequently, the growth retarded. Two of the *P. fortunei* plants which attained a height of almost 1 m (Table 10), flowered at 6 months (Fig. 17). But after flowering the plant defoliated in March and the growth stopped subsequently. *P. coreana* plants have not flowered so far.

At Devikulam, the apical portion of *P. fortunei* plants wilted and dried during November – January. But subsequently, during March 2002, new shoots emerged on most of the plants. The drying up of terminal branches during winter is a character of some species of *Paulownia,* which show pseudo-dichotomous branching. *Paulownia* plants are reported to dry up below $10^0$ C. It grows well in loamy soil with adequate moisture. It is too early to conclude about the growth of *Paulownia* in the predominantly lateritic soil of Kerala.

Table 10. Survival and growth of *Paulownia* out-planted at Kottappara and Devikulam

| Species | Age of plants | Percentage of survival | | Growth ( mean height in cm) | |
|---|---|---|---|---|---|
| | | Kottappara | Devikulam | Kottappara | Devikulam |
| *P. fortunei* | 7 months | 50 | 48 | 51 | 20 |
| *P. coreana* | 2 months | 58 | - | 46 | - |

### 3.7.2. Poplar

The axillary bud of poplar cuttings (Fig. 18) sprouted within one week (Fig. 19). Weeds were kept under control. Only single shoot was retained per cutting. The plants will be out-planted in the field during January-February next year when they are expected to be leafless. The height of 40-day-old-cutting planted at Kottappara and Devikulam is provided in Table 11.

Table 11. Height measurement of 40-day-old poplar cuttings planted at Kodanad Range (at Kottappara) and Devikulam Range

| Clone No. | Height (cm) | | Survival percentage | |
|---|---|---|---|---|
| | Kottappara (Kodanad) | Devikulam | Kottappara (Kodanad) | Devikulam |
| L 200/84 | 21.11 | 15.05 | 100 | 87.8 |
| L 34/82 | 28.67 | 16.64 | 100 | 67.0 |
| S7C2 | 24.40 | 9.68 | 50 | 85.2 |

## 3.8. Training of forest staff on vegetative multiplication of eucalypts and acacia, and extension visits

### 3.8.1. Training of forest staff

i. One-day-practical training was provided to staff of the Kulathupuzha and Nilambur Central Nurseries on Identification of CPTs of eucalypts and Acacia and vegetative multiplication of Eucalypts and Acacia clones during January 2001. There were eight participants. Study materials on identification of CPTs and methods adopted for vegetative propagation were provided to the participants (Fig. 20).

ii. A. 3-day-workshop/training on "Identification of provenances of new fast growing species and development of new clones of eucalypts and acacia" was held during 14-16 March 2002. The workshop comprised (1) two days of lecture classes on 12 topics covering provenances, candidate plus trees, vegetative multiplication, clonal forestry, root trainer technology, and aerobic composting and (2) one-day field trip/practical training at the KFRI clonal nursery and provenance trial plots of eucalypts and acacia at Kottappara (Kodanad) and field visit to show (a) growth of root trainer-raised and poly bag-raised seedlings at Kottappara, (b) 6-month-old and 30-month-old clonal plantation raised by KFD at Kodanad and (c) large scale production of compost and root trainer seedling at Central nursery, Chettikulam. The handouts given included two books on Aerobic Composting, and Root Trainer Technology and Clonal propagation, 10-page-write up on clonal propagation of eucalypts and acacia in Malayalam, its English version, photocopy of methods involved in production and multiplication of mangium hybrid and abstract of all the lecture classes. There were 15 participants which included seven Range officers, two Deputy Range officers, four Foresters and two Forest Guards (Fig. 21).

### 3.8.2. Extension visits to Central Nursery, Kulathupuzha and Nilambur

i. During 2000-2002, eight visits were made by the Principal Investigator of the project to the Central Nursery, Kulathupuzha and to the Central Nursery, Nilambur. The visits were made either on request from the Range officer /DFO/Conservator or as routine extension visit envisaged as part of the project work. During these visits, the problems faced by the central nursery staff for mass clonal propagation was discussed and practical solutions recommended. Modifications to be adopted to enhance the efficiency of the mist chamber for vegetative propagation of eucalypts and acacia clones were also suggested.

ii. The PI participated in a discussion on further improving the clonal propagation facility, maintenance of CMA and the procedure to be adopted for selection of mangium hybrid clones and their vegetative multiplication at Central Nursery, Kulathupuzha in the presence of DFO, Thenmala Division and RO on 26$^{th}$ November 2001. The discussion in Central Nursery, Nilambur was held in the presence of DFO, Nilambur North Division and RO for planning the proper maintenance of CMA of eucalypts and acacias and also for finalising the methods to be followed for vegetative multiplication of mangium hybrid and acacia clones procured from Mysore Paper Mills, Shimoga and West Coast Paper Mills, Dandeli.

# 4. DISCUSSION AND CONCLUSIONS

The clonal forestry programme has brought about unprecedented increase in yield of pulpwood species. Reviewing the experience on eucalypt clonal plantation programme undertaken by ITC Bhadrachalam Paper Boards Ltd (ITC-BPL), Venkatesh and Kulkarni (2001) reported productivity ranging from 22 to 58 $m^3 ha^{-1} yr^{-1}$ from clones compared to 6 to 8 $m^3 ha^{-1} yr^{-1}$ from seed origin plantations in Andhra Pradesh. The farmers are able to reduce the rotation period to 4-5 years from 8-10 years. So far 23,000 ha have been planted using Bhadrachalam clones in India. Taking the experience of ITC-BPL, Andhra Pradesh Forest Development Corporation (APFDC) raised clonal eucalypt plantations using Bhadrachalam clones initially and subsequently produced by APFDC itself. The Bhadrachalam clones are adapted to regions where the rainfall is less than 50 per cent of what we get in Kerala. Many of these clones are developed to suit semi-arid zones but with irrigation facilities. Hence, most of these clones may not be suitable to Kerala conditions where the warm humid climate causes serious disease problems. Hence, it is better to develop our own clones adapted to high rainfall, long dry period and undulating terrain, characteristics of this state. It was with this intention that KFRI undertook activities for development of eucalypt clones from Australian provenances suitable to Kerala.

## 4.1. New candidate plus trees and their vegetative multiplication

Among the 21 CPTs of *E. tereticornis,* and *E. urophylla* identified, 10 clones are being screened against diseases and tested for productivity. The *E. urophylla* clones are expected to be superior because it seems to be a hybrid (produced through natural cross) between *E. urophylla* and *E. tereticornis.* But, this is yet to be confirmed. Hybrid between *E. urophylla* and *E. grandis* has been developed as high yielding 'Uro-grandis' clones in Brazil and other countries.

With the construction of clonal propagation facility at Devikulam, it is possible to produce superior *E. grandis* and *E. globulus* clones suitable for high ranges. With the

establishment of this facility, we will be able to develop clones of six eucalypts species viz. *E. tereticornis, E. camaldulensis, E. pellita and E. urophylla* at KFRI clonal nursery at Kottappara and *E. grandis* and *E. globulus* at KFRI clonal nursery, Devikulam. The CMA established during 2001 at Devikulam using CPTs selected from existing plantations will yield coppice shoots during 2003 and clones will be supplied to KFD during the planting season. Simultaneously, new CPTs will be identified from the Australian provenance trial plots established at Muthanga and Vallakkadavu during 1993.

Even though, 80 CPTs were identified among the various Australian provenances of *A. auriculiformis, A.crassicarpa, A. peregrina* and *A. mangium*, unfortunately, these superior trees were lost as they did not produce coppice shoots properly. This was mainly due to loss of juvenility because of higher age and absence of irrigation facility. Attempt to obtain juvenile coppice shoots from branches during rainy season was a partial success and we hope to develop new clones during the current year. A few clones already obtained are undergoing screening. The Kulathupuzha Central Nursery staff were able to select and vegetatively multiply CPTs from 5-year-old KFRI provenance trial plot of Australian seed origin at Kulathupuzha based on the procedure supplied by KFRI. The mangium hybrid clones obtained from West Coast Paper Mill, Dandeli, and from Mysore Paper Mills, Shimoga are fast growing but highly branching. But it is comparatively easy to root them in coirpith or in red soil where the success is more than 90 per cent. The performance of the hybrid clones in Kerala is yet to be assessed. The clones, when raised in plantation scale may require an initial pruning of branches. This practice may cause heart rot problem after 7-8 years. But, it is yet to be confirmed in Kerala.

A remarkable feature of clones of *Acacia* spp. and mangium hybrid clones was that, unlike eucalypts, a hedge garden made by pruning the clones at 90 cm height during 6-18 months of age provided assured supply of cuttings. Watering and fertilizer application highly enhanced the yield of healthy coppice shoots and improved rooting. The hedge garden should be pruned periodically even if there is no clonal programme; otherwise the CMA will over grow too much to become unsuitable for production of coppice shoots. Another major difference between the procedure for vegetative multiplication of

eucalypts and acacia is that for acacia, the apical portion with 4-5 leaves and the terminal bud is the most appropriate cutting for rooting. However, leaves have to be pruned as done for eucalypt cuttings. The middle portions of the stem also will root but to a lesser extent.

Pink disease is the only major disease problem observed in *A. auriculiformis, A. mangium* and mangium hybrid. These clones have to be rejected even if the incidence is noticed in the CMA. Except for a transient pest which chews new flush of *A. auriculiformis, A. mangium* and Mangium hybrid, there is no pest problem to the clones of Acacia spp.

## 4.2. Supply of clones to the forest department and their field evaluation

During the project period, about 79,000 ramets of 20 KFRI clones of three species viz. *E. tereticornis* (9 clones), *E. camaldulensis* (8 clones) and *E. urophylla* (3 clones) and three Bhadrachalam clones have been supplied to the forest department. Substantial amount of the project money was used to meet the expenditure involved for the production of planting stock. All the ramets were supplied to raise plantations by KFD. The clonal plantation (>100 ha) raised using these clones and the clones distributed by the Central nurseries of Kulathupuzha and Nilambur and planted in various ranges throughout Kerala gave a preliminary indication of the success of the eucalypt clonal forestry programme initiated by the KFD during the last three years. The planting of Bhadrachalam clones along with KFRI clones and the side by side comparison of the performance of the two sets of clones gave an indication of the superior performance and adaptability of the KFRI clones for Kerala.

Since the first-planted clonal plantations (about 17 ha) are just reaching only 3 years by June-July 2002, it is too early to conclude about comparative performance of different clones *vis.-a-vis*. site conditions. The clones have to attain at least half the rotation period to obtain an indication of their productivity and comparative merit. However, when the growth of clones up to 3 years considered in terms of mean annual increment in volume, the KFRI clones viz. KFRI 14, KFRI 16, KFRI 49, KFRI 58, KFRI 65 *(E. tereticornis*

clones) and KFRI 23, KFRI 25, KFRI 55, KFRI 68 (*E. camaldulensis*) and BCM 3 (Bhadrachalam clone) have yielded above 16 $m^3$ $ha^{-1}$ $yr^{-1}$ at least in one location. This is more than double the estimated MAI of the existing *Eucalyptus* 'hybrid' plantations. Early growth data showed that, generally, productivity of KFRI clones are more than that of the most adapted BCM clones. The height and GBH of clones depend upon not only on spacing and soil fertility but also on aspect, terrain, wind and other microclimatic conditions. An example was found in the case of 2-year-old clone, KFRI 25 planted at Anchal in 2000. Though, KFRI 25 performed better than any other clone in almost all other places, the performance was poor at Anchal when it was planted on the eastward slope of a hillock while clones planted in the valley showed higher GBH and height. Actually, the clone was unable to trap sufficient sunlight; the soil was poorer uphill and generally the hilltop was windy.

Success of a clone depends upon not only on fast growth and disease resistance, but also on rootability. Since, rootability is genetically controlled, it is difficult to enhance the rooting success percentage substantially in mist chambers through other means. Hence, clones which show low rootability get low priority. Among the BCM clones, BCM 6 and BCM 10 are difficult-to-root clones.

Even though, it is not possible to conclude about the final productivity of the clones now, we got an indication of the susceptibility of the clones to cylindrocladium leaf blight and pink disease. Generally, persistence of squally weather for several days causes CLB infection of various intensities to the clones. While KFRI 26 (*E. pellitta*) is resistant against CLB, other clones are susceptible to some extent. But the better performing clones such as KFRI 25, KFRI 65, BCM 3, etc. are almost resistant. The susceptible clones are KFRI 10, KFRI 14, KFRI 49, BCM 10, BCM 130, BCM 83, BCM 7 and BCM 119. However, if the clones are distributed in less rainfall sites, infection will be less. Even though, pink disease was not observed in plantations except on BCM 7, BCM 83 and KFRI 7, the disease was observed in CMA at Central Nurseries on a few more clones. Hence, some of these clones had been uprooted from the central nurseries. The increased incidence of disease in CMA was due to the higher density of plants (1.5 m x

1.5 m spacing) than in the plantations (2.5 m x 2.5 m spacing). The increased density of plants will increase the density of fungal inoculum.

## 4.3. Establishment of new provenance trials

The adaptability of *Paulownia fortunei* and *P. coreana*, two important agroforestry species of China, and *Populus deltoides*, an important pulpwood species of northern India was tried in this project. The six-month growth of both the *Paulownia* spp. showed poor performance in respect of growth and survival. The species were unable to withstand heavy rain, lateritic soil and low temperature in high ranges and hence, there is not much scope for their introduction in Kerala.

Poplar, an important agroforestry and plantation species, is widely planted in northern India for its high timber and fibre value. It grows well above $28^0$ N latitude in India in Jammu and Kashmir, Punjab, Haryana, Uttar Pradesh, North Bengal and Arunachal Pradesh. Poplar grows in moist areas preferring loamy soils with pH ranging between 5.0 and 6.6. The adaptability of clones in southern India is by and large unknown. However, a few *P. deltoids* clones are showing promising growth in Maharashtra. Though, poplar can be raised through seeds and cuttings, commercial propagation is through vegetative means using superior clones adapted to particular agro-climatic zones. It is too early to comment upon the growth of Poplar.

## 4.4. Training of forest staff and extension visits

The practice of organizing training programme for the staff of the Central Nurseries, periodic extension visits to the Central nurseries by KFRI scientists and occasional discussion with senior officers to chalk out programmes for clonal multiplication of pulpwood species was continued during the project period. The production of sufficient number of ramets by both the Central Nurseries to meet the target fixed is a clear indication of the success of the two training programmes and the periodical extension visits by the scientists to the nurseries.

## 4.5. Conclusions

At a time when the productivity of eucalypt plantations raised through locally available seeds came down drastically, plantations raised using seeds of new Australian provenances recommended by KFRI showed improved yield potential. Development of superior disease resistant clones from these locally adapted provenances raised by KFRI has indicated a potential for further improvement of productivity. The productivity is expected to increase to three to four-fold over that of the original unimproved local seed-origin plantations. In order to sustain the improvement in productivity, the genetic improvement programme initiated should continued through production of new planting stock adapted to local conditions, resistant to emerging pest and disease problems, and changing scenarios in pulp and paper industry. For this purpose, clonal forestry programme should be made dynamic through introduction of more and more superior clones from new Australian provenances, establishment of seedling seed orchards, clonal seed orchards and hybridization plots. Such a programme will lead to a rearrangement of desirable genes for further selection of CPTs and development of new clones adapted to changing ecological and economic scenarios. DNA based molecular techniques such as marker assisted selection of CPTs for yield, disease resistance, pulp quality and rooting ability, and physical mapping of genes for other economically important characters have to be initiated to cope up with the productivity scale attained by other countries.

However, tree improvement alone may not be able to take productivity to new heights. Matching innovative silvicultural practices should be combined with genetic improvement programmes for ensuring productivity in highly degraded and undulating terrain where pulpwood species are generally planted in Kerala. Weeding, fertilizer application, soil conservation and above all a watershed approach in site management is essential for maintaining sustained productivity of the plantations. The APFDC experience substantiates this opinion (Rao and Das, 2001). The findings of another KFRI research project with Australian funding is expected to fulfil this objective.

# 5. RECOMMENDATIONS

1. As the productivity of pulpwood plantations has improved remarkably by using provenances of Australian seed origin and clones developed from such provenances, the genetic improvement programme initiated for pulpwood species should be continued for achieving still higher yields.
2. The growth and disease susceptibility of the clonal plantations raised by KFD should be monitored till they attain rotation period and feedback provided to KFRI for eliminating susceptible clones.
3. The genetic base of eucalypts and acacia clones should be widened by developing more and more clones of different species and provenances adapted to Kerala, especially from the existing KFD plantations of Australian seed origin. Clones suitable to the varied eco-climatic and topographic zones should be identified.
4. Clonal seed orchards of eucalypts and acacias should be established by assembling superior clones in statistically designed plots for obtaining improved seeds for future development of clones.
5. Sufficient area of eucalypt and acacia seedling plantations of Australian seed origin raised by KFD and provenance trial plots of KFRI should be converted to seed orchards.
6. DNA based molecular techniques such as marker assisted selection should be standardised for early identification of clones with high productivity, pulping quality and disease resistance.
7. CMA of eucalypt and acacia species should be maintained with irrigation and fertilizer application in order to improve the rooting percentage of cuttings. Hedge garden should be developed for assured supply of cuttings of acacia species.
8. While the performance of *Paulownia* is discouraging, adaptability of poplar clones should be monitored continuously with the introduction of a few more clones.

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## 7. ACKNOWLEDGEMENTS

We are grateful to Dr. J. K. Sharma, Director for his efficient guidance, unflinching support and keen interest during the project work. We are thankful to the Kerala Forest Department for providing facilities for establishing an eucalypt clonal nursery and mist chamber at Devikolam, carrying out field trials in forest land and for permitting to utilize the growth data from a few eucalypt clonal plantations. We acknowledge the kind help rendered by Dr. K. Yesodharan, Scientist, Division of Botany during identification of candidate plus trees of *E. grandis* at Devikolam. We are also thankful to the senior forest officers of the forest department for useful comments during the various review meetings and to Dr. R. Gnanaharan, Dr. E. P. Indira and Dr. V. V. Sudheendra Kumar for suggestions to improve the manuscript. The services rendered by Mrs. Binu C. Nair, Research fellow, Mr. K. A. Thankachan and Mr. K. K. Muraly are also acknowledged. Finally we thank the Kerala Forest Department once again for providing us financial assistance.