SELECTION AND CLONAL MULTIPLICATION OF SUPERIOR TREES OF TEAK *(TECTONA GRANDIS)* AND PRELIMINARY EVALUATION OF CLONES

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PALANISAMY K, GIREESAN K, NAGARAJAN V & HEGDE M. 2009. Selection and clonal multiplication of superior trees of teak (*Tectona grandis*) and preliminary evaluation of clones. Teak (*Tectona grandis*) is a valued timber species renowned for its durability and stability. Experiments have been conducted for the feasibility of establishing clonal plantations of teak with high yielding clones to enhance productivity. A total of 41 outstanding trees were selected from plantations in different parts of Kerala with a selection intensity of 0.3 to 0.5%, of which 13 trees showed substantially superior height (30–35 m) and girth at breast height (GBH) (151–220 cm). More than 30% increase in height and GBH was observed in 7 and 14 trees respectively, compared with trees in plantations, indicating the superiority of the selected trees and the possibility of increasing the productivity through clonal plantation. The selected trees were multiplied clonally using coppice shoots and subsequent mass propagation from a vegetative multiplication garden. Rooting in the clones reached a range of 45–100%. Clone NPT110 exhibited maximum height (35 m) and GBH (220 cm) with 100% rooting ability. This suggests that it may be a promising clone for large-scale plantings. The selected clones also showed better growth performance in the field than seedlings of local seed lots. It is thus recommended for *ex situ* preservation of superior genotypes of teak in breeding programmes.

Keywords: Clonal forestry, clone, coppice shoots, juvenility, productivity, rooting

PALANISAMY K, GIREESAN K, NAGARAJAN V & HEGDE M. 2009. Pemilihan dan pembiakan klon pokok jati (*Tectona grandis*) terbaik dan penilaian awal klon. Pokok jati (*Tectona grandis*) merupakan spesies balak yang tinggi nilainya dan terkenal kerana ketahanan serta kestabilannya. Uji kaji dijalankan untuk menentukan kemungkinan mendirikan ladang klon pokok jati yang mempunyai klon hasil tinggi untuk meningkatkan pengeluaran. Sebanyak 41 pokok terbaik dipilih daripada pelbagai ladang di Kerala dengan keintensifan pemilihan 0.3% hingga 0.5%. Terdapat 13 pokok yang menunjukkan ketinggian (30–35 m) dan lilit aras dada (GBH) (151–220 cm) yang terbaik. Peningkatan ketinggian dan GBH yang melebihi 30% dicerap masing-masing dalam tujuh dan 14 pokok berbanding pokok di ladang. Ini menunjukkan kelebihan pokok yang dipilih dan potensi meningkatkan hasil melalui ladang klon. Pokok yang dipilih dibiakkan secara klon menggunakan pucuk kopis dan kemudiannya dibiakkan dalam jumlah yang banyak di kebun pembiakan vegetatif. Pengakaran klon mencapai julat 45%–100%. Klon NPT110 menunjukkan ketinggian (35 m) serta GBH (220 cm) maksimum dengan kebolehan pengakaran sebanyak 100%. Ini mencadangkan bahawa klon ini berpotensi untuk digunakan dalam ladang berskala besar. Klon yang dipilih juga menunjukkan pertumbuhan di lapangan yang lebih baik berbanding anak benih daripada lot biji benih tempatan. Justeru, klon ini disyorkan untuk pemuliharaan *ex situ* bagi genotip terbaik pokok jati dalam program biak baka.

INTRODUCTION

Teak is widely distributed in natural forests in India, Myanmar, Laos and Thailand under different climatic and edaphic conditions. It has also been introduced to Indonesia, Malaysia, Sri Lanka, Africa, South America, Central America and Australia. There is a huge demand for teak wood in national and international markets. India has 8.9 million ha of natural teak-bearing forests, 1.5 million ha of plantations and 1000 ha of clonal seed orchards. Here, the tree is planted on a large scale every year, i.e. approximately 20 000 ha. The rotation period of teak is 50–60 years and 70–80 years in southern and central India respectively.

The seed production in clonal seed orchards is very poor and most of the plantations are raised from unselected seed source resulting in low productivity. It has been reported that the average productivity of teak in the state of Kerala is 2.85 m^3 ha^{-1} $year^{-1}$ over a 53-year rotation. This is very low in comparison with other teak-growing countries. This suggests that there is a

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need to enhance the productivity of teak using quality planting stock rather than extending the plantation hectarage.

It has been well established that clonal plantations play a vital role in increasing productivity of forest species. In Brazil, China and India significant enhancement of productivity has been reported through the application of clonal forestry of eucalypts and poplar (Zobel & Talbert 1984, Lal *et al.* 1993). However, clonal plantation of teak is not operational in India owing to lack of suitable clonal propagation methods, despite five decades of work on vegetative propagation using branch cuttings, grafting and micropropagation (Nautiyal *et al.* 1991, Palanisamy *et al.* 1995). In contrast, good success in rooting of teak has been reported in Malaysia (Monteuuis *et al.* 1995). In India, mature tissues which have poor rooting, slow growth in the field and poor stem form are used for propagation (Palanisamy *et al.* 2006). A cost effective vegetative propagation method for the multiplication of mature teak trees through coppice shoots have been reported (Palanisamy & Subramanian 2001). Coppice shoots are typically juvenile in respect to their morphology, growth and propagation characteristics.

There is also a permanent loss of superior genotypes with desirable wood properties from plantations after harvest and no attempt has been made to conserve them for further genetic improvement. The main aim of the present study was to select superior trees of teak, multiply them clonally and evaluate the performance of clones both in nursery and in the field. The feasibility of establishing clonal plantations of teak and a conservation strategy for valuable genotypes for future breeding programme will be discussed.

MATERIALS AND METHODS

Teak plantations in India are generally raised through stumps (root stocks prepared from 1–2 year old seedlings) which are planted at a spacing of 2 × 2 m to enhance the initial height growth. This is followed by two mechanical and three silvicultural thinnings performed at different stages, resulting in about 250 trees ha^{-1} after 30 years.

Forty one superior trees of teak (51–64 years old) were selected from plantations in different locations in Kerala (Southern India) with a selection intensity of 0.3 to 0.5%. Nilambur in Kerala produces the best teak growth in India, where the mean annual rainfall is about 2500 mm. A survey was conducted to identify plantations showing superior growth performance for tree selection. These are Padukka, Emangadu, Vazhikkadavu, Poolakkapara, Panayancode and Elanad. The superior trees were selected based on a check tree comparison method (five dominant trees were marked as check trees or comparison trees which surround and are in the vicinity of the superior tree) as described by Emmanuel and Bagchi (1989). The selection procedure involves measurement of total height, girth at breast height (GBH), clear bole height and stem form (straight and cylindrical bole), and free from pest attack and disease. For each selected tree data were recorded from six trees, i.e. one superior tree and five comparison trees.

Selected trees were felled at 20–30 cm above ground level. Coppice shoots emerged 2–3 weeks after felling and these were collected after 6–8 months and multiplied vegetatively following the method of Palanisamy and Subramanian (2001). Coppice shoot cuttings (15–20 cm length and 1.0–1.5 cm diameter) were prepared after excising the leaves. They were then dipped in a fungicide, namely, 1% aqueous Bavistin (2-methoxycarbamoyl benzimidazole) for 3 min before being rinsed with distilled water. The top end of the cutting was sealed with paraffin wax to reduce water loss. The cuttings were then planted in a moist sand bed inside a polytunnel (80–90% relative humidity and temperature 30 ± 2 °C) under intermittent misting. The polytunnels were 70 × 90 × 60 cm and each had about 120 cuttings. The polytunnels were placed in a shade house with natural radiation of 30%. New sprouts emerged from the planted coppice shoots within a week. Leafy cuttings (sprouts), each 4 to 6 cm length and 0.2 to 0.4 cm diameter with two or three pairs of leaves, were then prepared. They were sterilized with 0.1% Bavistin for 3 min and then rinsed with distilled water and treated with 2000 ppm IBA. The cuttings were then planted in root trainers (150 ml) filled with composted coir fibre as rooting media and kept in polytunnels (80–90% relative humidity and temperature 30 ± 2 °C) for rooting. The cuttings were misted with water four times daily.

Rooting occurs 20–25 days after planting. Rooted cuttings were transplanted to polythene bags containing sand, soil, farmyard manure and coir fibre (1:1:1:1) and hardened in a shade house exposed to full sunlight condition. The

hardened propagules were planted in a vegetative multiplication garden (VMG) in rows at a spacing of 30 × 30 cm, watered regularly and maintained for multiplication. To understand the variation in adventitious rooting among clones, cuttings were collected from 20 selected clones in the VMG (three clones already planted in the VMG and 17 others were from the original 41 selected trees). Rooting experiments were conducted in polytunnels following the procedure described above for coppice shoot cuttings.

The percentage of rooting, number of roots and root length in different clones were recorded 50 days after planting. For rooting experiments three replicates each of 20 cuttings were used for each clone. To study the growth performance of clones in the field, a clonal trial with 10 selected clones (three clones already planted in the VMG and 7 others were from the original 41 selected trees) was established at Nilambur under natural rainfall condition. The clonal trial was established in a randomized complete block design with three replications and nine trees per replication at a spacing of 2 × 2 m. The seedlings raised from the local seed lot were used as control. Data on height and collar girth were recorded three years after planting. Data were subjected to statistical analysis for significance and critical difference (CD 0.05%) values were calculated for comparing the treatment means.

RESULTS AND DISCUSSION

At Nilambur the height of the selected trees varied from 23–35 m while GBH ranged from 110–220 cm (Table 1). Trees in Trichur had lower height and GBH ranges, i.e. 17–29 m and 132–168 cm respectively. The selected trees at Panayancode showed a maximum height of 32–35 m. There were 24 trees with markedly superior heights of 30–35 m and 23 trees with substantially superior GBH of 150–220 cm (Table 1). Of these, 13 had superior height and GBH, namely, NPT16, NPT23, NPT24, NPT42, NPT54, NPT100, NPT104, NPT108, NPT110, NPT112, NPT114, NPT115 and NPT116 and can be used in clonal planting programmes to enhance genetic gain. In this study, the 41 trees selected in the plantations (Table 1) were in the selection intensity of 0.3 to 0.5%. Higher selection differentials suggest greater genetic gain. Superior teak trees with higher predicted gain values have been recommended for use in mass clonal multiplication and for further selective breeding programme (Bagchi 1995). The mean increase of height, GBH and clear bole height of selected trees were 19.5, 26.7 and 31.9% respectively compared with comparison trees (Table 1). It was also found that in Nilambur, 7 and 14 trees exhibited > 30% superiority for height and GBH respectively. Kaosa-ard *et al.* (1998) reported an estimated gain of 17% when seeds were collected from selected clones from a clonal seed orchard of teak and used for planting programme. It has been reported that gain obtained from 50-year-old teak trees grown from improved planting stock was approximately USD3600 ha^{-1} compared with trees grown from unimproved material (Kjaer & Foster 1996). In this study, the volume of the selected teak trees in the plantation was found to be 2–3 times higher than the average volume of the plantation (K Palanisamy, personal observation). Studies on eucalyptus clonal plantations in Brazil and India have shown similar findings (Zobel & Talbert 1984, Lal *et al.*1993).

The rooting percentage and root characteristics of clones multiplied from VMG are given in Table 2. Mean rooting percentage was 73.3%. Maximum rooting of 100% was observed in clones NPT110 and NPT111. Clones NPT13, NPT15, NPT23, NPTE and NPT108 had high rooting of 80 to 90%. Similarly, variation in rooting of clones was reported in *Allanblackia floribunda* (Atangana & Khasa 2008) and *Pinus taeda* (Baltunis *et al.* 2005). Best rooting clones are preferred for clonal forestry programme and they can be multiplied in a large scale for planting programmes.

Earlier reports of vegetative propagation of teak stated that branch cuttings from mature teak gave poor rooting and exhibited slow growth in the field, and hence were not suitable for operational planting programmes (Nautiyal *et al.* 1991, Palanisamy *et al.* 1995). To overcome poor performance of branch cuttings, we used coppice shoots as planting material in the vegetative propagation of teak which showed higher percentage of rooting (Table 2) and better height and collar diameter in the field (Table 3). This indicates the juvenility of coppice shoots (Palanisamy & Subramaniam 2001). It is thus suggested that juvenile material should be used in operational planting programme for timber production, while clones raised from mature explants can be used for clonal seed orchard establishment for early flowering and

Table 1 The height, GBH and clear bole height of selected teak trees and comparison trees in different locations in Kerala

Locations	Selected tree/ clone numbers	Height of the tree (m)			GBH (cm)			Clear bole height (m)		
		Selected tree	Mean of five comparison tree	Increase (%)	Selected tree	Mean of five comparison tree	Increase (%)	Selected tree	Mean of five comparison trees	Increase (%)
Nilambur										
Padukka	NPT10	28.8	21.6	33.3	135.0	118.0	14.4	17.8	13.4	32.8
Padukka	NPT11	31.0	23.9	29.7	142.0	128.8	10.2	18.8	16.8	11.9
Padukka	NPT12	29.0	19.8	46.5	142.0	128.8	10.2	20.8	12.6	65.1
Padukka	NPT13	30.3	28.0	8.2	148.0	131.0	13.0	21.2	20.3	4.4
Padukka	NPT14	29.8	25.2	18.3	132.0	114.6	15.2	19.0	18.8	1.1
Padukkar	NPT15	28.5	23.4	21.8	156.0	132.6	17.6	16.5	16.3	1.2
Padukka	NPT16	30.0	26.7	12.4	159.0	135.8	17.1	23.0	17.4	32.2
Padukka	NPT18	27.0	24.9	8.4	163.0	133.8	21.8	19.0	16.1	18.0
Padukka	NPT22	30.0	27.7	8.3	141.0	128.8	9.5	21.0	19.5	7.7
Padukka	NPT23	30.0	22.6	32.7	151.0	129.6	16.5	21.0	17.3	21.4
Padukka	NPT24	32.0	26.6	20.3	168.0	145.6	15.4	24.0	19.4	23.7
Emangadu	NPT25	27.0	26.7	1.1	180.0	136.2	32.2	15.5	11.7	32.5
Emangadu	NPT26	27.0	25.6	5.5	170.0	120.8	40.7	14.0	13.2	6.1
Emangadu	NPT28	26.0	24.8	4.8	155.0	146.6	5.7	17.0	10.1	68.3
Emangadu	NPT29	23.0	22.4	2.7	110.0	96.0	14.6	11.0	9.7	13.4
Vazhikkadavu	NPT42	30.0	24.9	20.5	205.0	119.0	72.3	19.0	14.7	29.3
Vazhikkadavu	NPT52	29.0	22.3	30.0	165.0	129.8	27.1	22.0	16.2	35.8
Vazhikkadavu	NPT54	31.0	24.6	26.0	157.0	127.6	23.0	26.0	18.2	42.9
Vazhikkadavu	NPT55	29.0	24.4	18.9	165.0	128.8	28.1	23.0	18.5	24.3
Poolakkapara	NPT91	32.0	28.8	11.1	137.0	108.0	26.9	26.0	22.0	18.2
Poolakkapara	NPT96	34.0	29.6	14.9	140.0	113.0	23.9	30.0	21.8	37.6
Poolakkapara	NPT98	34.0	28.0	21.4	142.0	101.0	40.6	27.0	19.0	42.1
Poolakkapara	NPT100	34.0	29.6	14.9	153.0	110.0	39.1	27.0	20.2	33.7

(continued)

Table 1 (continued)

Poolakkapara	NPT102	33.0	27.8	18.7	147.0	113.0	30.1	25.0	19.5	28.2
Poolakkapara	NPT104	34.0	28.9	17.6	154.0	130.0	18.5	24.0	20.7	15.9
Poolakkapara	NPT107	33.0	29.0	13.8	140.0	114.0	22.8	26.0	20.5	26.8
Panayancode	NPT108	32.0	28.2	13.5	165.0	113.0	46.0	25.0	17.4	43.7
Panayancode	NPT110	35.0	28.4	23.2	220.0	136.0	61.8	20.0	17.0	17.6
Panayancode	NPT111	34.0	28.6	18.9	140.0	102.0	37.3	25.0	18.2	37.4
Panayancode	NPT112	33.0	28.8	14.6	155.0	119.0	30.3	27.0	19.6	37.8
Panayancode	NPT113	35.0	27.8	25.9	140.0	86.0	62.8	26.0	17.4	49.4
Panayancode	NPT114	32.0	27.0	18.5	175.0	116.0	50.9	23.0	15.4	49.4
Panayancode	NPT115	34.0	26.2	29.8	180.0	132.0	36.4	28.0	16.6	68.7
Panayancode	NPT116	32.0	25.0	28.0	160.0	124.0	29.0	25.0	14.6	71.2
Panayancode	NPT117	33.0	25.2	31.0	145.0	102.0	42.2	23.0	13.0	76.9
Trichur										
Elanad	TR-E301	21.0	17.7	18.6	140.0	128.8	8.7	15.5	13.0	19.2
Elanad	TR-E305	29.0	24.1	20.3	132.0	117.0	12.8	22.0	17.7	24.3
Elanad	TR-E308	17.0	14.4	18.1	152.0	124.0	22.6	11.5	8.4	36.9
Elanad	TR-E309	19.3	15.4	25.3	148.0	126.8	16.7	13.5	10.0	35.0
Elanad	TR-E310	22.0	17.5	25.7	168.0	142.0	18.3	14.0	10.9	28.4
Elanad	TR-E311	20.0	15.7	27.4	152.0	134.4	13.1	12.8	9.3	37.6
Mean		29.5	24.8	19.5	154.4	122.5	26.7	21.1	16.2	31.9

seed production. The number of adventitious roots produced in cuttings contributes to the success of plantation establishment and subsequent development of clonal plantation. The numbers of roots were more in clones NPT15, NPT111 and NPT102 (4.0 to 4.2) compared with the rest and maximum root length was observed in NPT110 (17.1 cm) (Table 2). The ortet of clone NPT110 was outstanding with maximum height of 35 m and GBH of 220 cm (Table 1) and showed 100% rooting and maximum root length (Table 2) compared with other clones, indicating that it has potential to be used in large-scale planting.

Table 2 Adventitious rooting and root characteristics in selected clones of teak in VMG with 2000 ppm IBA treatment

Clone Number	Percentage of rooting	Number of roots	Maximum root length (cm)
NPT7	62.4	3.5	11.1
NPT13	80.0	2.9	14.0
NPT14	62.3	3.2	12.8
NPT15	89.7	4.0	14.2
NPT16	64.8	3.7	14.1
NPT23	87.7	3.2	14.7
NPT25	72.3	3.4	14.8
NPT26	69.0	3.8	14.8
NPT28	76.7	3.1	15.9
NPT30	65.0	2.3	14.3
NPTE	85.3	3.4	12.3
TR309	55.0	2.4	9.9
NPT102	67.3	4.2	16.3
NPT108	82.3	3.5	12.6
NPT110	100.0	3.8	17.1
NPT111	100.0	4.0	13.6
NPT112	55.7	3.8	14.2
NPT114	74.3	3.3	13.2
NPT116	44.7	3.1	14.1
NPT117	71.0	3.3	15.4
Mean	73.3	3.4	13.9
CD (0.05%)	27.5	1.1	3.0

VMG = Vegetative multiplication grarden; clones in the VMG are raised through the original coppice shoots of selected trees; results are the mean values of three replicates.

The early evaluation of clones in the field showed that most of the clones exhibited better growth performance than seedlings of local seed source (Table 3). After three years, maximum height of 7.3 m and GBH of 27.0 cm was recorded in NPT19 (Table 3), further confirming the expected juvenility of coppice shoot plants. Good growth performance have been reported in different parts of India in tissue culture raised teak clones (Parasharami & Jana 2006) and grafted teak clones (Rao *et al.* 2002).

CONCLUSIONS

The selected teak trees exhibited outstanding growth characteristics with superior stem form, good adventitious rooting ability and better growth performance in the field, indicating that clonal plantation of teak is possible. From the clones tested, we observed 13 clones to be most promising for the establishment of clonal forestry to improve productivity. It is suggested that the clonal technique can also be used to rescue and conserve valuable genotypes after harvest to be utilized in breeding programmes.

Table 3 Growth characteristics of teak clones in the field at Nilambur (Kerala) three years after planting

Clone number	Height (m)	Collar girth (cm)
NPT10	5.1	20.0
NPT11	5.8	22.8
NPT13	6.1	26.0
NPT16	5.9	26.4
NPT19	7.3	27.0
NPT22	5.9	22.6
NPTA	6.5	24.2
NPTE	6.1	21.6
TR308	6.1	23.6
TR309	4.3	21.0
Control(seedlings)	5.3	20.2
CD (0.05%)	0.7	4.2

Results are the mean values of three replicates.

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