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(Final Report of the Project KFRI 291/98 Phase I and Phase II)

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ABSTRACT OF PROJECT PROPOSAL

1. Project No. : KFRI 291/98

2. Investigators : M. Balasundaran
   E.J. Maria Florence

3. Title of the Project : Maintenance and Growth Observations On Multilocation Provenance Trial Plots of Eucalypts and Acacias.

4. Objectives :

   i. Maintenance of provenance trial plots of eucalypts established at Kodanad, Muthanga and Vallakkadavu and acacia plots at Kodanad and Kulathupuzha by fire tending, weeding, proper labeling, etc.

   ii. Recording growth measurements such as GBH and height, and disease resistance.

   iii. Selection of candidate plus trees and development of new eucalypt and acacia clones for supplying to the Kerala Forest Department.

   iv. Coppicing a portion of eucalypts provenance trial plots and studying the coppicing ability of provenances.

   v. Supply of quality seeds of eucalypts and acacias to the Forest Department and other agencies.

5. Project period : April 1998 -March 2003

6. Funding agency : Kerala Forest Department

ACKNOWLEDGEMENTS

We are extremely grateful to Dr. J.K. Sharma, former Director who was responsible form establishing the provenance trial plots of eucalypts and acacias. We thank him for his guidance and keen interest in the study. We are thankful to CSIRO, Australia for the free supply of Eucalypt and Acacia seeds to KFRI for the establishment of the provenance trial plots. We also thank Shri. T.K. Raghavan Nair IFS and Shri Govindan Kutty IFS, the former Principal Chief Conservators of Forests and other senior officers of the Kerala Forest Department who had extended their patronage during the tenure of the project. Thanks are also due to Dr. Jose Kallarackal, Dr. K.C. Chacko and Dr. U.N. Nandakumar for their editorial comments. Finally, we record our sincere thanks to Shri. K.A. Thankachan and M. Muraly, the nurserymen cum watchman for the provenance trial plot at Kottappara in Kodanad range and for the field clonal propagation unit at Devikulam respectively for their untiring assistance and devotion to the work.

M. Balasundaran

E.J. Maria Florence

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ABSTRACT

About 22 ha of eucalypt provenance trial plots raised at Kodanad (Malayattur), Muthanga (Wayanad) and Vallakkadavu (Peermedu) during 1990, 1992 and 1993 using seeds obtained from CSIRO, Australia, were maintained during 1998-2003 under this project. There were 78 provenances comprising *E. tereticornis* (20 provenances), *E. camaldulensis* (22 provenances), *E. urophylla* (8 provenances), *E. pellita* (10 provenances) and *E. grandis* (20 provenances). Two provenance trials comprising *A. auriculiformis* (11 provenances), *A. mangium* (12 provenances), *A. aulacocarpa (A. peregrina)* (8 provenances) and *A. crassicarpa* (7 provenances) raised during 1997 at Kodanad (4 ha) and Kulathupuzha (2 ha) were also maintained during the second phase (2001-2003). Plots for maintenance also included eucalypt clonal multiplication area (1 ha), clonal germplasm bank (0.5 ha), both at Kodanad, and mist chamber and hardening units at Kodanad and Devikulam, established for mass multiplying eucalypt and acacia clones for lowlands and high ranges, respectively. In addition to the maintenance work such as weeding and making fire line, activities such as recording data on growth measurements and disease resistance, development of new clones, mass multiplication of clones and supply of clones to the Forest Department and Hindustan Newsprint Ltd, Kottayam were also carried out.

Based on adaptability, growth performance and disease tolerance, eucalypt and acacia provenances suitable for raising plantations in Kerala had been identified at the age of 4 years and reported to the silviculture wing of Kerala Forest Department. Those provenances had shown consistently better performance during subsequent years also. The same provenances have shown similar performance when they were planted in separate trial plots during different periods. A few of the *E. urophylla* and *E. pellita* provenances have shown better performance than *E. tereticornis*. Considering the yield and the unique quality of water conservation possessed by *E. urophylla* and to a lesser extent by *E. pellita*, and their desirable tree architecture, the currently raised plantations of *E. tereticornis* can be replaced with these two species. *E. camaldulensis* is unsuitable for planting in Kerala because of severe leaf blight disease caused by *Cylindrocladium* spp. and pink disease caused by

Corticium salmonicolor. A few of the *E. grandis* provenances have shown tremendous growth in high ranges reaching up to 62 m^3/ha/yr at sixth year. Among the four acacia species, *A. mangium*, followed by a few provenances of *A. crassicarpa* and *A. auriculiformis* have performed well. Based on their performance, 2-5 provenances of each species have been recommended for planting in Kerala. The best performers are listed below.

Sl.No.	Species	Provenances	Yield (m^3/ha/yr)
1	*E. grandis*	BAROON POCKET MALENY, QLD	62
2	*E. urophylla*	N OF TELEMAR SW NETAR, IND	39
3	*E. pellita*	71-72 KM NE WENLOCK, QLD	43
4	*E. tereticornis*	PALMER RIVER, QLD	34
5	*A. mangium*	MOREHEAD, PNG	116
6	*A. auriculiformis*	S OF COEN CAPE YORK, QLD	27
7	*A. crassicarpa*	LIMAL-MALAM , PNG	40

Besides maintenance work and growth studies of provenances, about 95 candidate plus trees (CPTs) belonging to *Eucalyptus tereticornis, E. camaldulensis, E. urophylla* and *E. pellita* and 79 CPTs of *Acacia auriculiformis* and *A. mangium* and 45 CPTs of *E. grandis* were utilized for raising fast growing disease tolerant clones. Out of these, 34 eucalypt clones belonging to *E. tereticornis, E. camaldulensis, E. grandis* and *E. pellita* and 6 clones of *A. auriculiformis* and *A. mangium* and 10 clones of mangium hybrid were supplied to the Forest Department and HNL for raising Clonal Multiplication Area in their Central Nurseries and for raising clonal plantations. More than 1.33 lakh ramets of eucalypt and acacia clones have been supplied to the Kerala Forest Department till 2003. Seeds of *A. mangium and A. auriculiformis, E. tereticornis, E. grandis and E. pellita* have been supplied to Kerala Forest Dept., Kerala Forest Development Corporation, HNL and several private agencies.

1. INTRODUCTION

Eucalypts, natives of Australian continent, were introduced as early as 1790 in South India. Regular plantation activity was started after 1850, especially in the Nilgiris, at an altitude of 1500 m above msl. Subsequently eucalypts were planted extensively in North India. Large scale cultivation of eucalypts in Kerala was started about three decades ago to meet the raw material demand of paper and pulp industries. During 1990's, eucalypt plantations covered about 40,000 ha in Kerala. However, except for a few localities, the performance of the species was far from satisfactory (Chand Basha, 1986). The yield varied from 20 to 120 tonnes ha^{-1} in the case of *E. grandis* and 15 to 80 tonnes ha^{-1} in the case of *E. tereticornis*. But a study conducted subsequently (Jayaraman *et al*., 1997, unpublished) estimated the yield of seedling crop of *Eucalyptus* 'hybrid' as 7.65 m^3 ha^{-1} at 8 year rotation and for the first coppice crop 2.54 m^3 ha^{-1}. The yield of *E. grandis* at 10 years was 10 m^3 ha^{-1}. The data indicated that Kerala Forest Department would be unable to meet the annual requirements of 2.65 lakh tonnes of eucalypts wood (Karunakaran, 1982). The low productivity of the plantations was mainly due to their susceptibility to diseases besides the genetically poor seeds used of raising plantations. The two major diseases were pink disease caused by *Corticium salmonicolor* infecting 1- to 3-year-old plants causing die-back, and leaf blight caused by several species of *Cylindrocladium* affecting both seedlings and trees during rainy season. The loss due to pink disease has been estimated at 55 to 95 per cent in *E. tereticornis* plantations while Cylindrocladium infection can result in 100 per cent mortality in nurseries.

As the first step towards improving the productivity of eucalypts, KFRI had initiated testing the adaptability of several new Australian provenances by establishing four multi-location provenance trial plots during 1990, 1992 and 1993 in approximately 28 ha. Seeds of about 78 provenances of *E. tereticornis* (20 provenances), *E. camaldulensis* (22 provenances), *E. urophylla* (8 provenances) *and E. pellita* (10 provenances were obtained from Commonwealth Scientific and Industrial Research Organization, Australia. Using these species multi-location provenance trials were conducted in Kodanad range (Kottappara) in lowlands and Wayanad (Muthanga) and

Peermedu (Vallakkadavu) in high ranges. Based on the observations on growth and disease resistance of these provenances in the field, promising provenances having better growth and disease resistance were identified and recommended to the Kerala Forest Department for raising plantations during 1998.

Acacias were introduced in Kerala on a large scale during 1980's as part of the social forestry project funded by Word Bank. The two main species planted were *Acacia auriculiformis* and *A. mangium*, popularly known as mangium. These two species were also found suitable for afforestation of degraded lands. However, information on adaptability and growth performance of various provenances was unavailable. Two provenance trials involving *A. auriculiformis* (11 provenances), *A. mangium* (12 provenances), *A. peregrina* (8 provenances) and *A. crassicarpa* (7 provenances) were carried out at Kodanad (4 ha) and Kulathupuzha (2 ha) during 1997 to generate this information.

This report is a consolidated result of the research project carried out in two phases. The first phase started in 1998 and ended in 2000 and the second phase started in 2001 and ended in 2003. The objectives of the project were maintenance of the provenance trial plots of eucalypts and acacias, evaluating growth performances, monitoring disease and pest incidence, and identification of provenances suitable for Kerala. The project also envisaged identification of candidate plus trees of all the species, development of fast growing, disease and pest resistant clones, supply of the clones to Kerala Forest Department for raising clonal multiplication area and clonal pulpwood plantations, and supply of quality seeds to Kerala Forest Department, Kerala Forest Development Corporation, Hindustan Newsprint Ltd., and other user agencies.

2. MATERIALS AND METHODS

2.1. Seed source

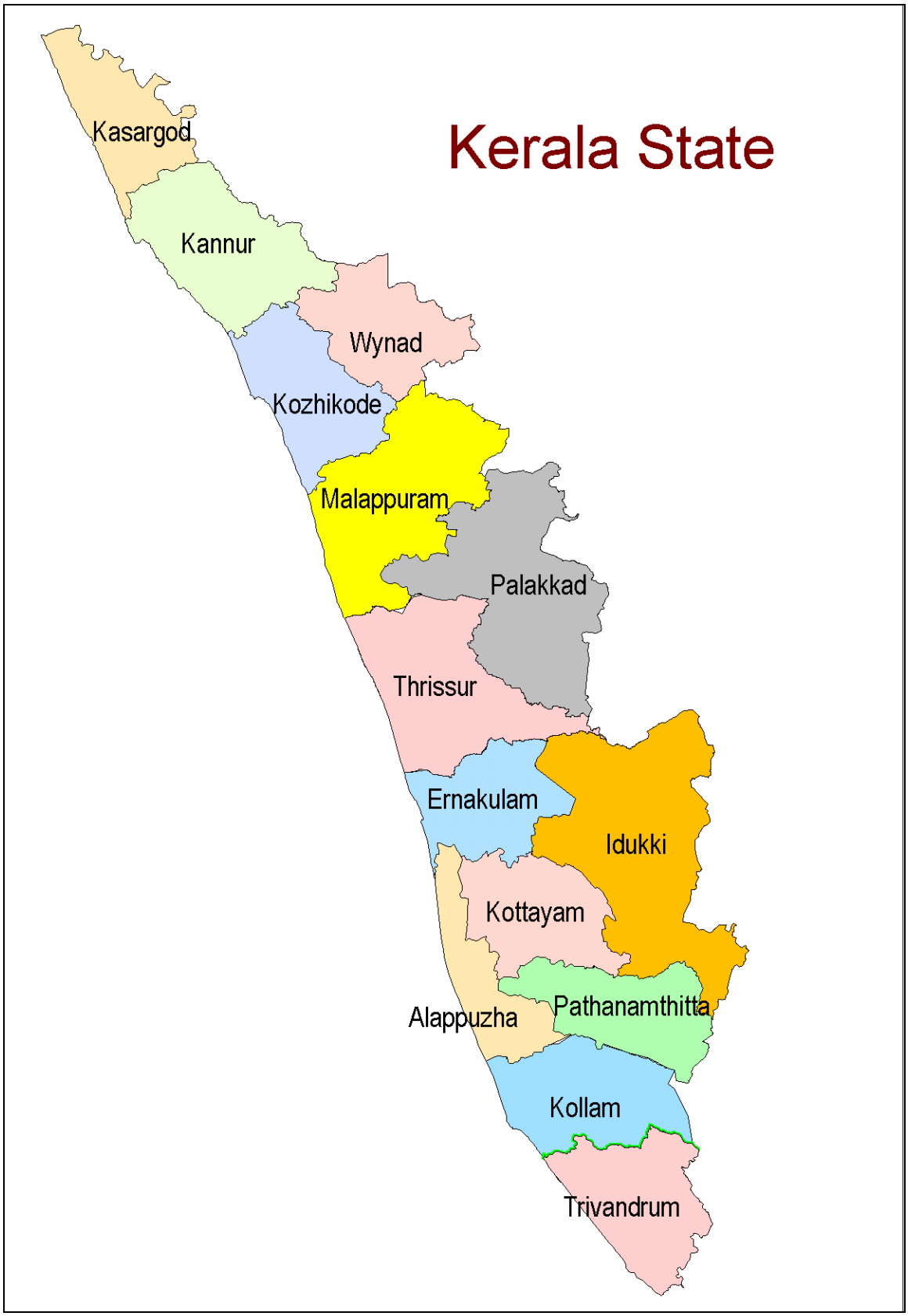
Seeds for both eucalypts and acacia provenance trials were provided by Australian Tree Seed Centre, CSIRO Division of Forest Research, Canberra, Australia during 1989, 1992 and 1993. The Australian provenances, having adaptability potentials in Kerala State were selected based on comparison of Kerala climate and geography with ecological factors of the locality of seed origin in Australia such as altitude and rainfall.

2.2. Location of the sites chosen

The provenance trial plots were established at five sites as shown below (Fig.1).

Table 1. Site details of provenance trial plots

Sl. No.	Name Locality	Extent of provenance trial	Forest Range and Division	Geographic region and altitude	Mean temp	Approx. annual rain fall (mm)
1	Kottappara	12.0 ha	Kodanad Range, Malayattur Division	Central Kerala 75 m msl	25° -36° C	2500 - 3000
2	Punalur	2.5 ha	Punalur Division	Southern Kerala 100 m msl	25° -36° C	2000 - 2500
3	Muthanga	2.0 ha	Muthanga Range, Wayanad Division (Wayanad Wild life sanctuary)	High Ranges (Northern Kerala) (1000 msl)	15° -28° C	<2000
4	Vallakkadavu	5.0 ha	Vallakkadavu, Peermedu Division (Periyar Tiger Reserve)	High Ranges (1200m msl)	15° –28° C	2000-2500
5	Kulathupuzha	2.0 ha	Kulathupuzha central Nursery	Southern Circle (100m msl)	24° – 34^{0}C	2500 - 3000


Kerala State
Kasargod
Kannur
Wynad
Kozhikode
Malappuram
Palakkad
Thrissur
Ernakulam
Idukki
Kottayam
Alappuzha
Pathanamthitta
Kollam
Trivandrum

2.3. Eucalypt provenances

E. tereticornis, E. camaldulensis, E. urophylla and *E. pellita* were planted in low elevation area, i.e., Kottappara (12 ha) in Malayattur Division and Punalur (2.5 ha) in Punalur Division. The eucalypt species planted in Muthanga (2 ha) in Wayanad Division and Vallakkadavu (5 ha) in Peermedu Division, the two high range sites, were predominantly *E. grandis.* The provenances were planted during 1990, 1992 and 1993 at Kottappara and Vallakkadavu while at Muthanga, planting was done in 1993 only. Details of species and the provenances planted are provided in Tables 2-10. The climate of lowland is extremely conducive for occurrence of pink disease and cylindrocladium leaf blight, while the leaf blight is the major disease in high ranges.

2.4. Acacia species

The *Acacia* spp. were planted at Kottappara and Kulathupuzha, adjacent to the Central nursery in Southern Kerala during 1997. The species planted were *Acacia auriculiformis, A. mangium, A. crassicarpa,* and *A. aulacocarpa (A. peregrina).* Details of the provenances planted are provided in Table 11.

2.5. Mist chambers, Clonal Multiplication Area (CMA) and Clonal Gene Bank (CGB) at Kottappara

Besides the provenance trials, Kottappara site had other plots such as Clonal Multiplication and Clonal Testing Areas (CMA and CTA) for eucalypts and acacias (1.5 ha), Clonal Gene Bank (1 ha), field mist chambers, hardening units and semi-permanent sheds for storing root trainers and nursery implements.

2.5.1. Clonal nursery at Devikulam

An additional clonal nursery was established in Devikulam in Idukki District for carrying forward the clonal forestry programme for high altitude pulpwood species. This

facility comprised a semi-permanent building, CMA for *E. grandis*, *E. urophylla*, *Urograndis* (hybrid of *E. urophylla x E. grandis*) and *E. globulus* (1 ha), mist chambers and hardening units.

2.6. Maintenance work

The major maintenance work carried out included weeding, making fire line before summer season, labeling the plots and fixing boards for larger plots. The maintenance work depended upon availability of funds in time. Except the plot in Punalur which failed at establishment phase itself, provenances in all other plots were included in the project work. Maintenance of clonal nurseries at Kottappara and Devikulam was also done during the project period.

2.7. Recording growth measurements

Girth at breast height (GBH) and height of eucalypt and acacia provenances, and clones planted in CMA and CGB were recorded twice a year, i.e., during March and September or once a year. The disease incidence in provenances and clones was recorded during and after rainy season.

2.8. Performance of eucalypt provenances and selection of candidate plus trees (CPT)

The performance of the provenances was assessed based on survival percentage, mean growth of trees, disease resistance and adaptability in different sites. The conical volume of the eucalypt trees was calculated using the formula suggested by Cameron *et al*. (1989) and that of acacia species using the formula suggested by Jayaraman and Rajan (1991). Volume per ha was estimated assuming a spacing of 2 m x 2m and 2500 trees per ha for both the species. Candidate plus trees were identified from promising provenances of all the species of eucalypts and acacias, based on GBH and height of trees, disease resistance,

tree form, etc., except for *E. grandis* planted in Wayanad and Vallakkadavu. The CPTs were generally selected from 4- year-age onwards (half the rotation periods).

Eucalypt CPTs were felled preferably during October - December. 45- to 60-day- old coppice shoots were made into single node, two-leaf cuttings; the lower portion of the shoots treated with 4000 ppm Indole Butyric Acid (IBA) dispersed uniformly in talcum powder. The treated cuttings were kept in field mist chamber in the nursery for three weeks for rooting and sprouting. The rooted cuttings were transferred to hardening unit for hardening. Cuttings were also prepared from 2- to 4-year-old plants from CMA where clones developed under other projects were planted. Details of CPT identification, mass vegetative multiplication and details of field mist chambers are provided in KFRI Research Report Nos. 180 (Balasundaran *et al.,* 2000), 204 (Sharma *et al.,* 2001) and 230 (Balasundaran and Maria Florence, 2002).

2.9. Supply of seeds

Seeds of *E. tereticornis, E. pellita* and *E. urophylla* were collected from the provenance trees growing at Kottappara in Kodanad Range and *E. grandis* from Muthanga. *A. auriculiformis* and *A. mangium* seeds were collected from provenance trees raised at Kottappara for supplying to Kerala Forest Department, Kerala Forest Development Corporation, Hindustan Newsprint Limited and several other agencies.

3. RESULTS AND DISCUSSION

3.1. Plantation maintenance

Three final research reports viz., KFRI 180 (Balasundaran *et. al*., 2000), KFRI 204 (Sharma *et. al*., 2000) and KFRI 275 (Balasundaran and Florence, 2002) related to this project have been submitted earlier. Those studies were done with specific objectives different from the objectives of the present project. But, the research work on those projects was done using part of the growing stock maintained under the present project such as plus trees identified among the provenances and clones developed from the plus trees. Hence, results in this report are not repetitive of those studies other than unavoidable overlapping.

This report provides the result of the project work carried out during 1998-2003. Weeding the provenance trail plots of eucalypts and acacias was done till third year and in selected plots during subsequent years. After three years, more importance was given to the maintenance and evaluation of new clones, and their mass multiplication. Fire lines were made in time and there was no fire incidence except in Vallakkadavu and Muthanga where weeding was not done for a few years since the provenance trial plots became part of the Wildlife Sanctuary.

The following are the eucalypt plots maintained at Kottappara.

3.1.1. Eucalypts

i. Eucalypts provenance trial plots for lowland species (*E. tereticornis, E. camaldulensis, E. urophylla* and *E. pellita)* planted in 1990, 1992 and 1993 (12 ha) (Tables 2-6).

ii. Clonal multiplication area (1 ha)

iii. Clonal gene bank (1 ha)

iv. Clonal testing area (CTA) (1 ha)

Other facilities maintained at Kottappara included field clonal multiplication units (mist chamber) and hardening units.

The following are the eucalypt plots maintained at Vallakkadavu and Muthanga,

i. Vallakkadavu : Eucalypt provenance trial plots for *E. grandis* and *E. urophylla* for high ranges planted in 1990, 1992 and 1993 (4ha) (Tables 7,8).

ii. Muthanga : Eucalypt provenance trial plots for *E. grandis* and *E. urophylla* for high ranges planted in 1993 (2 ha) (Tables 9,10).

iii. Devikulam : *E. grandis* CMA, progeny trial of *E. grandis* and *E. urophylla* provenance, CPTs from provenances, field clonal propagation unit and hardening units.

All the *E. urophylla* provenances were of Indonesian origin while almost all the provenances of other species were of Australian origin, except one provenance of *E. tereticornis* and *E. pellita* from Papua New Guinea.

Table 2. List of *E. tereticornis* provenances planted at Kottappara during 1990, 1992 and 1993 and their accession number.

Sl. No.	Species	Provenance name	1990 Acc. No.	1992 Acc. No.	1993 Acc. No.
1	*E. tereticornis*	16KM N WOOLGOOLGA, NSW	10837	10837	10837
2	*E. tereticornis*	34KM S CASINO, NSW	11239	11239	11239
3	*E. tereticornis*	40K N OF GLADSTONE, QLD	-	13544	13544
4	*E. tereticornis*	80 KM NNW COOKTOWN, QLD	15198	15198	15198
5	*E. tereticornis*	9K SW OF IMBIL, QLD	13541	-	-
6	*E. tereticornis*	CARDWELL, QLD	13277	13277	13277
7	*E. tereticornis*	CREDITON S.F., QLD	-	13994	13994
8	*E. tereticornis*	EAST OF KUPIANO, PNG	-	13398	13398
9	*E. tereticornis*	KENNEDY CK PEN DEV, RD QLD	15827	15827	15827
10	*E. tereticornis*	KENNEDY RIVER, QLD	14802	14802	14802
11	*E. tereticornis*	MOREHEAD RIVER, QLD	13444	-	13444
12	*E. tereticornis*	N OF MAREEBA, QLD	15370	15370	-
13	*E. tereticornis*	N OF WOOLGOOLGA, NSW	-	13319	-
14	*E. tereticornis*	ORO BAY TO EMO, PNG	13399	13399	13399
15	*E. tereticornis*	PALMER RIVER, QLD	13847	13847	13847
16	*E. tereticornis*	RAVENSHOE, QLD	-	14424	14424
17	*E. tereticornis*	R'HAMPTON RACECOURSE, QLD	-	13547	13547

18	*E. tereticornis*	S CARDWELL, QLD	-	14846	14846
19	*E. tereticornis*	S. OF HELENVALE, QLD	12944	-	-
20	*E. tereticornis*	SIRINUMU SOGERI PLAT, PNG	13418	13418	-

Table 3. List of *E. camaldulensis* provenances planted at Kottappara during 1990, 1992, 1993 and their accession number

Sl. No.	Species	Provenance name	1990 Acc.No.	1992 Acc. No.	1993 Acc. No.
1	*E. camaldulensis*	BATHURST BAY, QLD	-	13814	13814
2	*E. camaldulensis*	BULLOCK CREEK, QLD	15049	15049	15049
3	*E. camaldulensis*	CAMEL CREEK, WA	13930	13930	-
4	*E. camaldulensis*	CAPE RIVER, QLD	13815	13815	13815
5	*E. camaldulensis*	COCKATOO CREEK, NT	13929	13929	13929
6	*E. camaldulensis*	DALY WATERS, NT	13943	13943	13943
7	*E. camaldulensis*	EDITH RIVER, NT	13922	13922	-
8	*E. camaldulensis*	EMU CREEK PETFORD, QLD	12964	-	-
9	*E. camaldulensis*	GIBB R KIMBERLEY, AREAWA	12346	12346	-
10	*E. camaldulensis*	GILBERT RIVER, QLD	12963	-	12963
11	*E. camaldulensis*	KATHERINE RIVER, NT	-	-	17635
12	*E. camaldulensis var. obtusa*	KATHERINE, NT	13801	-	-
13	*E. camaldulensis*	LEICHHARDT RIVER, QLD	13696	13696	-
14	*E. camaldulensis*	LENNARD RIVER, WA	17465	17465	17465
15	*E. camaldulensis*	N FITZROY CROSSING, WA	13933	13933	13933
16	*E. camaldulensis*	ORD RIVER, WA	13931	13931	13931
17	*E. camaldulensis*	PETFORD, QLD	-	-	16536
18	*E. camaldulensis*	REGION OF E PETFORD, QLD	14338	14338	-
19	*E. camaldulensis var. obtusa*	VICTORIA RIVER, NT	13928	13928	13928
20	*E. camaldulensis*	W OF IRVINEBANK, QLD	15234	15234	15234
21	*E. camaldulensis var. obtusa*	W OF NORMANTON, QLD	13695	13695	-
22	*E. camaldulensis*	WILLARE BRIDGE, WA	17448	17448	17448

Table 4. List of *E. pellita* provenances planted at Kottappara during 1990, 1992, 1993 and their accession number

Sl. No.	Species	Provenance name	1990 Acc. No.	1992 Acc. No.	1993 Acc. No.
1	*E. pellita*	NEAR KURANDA, QLD	11947	-	11947
2	*E. pellita*	JULATTEN, QLD	-	-	13165
3	*E. pellita*	71-72 KM NE WENLOCK, QLD	13999	13999	13999
4	*E. pellita*	5-12 KM S HELENVALE, QLD	14211	14211	14211
5	*E. pellita*	14.6 KM NE COEN, QLD	14339	14339	14339
6	*E. pellita*	S OF CARDWELL, N.QLD	14915	14915	-
7	*E. pellita*	8 KM S BLOOMFIELD, QLD	15254	15254	15254
8	*E. pellita*	NW OF KURANDA, QLD	15255	15255	-
9	*E. pellita*	6KM S KERU TO MATA, PNG	-	16120	-
10	*E. pellita*	BETWEEN GGOE-KIRIWA, PNG	16122	16122	16122

Table 5. List of *E. urophylla* provenances planted at Kottappara, during 1990, 1992 and 1993, and their accession number

Sl. No.	Species	Provenance name	1990 Acc. No.	1992 Acc. No.	1993 Acc. No.
1	*E. urophylla*	MT LEWOTOBI, FLORES, IND	14532	-	-
2	*E. urophylla*	MT EGON FLORES IS, IND	15089	-	-
3	*E. urophylla*	MANDIRI FLORES, IND	-	-	17564
4	*E. urophylla*	N OF TELEMAR SW WETAR, IND	-	-	17834
5	*E. urophylla*	SW OF UHAKNE WETARN, IND	-	-	17836
6	*E. urophylla*	S OF HATO BULICO, IND	-	-	10140
7	*E. urophylla*	MT EGON FLORES IS, IND	-	-	13827
8	*E. urophylla*	MT MUTIS W TIMOR, IND	-	-	13828
9	*E. urophylla*	MT WUKO FLORES IS, IND	-	-	15982

Table 6. List of *E. grandis* provenances planted at Kottappara, during 1990, 1992 and 1993, and their accession number

Sl. No.	Species	Provenance name	1990 Acc. No.	1992 Acc. No.	1993 Acc. No.
1	*E. grandis*	17KM N COFFS HARBOUR, NSW	-	-	7823
2	*E. grandis*	W OF COFFS HARBOUR, NSW	-	-	13031
3	*E. grandis*	PALUMA DAM, QLD	-	-	16723
4	*E. grandis*	15K W CAIRNS, QLD	-	-	17826
5	*E. grandis*	MOUNT LEWIS T RES. 66, QLD	-	-	13289
6	*E. grandis*	WNW CARDWELL, QLD	-	-	14838
7	*E. grandis*	SMITHS LAKE, NSW	10525	10525	-
8	*E. grandis*	25.7 KM N WOOLGOOLGA, NSW	11681	11681	11681
9	*E. grandis*	BULANDELAH, NSW	11996	-	11996
10	*E. grandis*	SEED ORCHARD, S.AFRICA	13365	13365	-
11	*E. grandis*	10 KM OF BEER BURRUM, QLD	13536	13536	13536
12	*E. grandis*	WOONDUM SF GYMPIE, QLD	13886	-	-
13	*E. grandis*	30 KM N COFFS HARBOUR, NSW	15236	15236	15236
14	*E. grandis*	BAROON POCKET MALENY, QLD	15875	15875	15875
15	*E. grandis*	KEMPSEY TAN BAN SF, NSW	15921	15921	15921
16	*E. grandis*	KENILWORTH, SF	-	17276	-
17	*E. grandis*	25-36 KM SE MAREEBA, QLD	-	-	14393
18	*E. grandis*	10K S RAVENSHOE, QLD	-	-	17857

Table 7. List of *E. grandis* provenances planted at Vallakkadavu during 1990, 1992, 1993, and their accession number

Sl. No.	Species	Provenance name	1990 Acc. No.	1992 Acc. No.	1993 Acc. No.
1	*E. grandis*	10K S RAVENSHOE, QLD	-	-	17857
2	*E. grandis*	10K W OF BEERBURRUM, QLD	-	-	13536
3	*E. grandis*	12 KM S RAVENSHOE, QLD	14420	-	-
4	*E. grandis*	15K W CAIRNS, QLD	-	-	17826
5	*E. grandis*	17KM N COFFS HARBOUR, NSW	-	-	7823

6	*E. grandis*	22 KM NE ATHERTON, QLD	15244	15244	11239
7	*E. grandis*	25.7KM N WOOLGOOLGA, NSW	-	-	11681
8	*E. grandis*	25-36 KM SE MAREEBA, QLD	14393	-	13399
9	*E. grandis*	25-36 KM SE MAREEBA, QLD	-	-	14393
10	*E. grandis*	30KM N COFFS HARBOUR, NSW	-	-	15236
11	*E. grandis*	BALDY ST FOREST 194 ?	14423	-	13444
12	*E. grandis*	BAROONPOCKET MALENY, QLD	-	-	15875
13	*E. grandis*	BULADELAH, NSW	-	-	11996
14	*E. grandis*	E OF ATHERTON, QLD	14698	-	13544
15	*E. grandis*	KEMPSEY TAN BAN SF, NSW	-	-	15921
16	*E. grandis*	KENILWORTH SF	17276	17276	-
17	*E. grandis*	MOUNT GEORGE	10640	10640	-
18	*E. grandis*	MOUNT LEWIS T RES. 66, QLD	13289	13289	13398
19	*E. grandis*	N.W. OF TOWNSVILLE	14716	-	13277
20	*E. grandis*	ORARAWEST C.HARBOUR, NSW	-	-	13897
21	*E. grandis*	PALUMA DAM, QLD	-	-	16723
22	*E. grandis*	W OF COFFS HARBOUR, NSW	-	-	13031
23	*E. grandis*	WNW CARDWELL, QLD	14838	14838	14838

Table 8. List of *E. urophylla* provenances planted at Vallakkadavu during 1990, 1992 and 1993, and their accession number

Sl. No.	Species	Provenance name	1990 Acc. No.	1992 Acc. No.	1993 Acc. No.
1	*E. urophylla*	MANDIRI FLORES, IND	-	-	17564
2	*E. urophylla*	N OF TELEMAR SW WETAR, IND	-	-	17834
3	*E. urophylla*	SW OF UHAKNE WETARN, IND	-	-	17836
4	*E. urophylla*	S OF HATO BULICO, IND	10140	10140	10140
5	*E. urophylla*	MT EGON FLORES IS, IND	13827	13827	13827
6	*E. urophylla*	MT MUTIS W TIMOR, IND	13828	13828	13828
7	*E. urophylla*	MT WUKO FLORES IS, IND	15982	15982	15982

Table 9. List of *E. grandis* provenances planted at Muthanga during 1993 and their accession number

Sl. No.	Species	Provenance name	1993 Acc. No.
1	*E. grandis*	10K S RAVENSHOE, QLD	17857
2	*E. grandis*	10K W OF BEERBURRUM, QLD	13536
3	*E. grandis*	BAROON POCKETMALENY, QLD	15875
4	*E. grandis*	15K W CAIRNS, QLD	17826
5	*E. grandis*	25-36 KM SE MAREEBA, QLD	14393
6	*E. grandis*	30KM N COFFS HARBOUR, NSW	15236
7	*E. grandis*	KEMPSEY TAN BAN SF, NSW	15921
8	*E. grandis*	MOUNT LEWIS T RES. 66, QLD	13289
9	*E. grandis*	PALUMA DAM, QLD	16723
10	*E. grandis*	WNW CARDWELL, QLD	14838

Table 10. List of *E. urophylla* provenances planted at Muthanga during 1993 and their accession number

Sl. No.	Species	Provenance name	1993 Acc. No.
1	*E. urophylla*	MANDIRI FLORES, IND	17564
2	*E. urophylla*	N OF TELEMAR SW WETAR, IND	17834
3	*E. urophylla*	SW OF UHAKNE WETARN, IND	17836
4	*E. urophylla*	MT MUTIS W TIMOR, IND	13828

3.1.2. Acacias

The *Acacia* spp. were planted at Kottappara in Malayattur Division (Fig. 2) and Kulathupuzha (Fig.5), adjacent to the Central nursery in Southern Kerala during 1997. The species planted were *Acacia auriculiformis, A. mangium, A. crassicarpa* (Figs.3a-c), *and A. aulacocarpa (A. peregrina)* (Fig.4). Details of the provenances planted are provided in Table 11.

Table 11. Acacia provenances planted at Kottappara and Kulathupuzha

Sl. No	Provenance Name	Seedlot No.	Kottappara	Kulathupuzha
			Total number of plants and number of replication (plots) in brackets (each plot has 7 x 7 plants)	Total number of plants and number of replication (plots) in brackets (each plot has 7 x 7 plants)
A. auriculiformis				
1	S OF COEN CAPE YORK	15697	147 (3)	98(2)
2	SAI THONG	15951	147 (3)	147(3)
3	MOREHEAD R ROUKU, WP	16606	147 (3)	98(2)
4	BENSBACH R, WESTERN P	16684	147 (3)	98(2)
5	OLIVE RIVER	17705	147 (3)	147(3)
6	POHATURI RIVER	18059	147 (3)	98(2)
7	ORIOMO	19267	147 (3)	147(3)
8	DIMISSI	19274	147 (3)	98(2)
9	BINATUR R, WP	19391	147 (3)	98(2)
10	MELVILLE ISLAND SO NT	19514	147 (3)	147(3)
11	SPRINGVALE (HALF-SIB PROGENY)	MPM Karna-taka	147 (3)	147(3)
A. mangium				
1	INNISFAIL REGION	15266	147 (3)	147(3)
2	KINI WP	16938	147 (3)	147(3)
3	MUTING IRIAN JAYA	17852	147 (3)	49(1)
4	MOREHEAD	17868	147 (3)	147(3)
5	ARUFI VILLAGE	18206	147 (3)	147(3)
6	KAPAL VILLAGE/ORIOM	18214	147 (3)	147(3)
7	CLAUDIE RIVER	18994	147 (3)	147(3)
8	BALIMO ARAMIA RIVER	19139	147 (3)	98(2)
9	PASCOE R CAPE YORK	19151	147 (3)	147(3)
10	DESI DESI MOREHEAD	16990	147 (3)	147(3)
11	WIPIM ORIOMO	17872	147 (3)	147(3)
12	CLAUDIE RIVER	17701	147 (3)	147(3)
A. aulacocarpa (A. peregrina)				
1	WASUA PEDEYA WP	16950	147 (3)	147(3)

2	W OF WIPIM WP	16979	147 (3)	147(3)
3	PONGAKIE MOREHEAD WP	16988	147 (3)	147(3)
4	BENSBACH- BALAMUK WP	17551	147 (3)	147(3)
5	3K S MT LARCOM	17739	147 (3)	-
6	SAMFORD	17891	147 (3)	147(3)
7	OLD LOCKHART AIRSTRIP	18358	147 (3)	147(3)
8	PNG PROV. SEED ORCH.	19301	147 (3)	147(3)
A. crassicarpa				
1	JARDINE RIVER BAMAGA	16128	49 (1)	49(1)
2	PONGAKI E OF MOREHEAD	16599	147 (3)	-
3	BENSBACH WP	17552	98 (2)	98(2)
4	LIMAL-MALAM	17561	98 (2)	98(2)
5	DIMISSI VILLAGE WP	18202	98 (2)	98(2)
6	BENSBACH WP	18836	98 (2)	98(2)
7	MOREHEAD	18962	49(1)	35(1)

3.2. Growth performance of eucalypt provenances

The performance of the provenances was evaluated based on disease resistance and growth. For eucalypts, the climate of lowlands (Kottappara and Kulathupuzha) was extremely conducive for occurrence of pink disease and cylindrocladium leaf blight, while leaf blight was the major disease in high ranges (Muthanga and Vallakkadavu). Pink disease occurred on *A. auriculiformis and A. mangium*.

3.2.1. Performance in high ranges

3.2.1.1. *E. grandis*

The yield of *E. grandis* at Muthanga at sixth year for almost all the provenances was enormous (Table 12). The annual yield ranged from 43.5-61.6 m^3/ha/yr. The highest yielding provenance was BAROON POCKET MALENY (61.6 m^3/ha/yr) followed by PALUMA DAM, 15 KW CAIRNS and MOUNT LEWIS. Evaluation of *E. grandis* provenances at Vallakkadavu was not possible because the plantation had become part of the Periyar Tiger Reserve and we were unable to do maintenance work in the plantation. However, in order to come to a consensus on the best provenances suitable for Kerala, we considered the performance of the provenance trial plot established at Vallakkadavu in 1990. The evaluation was done at the fourth year based on GBH, survival percentage and

disease resistance, especially Cylindrocladium leaf blight (Balasundaran *et al*., 1995). The provenances were ranked based on performance index (Table 13). The best adapted provenances were E OF ATHERTON followed by 22 KM E ATHERTON, 12 KM S OF RAVENSHOE and 25-36 KM SE MAREEBA. For recommending the best provenances of *E. grandis* for planting in Kerala (Table 13), the data from Muthanga was also considered.

3.2.1.2. *E. urophylla*

The performance of *E. urophylla* provenances was poor in high ranges (Table 12). The yield of the best provenance (28.3 m^3/ha/year) namely SW OF UHAK NE WETAR at sixth year at Muthaga was less than half the yield of the best *E. grandis* provenance. The performance of *E. urophylla* was generally poorer than the performance of *E. grandis* at Vallakkadavu also (Balasundaran *et al.,* 1995). Hence, *E. urophylla* provenances are not suitable for high ranges as far as yield is concerned. For identifying the best *E. urophylla* provenance for high ranges, the performance up to fourth year of the provenances planted at Vallakkadavu in 1990 (Table 13) was considered. MT. EGON FLORES IS and SW OF UHAK NE WETAR are recommended for planting in high ranges.

Table 12. Eucalypt provenance trial plot at Muthanga, Wayanad established in 1993. Estimated yield of provenances based on GBH and height recorded in 1999 (6^{th} year) (spacing 2m x 2m) (Average of 49-147 trees).

Provenance Name	Seed lot No.	Yield per ha (Volume in m^3) at 6^{th} year	Yield m^3/ha/year
Eucalyptus grandis			
PALUMA DAM, QLD	16723	366.46	61.1
15 K W CAIRNS, QLD	17826	338.07	56.3
MOUNT LEWIS, T. RES. 66, QLD	13289	334.35	55.7
30KM N COFFS HARBOUR, NSW	15236	268.27	44.7
10 K W OF BEERBURRUM, QLD	13536	261.02	43.5
WNW CARDWELL, QLD	14838	289.90	48.3
BAROON POCKET MALENY, QLD	15875	369.30	61.6
25-36 KM SE MAREEBA, QLD	14393	320.20	53.3

KEMPSEY TANDBAN SF, NSW	15921	301.66	50.3
10KS RAVEN- SHOE, QLD	17857	283.12	47.2
Eucalyptus urophylla			
MANDIRI FLORES, IND	17564	101.62	16.9
N OF TELEMAR SW WETAR, IND	17834	14.53	2.4
SW OF UHAK NE WETAR, IND	17836	169.89	28.3
MT.MUTIS W. TIMOR, INDO	13828	120.24	20.0

Table 13. Eucalypt provenance trial plot at Vallakkadavu, Idukki Dist. established in 1990. Evaluation of the provenances done at the fourth year based on GBH, disease resistance and survival percentage (Average of 20 trees).

Provenance name	Seed lot No.	Ranked according to the performance index based on yield, disease resistance and survival (total score 16)
E. grandis		15.0
E OF ATHERTON, QLD	14698	
22 KM NE ATHERTON, QLD	15244	14.5
12 KM S RAVENSHOE, QLD	14420	14.0
25-36 KM SE MAREEBA, QLD	14393	14.0
N.W. OF TOWNSVILLE	14716	14.0
WNW CARDWELL, QLD	14838	14.0
MOUNT GEORGE	10640	13.5
MOUNT LEWIS T RES. 66, QLD	13289	13.5
BALDY ST FOREST	14423	13.0
E. grandis LOCAL	Local	12.1
E. urophylla		
E. OF HATO BULICO	10140	11.0
MT.EGON FLORES IS	13827	13.5
MT. MUTISW. TIMOR	13828	12.0
MT WUKO FLORES ISLAND	15982	11.5
MT.WUKO FLORES ISLAND	15982	11.5

3.2.2. Performance in low altitudes

3.2.2.1. *E. tereticornis*

Among the *E. tereticornis* provenances, PALMER RIVER (33.6 m^3/ha/year) and RAVENSHOE (33.5 m^3/ha/year) were the best (table 14) which were followed by KENNEDY RIVER, KENNEDY CK PENDEN RD, and CARDWELL. These provenances were also the best ones found in 1990 trial at Kottappara (Balasundaran *et al.*, 2005). Hence, these provenances are recommended for planting in lowlands in Kerala (Table 15).

3.2.2.2. *E. grandis*

The performance of *E. grandis* provenances in lowlands was extremely poor (Table 14). PALUMA DAM (18.1 m^3/ha/year) and 10 KS RAVENSHOE (15.1 m^3/ha/year) showed better result among the *E. grandis* provenances. If *E. grandis* are proposed to be planted in lowlands, PALUMA DAM and 10 KS RAVENSHOE can be planted. PALUMA DAM provenance was included among the best provenances in high ranges also.

3.2.2.3. *E. urophylla*

The average performance of *E. urophylla* provenances planted in 1993 was far better than the performance of provenances of all other species (Table 14). While the mean yield of 14 *E. tereticornis* provenances was 21.3 m^3/ha/year, the mean yield of six *E. urophylla* provenances was 28.8 m^3/ha/year. The highest performance was shown by N OF TELEMAR SW NETAR (39.2 m^3/ha/year) followed by MT. EGON FLORES IS (32.5 m^3/ha/year), MANDIRI FLORES (31.2 m^3/ha/year), MT. MUTIS W. TIMOR (30.5 m^3/ha/year) and SW OF UHAK NE WETAR (30.2 m^3/ha/year). During the previous study initiated in 1990 (Balasundaran *et al*., 2005), only two provenances namely, MT. EGON FLORES IS and MT LEWOTOBI were tested. MT. EGON FLORES IS was better than MT LEWOTOBI and hence it was included among the species of *E. urophylla* recommended for low elevation (Table 15).

While 83 per cent of the *E. urophylla* provenances yielded more than 30 m^3/ha/year, only 29 per cent of the *E. tereticornis* provenances gave more than 30 m^3/ha/year. *E. urophylla* is more water conserving than other eucalypt species grown as pulpwood species in Kerala (Kallarackal and Somen, 1998). Decreased water loss from leaves leads to decreased soil water uptake. The water use efficiency of *E. tereticornis* is poorer than other species of eucalypts. *E. urophylla* is tolerant to Cylindrocladium leaf blight and resistant against pink disease. Hence, *E. urophylla* provenances can replace *E. tereticornis* in lowlands.

3.2.2.4. *E. camaldulensis*

In general, the performance of *E. camaldulensis* provenances was poor. The highest yield of 26 m^3/ha/year was shown by the provenance W OF IRVINE BANK. The mean yield of the tested 12 provenances was 16.0 m^3/ha/year (Table 14). All the provenances were highly susceptible to Cylindrocladium leaf blight (Fig.6) and most of them infected by pink disease (Fig.7). Nineteen provenances were screened during the previous study of 1990 (Balasundaran *et al*., 2005). Among them, KATHERINE, CAPE RIVER, PETFORD and W OF IRVINE BANK were the better performers. Although, *E. camaldulensis* provenances are not suitable for Kerala which receives very high rainfall, this species is suitable for planting in low rainfall area with unfertile soil. The provenances suggested in table 15 are suitable for planting in such areas.

3.2.2.5 *E. pellita*

The performance of *E. pellitta* provenances varied widely (table 14). 71-72 KM NE WENLOCK gave the highest performance of 42.8 m^3/ha/year not only among the *E. pellita* provenances but among all the provenances planted at Kottappara. *E. pellita* provenances were resistant against pink disease and Cylindrocladium leaf blight. Even though, *E. pellita* is not a water conserving species as *E. urophylla*, it is a better species than *E. tereticornis*, *E. camaldulensis* and *E. grandis* (Kallarackal and Somen, 1998). The best performers among the *E. pellita* provenances were 71-72 KM NE WENLOCK, JULATTEN and BETWEEN GGOE KIRWA. BETWEEN GGOE KIRWA was the best

performer during the 1990-trial (Balasundaran *et al*., 2005) and hence these three species are recommended (table 15) for planting in lowlands with moderately heavy rainfall.

Table 14. Eucalypt provenance trial plot at Kottappara, Malayattur Division established in 1993. Estimated yield of provenances based on GBH and height recorded in 1999 (6^{th} year) (spacing 2m x 2m) (Average of 49-147 trees).

Provenance Name	**Seedlot No.**	**Yield per ha (Volume in m^3) at 6^{th} year**	**Volume in m^3/ha/year**
E. tereticornis			
16 KM N WOOLGOOLGA, NSW	10837	58.72	9.8
34 KM S CASINO, NSW	11239	58.84	9.8
MOREHEAD RIVER, QLD	13444	81.05	13.5
CARDWELL, QLD	13277	173.67	28.9
EAST OF KUPIANO, PNG	13398	131.15	21.8
ORO BAY TO EMO, PNG	13399	125.46	20.9
40 K N OF GLADSTONE, QLD	13544	58.18	9.7
R HAMPTON RACE COURSE, QLD	13547	98.46	16.4
PALMER RIVER, QLD	13847	201.69	33.6
CREDITON S.F., QLD	13994	54.18	9.0
RAVENSHOE, QLD	14424	201.15	33.5
KENNEDY RIVER, QLD	14802	189.84	31.6
CARDWELL, QLD	14846	173.67	28.9
KENNEDY CK PENDEN RD. QLD	15827	185.27	30.9
Eucalyptus grandis			
10 KS RAVENSHOE	17857	90.31	15.1
PALUMA DAM	16723	108.48	18.1
ORARAWEST C HARBOUR, NSW	13897	53.81	9.0
E. urophylla			
MANDIRI FLORES, IND	17564	187.16	31.2
N OF TELEMAR SW NETAR, IND	17834	235.41	39.2
SW OF UHAK NE WETAR, IND	17836	181.16	30.2
MT. EGON FLORES IS, IND	18827	194.86	32.5
MT. MUTIS W. TIMOR, INDO	13828	183.12	30.5
MT. WUKO FLORES ISLAND, IND	15982	54.73	9.1
E. camaldulensis			
CAPE RIVER, QLD	13815	99.45	16.6

VICTORIA RIVER, MT.	13928	92.35	15.4
COCKATOO CREEK	13929	62.10	10.3
ORD RIVER	13931	63.40	10.5
N FITZROY CROSSING	13933	78.81	13.1
DALY WATERS	13943	73.15	12.2
W OF IRVINE BANK, QLD	15234	155.71	26.0
KATHERINE RIVER, NT	17635	106.28	17.7
GILBERT RIVER, QLD	12963	94.27	15.7
LENNARD RIVER,W.A.	17465	79.38	13.2
PETFORD,QLD	16536	112.37	18.7
BULLOCK CREEK, QLD	15049	135.76	22.6
E. pellita			
NEAR KURANDA, QLD	11947	76.04	12.7
JULATTEN, QLD	13165	125.42	20.9
71-72 KM NE WENLOCK	13999	256.77	42.8
5-12 KM S HELENVALE, QLD	14211	35.24	5.9
14.6KM NE COEN, QLD	14339	57.80	9.6
8 KM S BLOOMFIELD, QLD	15254	49.56	8.3
BETWEEN GGOE KIRWA, PNG	16122	126.13	21.0

Table 15. Eucalypt provenances tolerant against pink disease and Cylindrocladium leaf blight recommended for planting in Kerala based on multilocation provenance trial.

Sl. No.	Provenance name	Seedlot Number
Eucalyptus tereticornis - for low altitudes		
1.	Kennedy River	14802
2.	S. Cardwell	14846
3.	Kennedy CK	15827
4.	Palmer River	13847
5.	Ravenshoe	14424
Eucalyptus camaldulensis - for low altitudes		
1.	Catherine	13801
2.	Cape River	13815
3.	W. of Irvine Bank	15234
4.	Petford	16536
Eucalyptus urophylla - for low altitudes		
1.	Mt. Egon Flores Is	13827
2.	N. of Telemar SW Netar	17834
3.	Mandiri Flores	17564
4.	Mount Mutis W. Timor	13828
5.	SW of Uhakne Wetarn	17836
Eucalyptus pellita - for low altitudes		

1.	Julatten	13165
2.	71-72 Km NE Wenlock	13999
3.	Between GGOE-KIRIWA	16122
Eucalyptus grandis - for high ranges		
1.	East of Atherton	14698
2.	Paluma Dam	16723
3.	15 Km Cairns	17826
4.	Baroon Pocket Malony	15875
5.	Mount Lewis	13289
6.	25-36 Km SE Mareeba	14393

3.3. Eucalypt Candidate Plus Trees (CPTs) and clones produced from CPTs

One hundred and six eucalypt CPTs were identified at Kottappara; the following are those species and the number of CPTs identified in each species. Most of the eucalypt clones developed from each CPTs were established in clonal gene bank at Kottappara. Though, cloning was attempted from several CPTs of *E. pellita* and from other provenances, results of only successful attempts are listed here.

1. *E. tereticornis* - 41
2. *E. camaldulensis* - 27
3. *E. urophylla* - 14
4. *E. grandis* - 2
5. *E. pellita* - 2
6. Eucalyptus 'Hybrid' - 10 (used as control)
7. ITC Bhadrachalam clones - 10

Generally rooting ability was poor in *E. urophylla* and *E. pellita* provenances compared to the provenances of *E. tereticornis, E. camaldulensis* and *E. grandis*. Since *E. camaldulensis* provenances were highly susceptible to pink disease and Cylindrocladium leaf blight, CPTs were identified from disease tolerant provenances only. Details of all the clones produced and tested, and their origin are presented in Table 16. The Table 16 also shows the list of ITC clones procured from ITC paper boards, Bhadrachalam, Andhra Pradesh for testing their suitability in Kerala.

Table 16. List of candidate plus trees (CPTs) identified in 1990-, 1992- and 1993-eucalypts provenance trial plots for developing clones and for raising clonal germplasm bank (CGB)

Sl. No.	*Species*	Provenance name/category	Year of raising proven-ance trial plot	Clone developed		Clones establi shed in CGB
				Prov-enance code	KFRI clone NO.	
E. tereticornis						
1	*E. tereticornis*	KENNEDY RIVER	1990	P14	KFRI 14	*
2	*E. tereticornis*	MOREHEAD RIVER	1990	P15	KFRI 15	*
3	*E. tereticornis*	MOREHEAD RIVER	1990	P16	KFRI 16	*
4	*E. tereticornis*	E."HYBRID"	1990	V9	KFRI 17	_
5	*E. tereticornis*	ORO BAY TO EMO	1990	P18	KFRI 18	_
6	*E. tereticornis*	CARD WELL	1990	P19	KFRI 19	_
7	*E. tereticornis*	KENNEDY CK PEN DEV RD	1990	P20	KFRI 20	*
8	*E. tereticornis*	KENNEDY CK PEN DEV RD	1990	P21	KFRI 21	*
9	*E. tereticornis*	80 KM NNW COOK TOWN	1990	P27	KFRI 27	_
10	*E. tereticornis*	80 KM NNW COOK TOWN	1990	P28	KFRI 28	*
11	*E. tereticornis*	KENNEDY RIVER	1990	P29	KFRI 29	*
12	*E. tereticornis*	ORO BAY TO/ EMO	1990	P30	KFRI 30	_
13	*E. tereticornis*	CARD WELL	1990	P31	KFRI 31	_
14	*E. tereticornis*	E.OF HATOBULICO	1990	P32	KFRI 32	_
15	*E. tereticornis*	80 KM NNW COOK TOWN	1990	P33	KFRI 33	*
16	*E. tereticornis*	KENNEDY CREECK PEN DEV RD ,(QLD)	1993	R5	KFRI 35	*
17	*E. tereticornis*			K9	KFRI 36	
18	*E. tereticornis*	EAST OF KUPIANO	1993	R21	KFRI 38	*
19	*E. tereticornis*	MOREHEAD	1993	R2	KFRI 44	*

		RIVER				
20	*E. tereticornis*	RAVENSHOE	1993	K3	KFRI 43	*
21	*E. tereticornis*	KENNEDY CK PEN DBE RD (QLD)	1993	R5	KFRI 47	*
22	*E. tereticornis*	_	1993	K12	KFRI 48	*
23	*E. tereticornis*	KENNEDY RIVER	1993	R24	KFRI 49	*
24	*E. tereticornis*	KENNEDY RIVER	1993	R1	KFRI 50	*
25	*E. tereticornis*	RAVENSHOE (QLD)	1992	K2	KFRI 56	*
26	*E. tereticornis*	SIRINUMU SOGERI PLAT (PNG)	1992	K4	KFRI 57	*
27	*E. tereticornis*	KENNEDY RIVER	1992	K7	KFRI 58	*
28	*E. tereticornis*	MOREHEAD RIVER(QLD)	1993	R2	KFRI 79	_
29	*E. tereticornis*	EAST OF KUPIANO (PNG)	1993	R20	KFRI 80	_
30	*E. tereticornis*	PALMER RIVER	1993	R23	KFRI 81	_
31	*E. tereticornis*	CARD WELL	1993	R4	KFRI 82	_
32	*E. tereticornis*	RAVENSHOE	1993	R3	KFRI 83	_
33	*E. tereticornis*	34 KM S, CASINO	1992	K9	KFRI 84	_
34	*E.tereticornis*	34 KM S, CASINO	1992	K10	KFRI 85	_
35	*E.tereticornis*	PALMER RIVER	1992	K12	KFRI 86	_
36	*E. tereticornis*	ORO BAY TO EMO	1993	R10	KFRI 60	*
37	*E. tereticornis*	KENNEDY RIVER(QLD)	1992	K1	KFRI 62	*
38	*E. tereticornis*	KENNEDY CREECK PEN DEV RD,(QLD)	1992	K11	KFRI 65	*
39	*E. tereticornis*	ORD RIVER (WA)	1993	R12	KFRI 66	*
40	*E. tereticornis*	ORO BAY TO/ EMO (PNG)	1992	K8	KFRI 67	*
41	*E. tereticornis*	R' HAMPTON RACE COURSE (QLD)	1992	K5	KFRI 71	*

E. camaldulensis						
1	*E. camaldulensis*	W.OF IRVINE BANK	1990	P22	KFRI 22	*
2	*E. camaldulensis*	W. OF NORMANTON	1990	P23	KFRI 23	_
3	*E. camaldulensis*	W. OF NORMANTON	1990	P24	KFRI 24	*
4	*E. camaldulensis*	KATHERINE	1990	P25	KFRI 25	*
5	*E. camaldulensis*	KATHERINE	1990	P7	KFRI 7	*
6	*E. camaldulensis*	KATHERINE	1990	P8	KFRI 8	*
7	*E. camaldulensis*	CAPE RIVER	1990	P10	KFRI 10	*
8	*E. camaldulensis*	COCKATOO CK (NT)	1993	R19	KFRI 39	*
9	*E. camaldulensis*	GILBERT RIVER (QLD)	1993	R18	KFRI 40	*
10	*E. camaldulensis*	VICTORIA RIVER (NT)	1993	R17	KFRI 41	*
11	*E. camaldulensis*	KATHERINE RIVER	1993	R14	KFRI 42	*
12	*E. camaldulensis*	BULLOCK CK	1993	R26	KFRI 45	*
13	*E. camaldulensis*	KATHERINE RIVER	1993	R13	KFRI 51	*
14	*E. camaldulensis*	CAPE RIVER(QLD)	1992	K15	KFRI 54	*
15	*E. camaldulensis*	VICTORIA RIVER (NT)	1992	K6	KFRI 55	*
16	*E. camaldulensis*	REGION E OF PETFORD	1992	K16	KFRI 59	*
17	*E. camaldulensis*	W.OF IRVINE BANK (QLD)	1993	R9	KFRI 61	*
18	*E. camaldulensis*		1993	R27	KFRI 64	*
19	*E. camaldulensis*	CAPE RIVER	1993	R16	KFRI 68	*
20	*E. camaldulensis*	W.OF IRVINE BANK (QLD)	1993	R25	KFRI 69	*
21	*E. camaldulensis*	BULLOCK CREEK	1992	K13	KFRI 70	*
22	*E. camaldulensis*	W OF NORMANTON	1990	P72	KFRI 72	*
23	*E. camaldulensis*	W OF NORMANTON	1990	P73	KFRI 73	*
24	*E. camaldulensis*	VICTORIA RIVER (NT)	1993	R15	KFRI 75	*
25	*E. camaldulensis*	VICTORIA RIVER (NT)	1993	R16	KFRI 76	*
26	*E. camaldulensis*	GILBERT	1993	K18	KFRI 77	*

		RIVER (QLD)				
27	*E. camaldulensis*	-	1997	KFRI 97	KFRI 97	-
E. urophylla						
1	*E. urophylla*	LEWOTOBI	1990	P34	KFRI 34	*
2	*E. urophylla*	SW OF UHAK NE WETAR (IND)	1993	R22	KFRI 37	*
3	*E. urophylla*	M.T MUTIS W.TIMOR (INDO)	1993	R8	KFRI 46	*
4	*E. urophylla*	MT.EGON FLORES (IND)	1993	R6	KFRI 52	*
5	*E.urophylla*	LEWOTOBI	1990	P12	KFRI 12	*
6	*E. urophylla*	MT.EGON FLORES	1990	P13	KFRI 13	*
7	*E. urophylla*	Half sib progeny				
8	*E. urophylla*	-				
9	*E. urophylla*	-				
10	*E. urophylla*	-				
11	*E. urophylla*	-				
12	*E. urophylla*	-				
13	*E. urophylla*	-				
14	*E. urophylla*	-				
E. grandis						
1	*E. grandis*	ORARA WEST C HARBOUK (NSW)	1993	R11	KFRI 78	_
2	*E.grandis*	LOCAL	1990	C6	KFRI 3	_
***Eucalyptus* 'hybrid'**						
1	*E .tereticornis*	E."HYBRID"	1990	B7	KFRI 1	_
2	*E. tereticornis*	E."HYBRID"	1990	B10	KFRI 2	_
3	*E. tereticornis*	E."HYBRID"	1990	WH5	KFRI 4	_
4	*E. tereticornis*	E."HYBRID"	1990	V4	KFRI 5	_
5	*E. tereticornis*	E."HYBRID"	1990	WH6	KFRI 6	_
6	*E. tereticornis*	E."HYBRID"	1990	V3	KFRI 9	_
7	*E. tereticornis*	E. "HYBRID"	1990	FRI4	KFRI 11	*
8	*E. tereticornis*	E."HYBRID"	1993	R7	KFRI 53	*
9	*E. tereticornis*	E."HYBRID"	1992	K14	KFRI 63	*
10	*E. tereticornis*	E."HYBRID"	1990	P74	KFRI 74	*
E. pellita						
1	*E. pellita*	BETWEEN GGDE KIRIWA	1990	P26	KFRI 26	*
ITC Bhadrachalam clones						
1	*BHADRACHALAM CLONE*	_	_	_	BCM-3	*

2	*BHADRACHALAM CLONE*	_	_	_	BCM-6	*
3	*BHADRACHALAM CLONE*	_	_	_	BCM-7	*
4	*BHADRACHALAM CLONE*	_	_	_	BCM-10	*
5	*BHADRACHALAM CLONE*	_	_	_	BCM-27	*
6	*BHADRACHALAM CLONE*	_	_	_	BCM-71	*
7	*BHADRACHALAM CLONE*	_	_	_	BCM-83	*
8	*BHADRACHALAM CLONE*	_	_	_	BCM-128	*
9	*BHADRACHALAM CLONE*	_	_	_	BCM-130	*
10	*BHADRACHALAM CLONE*	_	_	_	BCM-404	*

* Established in clonal gene bank.

3.3.1. Clonal multiplication area (CMA) for eucalypts

One hectare clonal multiplication area was raised at Kottappara by planting 52 clones which produced more than 50 per cent success in rooting of cuttings (table 17). Out of these, 19 clones belonged to *E. tereticornis*, 18 clones belonged to *E. camaldulensis*, two clones to *E. urophylla* and only one clone to *E. pellita*. Two clones were produced from the local *Eucalyptus* 'hybrid' CPTs grown as control for comparison. Ten clones were from ITC Bhadrachalam, some of which showed adaptability in Kerala. The CMA was also used as Clonal Testing Area (CTA); the growth and disease resistance of the clones were monitored in the plot every six months.

3.3.2. Disease incidence in Eucalypt clones

The clones assembled in CMA/CTA were examined for occurrence of leaf blight disease caused by *Cylindrocladium* species and pink disease caused by *Corticium salmonicolor* during the season of disease prevalence for three years (Table 18). The two clones produced from local eucalypt 'hybrid' trees were severely infected by leaf blight and pink disease. Most of the clones produced from plus trees identified among

provenances were free from infection or suffered low infection. Clones which showed fast growth and disease tolerance/resistance consistently for three years were selected and supplied to the Central Nurseries of Kerala Forest Department and HNL for establishing their CMA for further mass multiplication (Figs. 9-13), and for raising plantations (Fig.14). Out of 42 KFRI clones tested in CMA/CTA, 20 clones were finally selected for this purpose. These clones are listed in Table 19 and their potential yield is provided. The productivity potential is very high (10 - >40 $m^3ha^{-1}yr^{-1}$) and higher than that of the seedling crop of the best provenances. During 1998-2003, about 1.33 lakh ramets (seedlings) have been supplied to Kerala Forest Department alone (Table 20).

Table 17. List of eucalypts clones planted in Clonal Multiplication Area (CMA) at Kottappara

Sl. No.	Clone No.	Provenance Name/Source	Seed lot No.
E. tereticornis			
1	KFRI 14	Kennedy River, Qld[1]	14802
2	KFRI 15	Morehead River, Qld	13444
3	KFRI 16	Morehead River, Qld	13444
4	KFRI 20	Kennedy Ck Pen Dev Rd, Qld	15827
5	KFRI 21	Kennedy Ck Pen Dev Rd, Qld	15827
6	KFRI 28	80 Km NNW Cook town, Qld	15198
7	KFRI 33	80 Km NNW Cook town, Qld	15198
8	KFRI 43	Ravenshoe, Qld	14424
9	KFRI 44	Morehead River, Qld	13444
10	KFRI 49	Kennedy River, Qld[1]	14802
11	KFRI 50	Kennedy River, Qld[1]	14802
12	KFRI 56	Ravenshoe, Qld	14424
13	KFRI 57	Sirinumu Sogeri Plat, Png	14424
14	KFRI 58	Kennedy River, Qld[1]	14802
15	KFRI 60	Oro Bay to Emo, Png	13399
16	KFRI 62	Kennedy River, Qld[1]	14802
17	KFRI 65	Kennedy Creek Pen Dev Road, Qld	15827
18	KFRI 67	Oro Bay to Emo, Png	13399
19	KFRI 71	R' Hampton Race Course, Qld	13547
E. camaldulenis			
20	KFRI 8	Katherine, NT	13801
21	KFRI10	Cape River, Qld	13815
22	KFRI 22	W. of Irvine Bank, Qld	15234
23	KFRI 23	W. of Normanton	13695

24	KFRI 24	W. of Normanton	13695
25	KFRI 25	Katherine NT	13801
26	KFRI 39	Cockatoo Creek, NT	13929
27	KFRI 40	Gilbert River, Qld	12963
28	KFRI 41	Victoria River, Nt	13928
29	KFRI 45	Bullock Creek, Qld	15049
30	KFRI 51	Katherine River	17635
31	KFRI 54	Cape River, Qld	13815
32	KFRI 55	Victoria River, Nt	13928
33	KFRI 59	Region E of Petford, Qld	14338
34	KFRI 61	W of Irvine Bank, Qld	15234
35	KFRI 68	Cape River, Qld	13815
36	KFRI 69	W of Irvine Bank, Qld	15234
37	KFRI 70	Bullock Creek, Qld	15049
E. pellitta			
38	KFRI 26	Between GGOE Kiriwa, Png	15122
E. urophylla			
39	KFRI 52	Mt. Wuko Flores, Ind	15982
40	KFRI 37	SW of Uhak NE Wetar, Ind	
***Eucalyptus* hybrid clones**			
41	KFRI 11	Local seeds	-
42	KFRI 63	Local seeds	-
ITC Bhadrachalam Clones			
43	BCM 3	-	-
44	BCM 6	-	-
45	BCM 7	-	-
46	BCM 10	-	-
47	BCM 27	-	-
48	BCM 28	-	-
49	BCM 83	-	-
50	BCM 128	-	-
51	BCM 130	-	-
52	BCM 404	-	-

Table 18. Pink disease and cylindrocladium infection on KFRI clones of *Eucalyptus tereticornis, E. camaldulenis and E. pellita* planted in clonal testing area

Sl. No.	Clone No.	Provenance Name	Disease incidence					
			1998		1999		2000	
			CLB	Pink	CLB	Pink	CLB	Pink
E. tereticornis								
1	KFRI 14	Kennedy River, Qld[1]	M	NIL	L	L	L	NIL

2	KFRI 15	Morehead River, Qld	L	NIL	NIL	NIL	L	NIL
3	KFRI 16	Morehead River, Qld	L	NIL	L	L	L	L
4	KFRI 20	Kennedy Ck Pen Dev Rd, Qld	L	NIL	L	L	L	NIL
5	KFRI 21	Kennedy Ck Pen Dev Rd, Qld	M	NIL	M	L	M	M
6	KFRI 28	80 Km NNW Cook town, Qld	M	NIL	L	NIL	L	M
7	KFRI 33	80 Km NNW Cook town, Qld	M	NIL	L	L	L	L
8	KFRI 43	Ravenshoe, Qld	L	NIL	L	NIL	L	NIL
9	KFRI 44	Morehead River, Qld	L	NIL	L	NIL	L	NIL
10	KFRI 65	Kennedy Creek Pen Dev Road, Qld	M	NIL	L	NIL	L	NIL
E. camaldulensis								
11	KFRI 7	Katherine, NT	L	NIL	M	M	S	S
12	KFRI 8	Katherine, NT	L	NIL	S	S	S	S
13	KFRI10	Cape River, Qld	M	NIL	L	L	M	L
14	KFRI 22	W. of Irvine Bank, Qld	M	NIL	L	L	L	L
15	KFRI 25	Katherine NT	L	NIL	L	NIL	L	NIL
16	KFRI 39	Cockatoo Creek, NT	M	NIL	L	L	M	M
17	KFRI 45	Bullock Creek, Qld	L	NIL	L	L	M	L
18	KFRI 68	Cape River, Qld	M	NIL	L	L	L	NIL
19	KFRI 70	Bullock creek, Qld	NIL	NIL	L	L	M	L
E. urophylla								
20	KFRI 26	Between GGOE Kiriwa, Png	L	NIL	NIL	NIL	NIL	NIL
21	KFRI 63	Eucalyptus hybrid clone	S	L	S	S	S	S
Eucalyptus hybrid								
22	Control	Local seedlings	S	NIL	S	S	S	S

Table 19. Disease tolerant and highly productive clones of *Eucalyptus* species recommended for planting in Kerala

Eucalypts species and Clone No. Name of provenances from which developed		Productivity rating[1]		Disease[2] resist-ance rating
		In 4th year old KFD plantation	In 6th year old KFRI clonal testing area	
Eucalyptus tereticornis				
KFRI 14	Kennedy River	*	****	*
KFRI 15	Morehead River	**	***	**
KFRI 16	Morehead River	**	***	*
KFRI 28	80 Km NNW Cook Town	**	****	*
KFRI 38	East of Kupiano	**	****	***
KFRI 43	Ravenshoe,	**	****	*
KFRI 47	Kennedy Creek Pen Dev Road	*	**	*
KFRI 49	Morehead River	**	****	**
KFRI 56	Ravenshoe	**	****	*
KFRI 58	Kennedy River	**	***	*
KFRI 62	Palmer River	*	**	
KFRI 65	Kennedy Creek Pen	**	****	**
Eucalyptus camaldulensis				
KFRI 10	Katherine	**	****	*
KFRI 23	West of Normanton	**	***	**
KFRI 25	Katherine	**	****	***
KFRI 54	Cape River	*	***	*
KFRI 68	Cape River	*	***	*
Eucalyptus urophylla				
KFRI 101	-	*	**	**
Eucalyptus pellita				
KFRI 26	Between GGOE-Kiriwa	**	**	****
Eucalyptus grandis				
KFRI UG 1	*E. urophylla x E.grandis*	**	**	***[3]

1. Low (< 10$m^2ha^{-1}yr^{-1}$), ** Moderate (10-25 $m^2ha^{-1}yr^{-1}$); *** High (25-40 $m^3ha^{-1}yr^{-1}$); **** Very High (> 40$m^3ha^{-1}yr^{-1}$)

2 * Susceptible, ** Moderately resistant, *** Highly resistant, **** Very highly resistant

3 In 2-year-old plantation

Table 20. Eucalyptus clones supplied to Kerala Forest Department by KFRI during 1998-2003.

Sl.No.	Year	No. of ramets (clones) supplied
1	1998	17,400
2	1999	28,156
3	2000	33,200
4	2001	25,250
5	2002	10,400
6	2003	18,500
	Total	**1,32,906**

3.4. Acacia

3.4.1. Growth performance of acacia provenances

The mean height and GBH of acacia provenances planted at Kottappara and Kulathupuzha were recorded every year. But the measurements for the Kulathupuzha plot were available for the first three years. The estimated yield at sixth year (mean of the two locations) and at third year separately for Kottappara and Kulathupuzha are provided in Table 21. *A. mangium* provenances showed the highest mean yield of 61.6 m^3/ha/yr at the end of third year at Kulathupuzha. Unfortunately it was not possible to find out the mean yield at sixth year as the measurements were unavailable. However, measurements of MOREHEAD provenance was available at Kottappara site at the end of sixth year and the yield was the highest (116.2 m^3/ha/yr). When the yields at the end of third year were considered, BALIMO ARAMIA RIVER, CLAUDIE RIVER18994, DESI DESI MOREHEAD, WIPIM ORIOMO, KAPAL VILLAGE/ORIOMO and MOREHEAD provenance are recommended for planting in Kerala (Table 23). *A. crassicarpa* was the next high yielding species. LIMAL-MALAM, BENSBACH WP, MOREHEAD and PONGAKI E OF MOREHEAD are recommended for planting. *A. auriculiformis* was the third best species for Kerala. MELVILLE ISLAND SO, DIMISISI, S OF COEN CAPE YORK, MOREHEAD R ROUKU and SPRINGWALE provenance are recommended

for planting based on the growth performance. The seed source of SPRINGWALE provenance was Mysore Paper Mills, Shimoga and it was a second generation seedlot. Neverthless, SPRINGWALE provenance has the additional advantage because of its low branching character. *A. aulacocarpa* are the least adapted species in Kerala with lowest yield.

3.4.2. Disease incidence

Except for pink disease (Fig. 8), the provenances were generally free from diseases. Incidence of pink disease also was not serious and the susceptible provenances are shown in Table 22. The incidence of heart rot was not observed till the age of seven years in *A. mangium*. Incidence of a weevil, *Myllocerus* sp., attack was noticed during pre-monsoon showers on *Acacia mangium* and *A. auriculiformis*. The affected plants gave a burnt appearance at the apical region of plants. Other species were not susceptible to insect attack.

Table 21. Estimated mean yield of acacia provenances at 6th year (spacing 2 m x 2m) (Average of 49 – 147 plants)

Sl. No.	Provenance	Estimated yield at 6th year at Kottappara		Estimated mean yield/ha/yr at 3rd year (mean of 3 year total)	
		Total yield (m^3/ha) at 6th year	Mean annual volume increment (m^3/ha/yr)	Kotta-ppara	Kulu-thup-uzha
A. auriculiformis					
1	S OF COEN CAPE YORK, QLD	162.18	27.0	33.2	41.4
2	SAI THONG, THAI	103.22	17.2	21.3	22.6
3	MOREHEAD R ROUKU, WP, PNG	140.82	23.5	21.5	38.5
4	BENSBACH R, WESTERN P, PNG	133.90	22.3	27.6	33.5
5	OLIVE RIVER, QLD	115.66	19.3	24.5	35.8
6	POHATURI RIVER, PNG	124.6	20.8	26.7	44.0
7	ORIOMO, PNG	124.14	20.7	26.2	36.5
8	DIMISSI, PNG	146.48	24.4	29.7	46.5
9	BINATURIR, WP, PNG	125.86	21.0	28.8	39.2

10	MELVILLE ISLAND SO NT, SSO	150.50	25.1	37.8	44.7
11	SPRINGWALE (HALF-SIB PROGENY)	124.26	20.7	29.4	37.8
	Average	132.0	22.0	27.9	38.2
A. mangium					
1	INNISFAIL REGION, QLD	-	-	-	52.2
2	KINI WP, PNG	-	-	-	49.0
3	MUTING IRIAN JAYA, IND	-	-	-	42.1
4	MOREHEAD, PNG	697.32	116.2	-	60.6
5	ARUFI VILLAGE, PNG	-	-	-	50.1
6	KAPAL VILLAGE/ORIOMO, PNG	-	-	-	65.1
7	CLAUDIE RIVER18994, QLD	-	-	-	68.7
8	BALIMO ARAMIA RIVER, PNG	-	-	-	104.8
9	PASCO R CAPE YORK, QLD	-	-	-	53.4
10	DESI DESI MOREHEAD, PNG	-	-	-	66.9
11	WIPIM ORIOMO, PNG	-	-	-	66.0
12	CLAUDIE RIVER 17701, PNG	-	-	-	60.2
	Average	697.32	116.2	-	61.6
A. aulacocarpa					
1	WASUA PEDEYA WP, PNG	98.22	16.3	17.8	26.4
2	W OF WIPIM WP, PNG	103.43	17.2	21.8	27.9
3	PONGAKIE MOREHEAD WP, PNG	134.2	22.4	23.6	32.8
4	BENSBACH- BALAMUK WP, PNG	135.52	22.6	29.1	31.9
5	3K S MT LARCOM, QLD	63.81	10.6	11.7	22.1
6	SAMFORD, QLD	95.33	15.9	11.7	15.6
7	OLD LOCKHART AIRSTRIP, QLD	78.27	13.0	15.4	21.0
8	PNG PROV. SEED ORCH., FIJI	125.65	20.9	27.3	27.0
	Average	104.3	17.4	19.8	25.6
A. crassicarpa					
1	JARDINE RIVER BAMAGA, QLD	93.23	15.4	25.3	31.9
2	PONGAKI E OF MOREHEAD, PNG	209.83	35.0	45.5	-
3	BENSBACH WP, PNG	214.75	35.8	44.0	54.2
4	LIMAL-MALAM, PNG	241.81	40.3	56.3	61.1
5	DIMISSI VILLAGE WP, PNG	185.82	31.0	45.5	59.7
6	MOREHEAD, PNG	211.12	35.2	46.6	71.6
	Average	193.4	32.2	43.3	44.7

3.4.3. *Acacia* species recommended for planting in Kerala

Selected provenances of *A. mangium, A. auriculiformis* and *A. crassicarpa* can be planted in Kerala (Table 23). Performance of *A. aulacocarpa (A. peregrina)* is poor when the growth of other three species is considered. *A. mangium* provenances are the most preferred as its provenances are faster in growth than *A. auriculiformis* and *A. crassicarpa* especially in medium to high rainfall areas with comparatively fertile soil. *A. auriculiformis* provenances can come up in comparatively dry area with unfertile soil also. *A. crassicarpa* is not popular in Kerala so far. It has luxuriant foliage but less than that of *A. mangium*. All the four species have nitrogen fixing ability as evident from root nodulation. But, *A. auriculiformis* and *A. mangium* roots nodulate profusely especially in degraded acidic soils of Kerala. *A. mangium* and *A. auriculiformis* are the most widely planted species among exotic acacias in Malaysia, Indonesia, Vietnam and Philippines (Wood and Awang, 1998). Eldoma and Awang (1999) reported the site adaptability of all the four species in several tropical countries of South and South East Asia, the Far East and Africa and concluded that Papua New Guinea (PNG) provenances performed better than other provenances. The performance of the species varied depending upon the climate of the country. In our trial also PNG provenances have performed better than other provenances.

Table 22. List of Acacia provenances affected by pink disease

Sl. No.	Provenance Name	Seedlot No.	Severity
A. auriculiformis			
1	SPRINGVALE (HALF-SIB PROGENY)	MPM Karna-taka	Low
A. mangium			
2	MOREHEAD	17868	Low
A. aulacocarpa			
3	SAMFORD	17891	Low
4	PNG PROV. SEED ORCH.	19301	Low
A. crassicarpa			
5	DIMISSI VILLAGE WP	18202	Low
6	BENSBACH WP	18836	Low

Table 23. Australian acacia provenances recommended for planting in Kerala based on growth performance, disease resistance and adaptability

Sl. No.	Provenances
Acacia auriculiformis (Out of 10 provenances tested)	
1	MELVILLE ISLAND SO, SSO
2	DIMISISI, PNG
3	S OF COEN CAPE YORK, QLD
4	MOREHEAD R ROUKU, PNG
5	SPRINGWALE (HALF SIB PROGENY)
A. crassicarpa (Out of 7 provenances tested)	
1	LIMAL-MALAM, PNG
2	MOREHEAD, PNG
3	BENSBACH, PNG
4	PONGAKIE OF MOREHEAD, PNG
A. aulacocarpa (A. peregrina) (Out of 8 provenances tested)	
1	BENSBACH- BALAMUK WP, PNG
2	PNG PROV. SEED ORCHARD, FIJI
3	PONGAKIE MOREHEAD WP, PNG
A. mangium (Out of 12 provenances tested)	
1	BALIMO ARAMIA RIVER, PNG
2	CLAUDIE RIVER 18994, QLD
3	MOREHEAD,PNG
4	WIPIM ORIOMO, PNG
5	KAPAL VILLAGE/ORIOMO, PNG
6	DESI DESI MOREHEAD, PNG

3.5. Candidate plus trees of acacias

Eighty CPTs belonging to *A. auriculiformis, A. mangium, A. crassicarpa* and *A. aulacocarpa* were identified in 4-year-old provenance trial plot at Kottappara. Felling these trees at 90 cm height, did not produce coppice shoots. But pruning 6- to 18-month-

old trees at 90 cm height provided plenty of coppice shoots. Cuttings produced from coppice shoots rooted readily in mist chamber when treated with 4000 ppm IBA. Watering and fertilizer application improved coppice shoot production. List of Acacia clones developed are provided in Table 24.

3.6. CMA for Acacias

The clones of acacia species consisted of the following:

1. *A. mangium* : 4
2. *A. auriculiformis* : 5
3. *A. crassicarpa* : 3
4. *A. aulacocarpa* : 4
5. Mangium hybrid : 10

All the clones of *Acacia* spp. were developed from provenance trees (Table 24) Ten mangium hybrid clones viz. SU 3, SU 4, SU5, SU 38, SU 40, SU 47, HT 7, HT 10, BC 65, FC 6, were also maintained in the acacia clonal nursery. The mangium hybrid clones were obtained from West Coast Paper Mills, Dandeli and Mysore Paper Mills, Shimoga.

Table 24. List of KFRI Acacia clones planted in CMA

Sl. No.	Clone No.	Provenance Name/Source	Seed lot No.
A. mangium			
1	KFRI AM 1	WIPIM ORIOMO, PNG	17872
2	KFRI AM 2	BALIMO ARAMIA RIVER	19139
3	KFRI AM 3	KAPAL VILLAGE ORIOMO	18214
4	KFRI AM 4	MOREHEAD	17868
A. auriculiformis			
1	KFRI AA 1	SPRINGVALE (HALF SIB PROGENIES)	MPM
2	KFRI AA 2	MELVILLE ISLAND SO NT	19514
3	KFRI AA 3	BINATUR R, WP	19391
4	KFRI AA 4	SAI THONG	15951
5	KFRI AA 5	S OF COENCAPE YORK	15697
A. crassicarpa			
1	KFRI AC 1	JARDINE RIVER BAMAGA	16128
2	KFRI AC 2	PONGAKI E OF MOREHEAD	16599
3	KFRI AC 3	BENSBACH WP	17552

A. aulacocarpa			
1	KFRI AP 1	PONGAKIE MOREHEAD WP	16988
2	KFRI AP 2	BENSBACH-BALAMUK WP	17551
3	KFRI AP 3	WASUA PEDEYA WP	16950
4	KFRI AP 4	OLD LOCKHART AIRSTRIP	18358

The plants in the CMA were pruned at a height of 90 cm before one and a half year growth to develop large number of coppice shoots. The apical portion of the new shoots having two mature leaves were used for vegetative propagation. Detailed methodology adopted for vegetative propagation is provided in the KFRI Research Report No.230 (Balasundaran and Maria Florence, 2002).

4. CONCLUSIONS AND RECOMMENDATIONS

1. The provenance trials in lowlands using seeds of Australian/Indonesian origin have revealed that, the average performance of *E. urophylla* provenances was better than that of *E. tereticornis*, the species widely grown in lowlands in Kerala. *E. urophylla* provenance, N of Telemar SW Netar, *Indonesia* and *E. pellita* provenance 71-72 km NE Wenlock gave better volume yield than all the provenances indicating suitability of these two species for raising plantations in lowlands.
2. Kallarackal and Soman (1998) studied the stomatal conductance of six species of *Eucalyptus* namely, *E. tereticornis, E. camaldulensis, E. urophylla, E. brassiana, E. pellita and E. deglupta* and reported lowest values of stomatal conductance for *E. urophylla* and highest for *E. camaldulensis*. *E. urophylla* showed closure of stomata in response to atmospheric vapour pressure deficit. The relation between net photosynthesis and stomatal conductance was almost linear for *E. urophylla* and *E. pellita.* Moreover, the pre-monsoon values for net photosynthesis were higher at lower stomatal conductance for these two species indicating better water use efficiency than the other species. Kallarackal and Soman (1998) also recommended *E. urophylla* for locations where water conservation and plantation productivity are equally important. The present study also support their recommendations.
3. The Australian provenances of *E. grandis* have given higher yield than the local seed sources. More provenance seeds can be procured from CSIRO, Australia. Half sib seeds of the best provenances from provenance trial plot at Muthanga can also be utilized after converting the provenance trial to a seed stand.
4. *A. mangium* provenances have performed better than *A. auriculiformis* provenances. *A. auriculiformis* will be better suited in comparatively drier areas. Seeds of the promising provenances can be procured from CSIRO, Australia. The half sib progenies of *A. mangium* and *A. auriculiformis* provenances planted at Kottappara and Kulathupuzha can also be used as seed source after culling undesirable trees/provenances from these plots.

5. *E. tereticornis* clones developed from new Australian provenances had performed better than the average provenance yield and far better than local *Eucalyptus* 'hybrid' plantations. Though many of the clones have remained resistant to pink disease, the clones, especially the coppice shoots are being attacked increasingly by several species of *Cylindrocladium* causing leaf blight. Hence, new clones of *E. urophylla* and *E. pellita* have to be developed for replacing the *E. tereticornis* clones. *E. urophylla* is tolerant to both the diseases while *E. pellita* is highly resistant. Since hybrids are more productive, a better option will be hybrids between *E. urophylla, E. grandis* and *E. pellita* with *E. urophylla* and *E. pellita* as mother plants. Disease resistant seedlings from seeds of closely planted provenances of these three species can be screened for natural hybrids using molecular markers.
6. Heart rot of *A. mangium* was not observed in young trees. But the disease occurs in trees above the age of 10 years. Hence, it may be better to extract mangium plantations sufficiently earlier. Hybrid plants between *A. mangium* and *A. auriculiformis* with *A. mangium* as the mother plant are also more productive than either of the parents. Close planting of the two species as clonal seed orchard or seedling seed orchard will produce natural hybrids between the two species. Hybrids can be identified visually at the seedling stage itself and several such hybrids can be tested for developing fast growing disease resistant clones.
6. The provenance plots of eucalypts and acacias have to be maintained as they are precious stock of original introduction of the popular exotics.

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