

**GROWTH CHARACTERISTICS OF  
*EUCALYPTUS CAMALDULENSIS* DEHN.H. CLONES**

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**ABSTRACT**

Clonal test plots of *Eucalyptus camaldulensis* were made at FIO Sakaew Plantation, Wang Namyen district, Sakaew province. Nine-teen which included seventeen clones produced through tissue culture technique and two groups of trees originated from seeds, imported seeds by Shell and locally collected seeds, were compared. Annual growth, diameter at breast height (dbh) and total height (Ht) were measured until 5 years. Total height, merchantable height (Hm), Hm/Ht, stem taper, wood and bark characteristics of 5-year-old trees were investigated from the cut sample trees and compared.

Total height and dbh for all trees were rapidly increase from age 1 to 2 years which the maximum growth at 7.50 m/yr for height and 7.56 cm/yr for dbh, then the growth were abruptly decline from age 3 to 5 years. Growth characteristics; dbh, Ht, Hm, Hm/Ht and taper of stems were significantly different between clones and trees originated from seeds. Based on dbh, 3 groups of the experimental trees were classified as follows : fast growing (> 16 cm), moderate growing (14-16 cm) and slow growing (<14 cm). Five clones (K2, T5, S9, Y2 and Kitti) were considered as fast growing group which dbh were 16.88-18.43 cm. Trees originated from seeds, Shell and local seeds, were in slow dbh growing group which dbh were 13.72 cm and 13.10 cm, respectively. Total tree heights were mainly coincident with dbh, the clones in fast dbh growing group showed the highest height ranged from 17.86 to 20.40 m. The average height of trees from the local seeds was 16.61 m while those of the trees from Shell seed source was 18.23 m which was as high as the tree in the fast growing group. Hm and Hm/Ht were highly correlated to Ht ( $r=0.9788$ ), but less correlated to dbh ( $r=0.5732$ ). Stem taper was significantly different between clones but did not correlate to the dbh and height growth groups. Bark thickness and moisture content did not correlate to the size and the growth rate of trees, they were specific characteristics for each individual.

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## INTRODUCTION

*Eucalytus camaldulensis* is the most potential fast-growing tree commercially grown in Thailand. They can grow well throughout the country. However, large scale plantations are confined in eastern, northeastern and western parts of Thailand

where related industries located. Generally, planting materials are from seeds. While the plantations of *E. camaldulensis* grown from seeds in Thailand were extremely variable in growth rate, forms and quality, leading to poor performances. To reduce the variation and increase growth and yeild of the plantations, the clonal plantations of superior clones have been made in most eucalypt planting countries (Anonymous, 1984; Cornelius *et al.*, 1986; Zobel and Talbert, 1984). There was a report in Brazil that clonal plantations from hybrid (*E. grandis xurophylla*) could raise plantation yeild from 33m<sup>3</sup>/ha/yr to 70m<sup>3</sup>/ha/yr, wood density from 460 kg/m<sup>3</sup> to 575 kg/m<sup>3</sup>, pulp yeild from 48% to 51%, and pulp productivity from 7.85 tons-pulp/ha/yr to 18.45 tons-pulp/ha/yr (Anonymous, 1984). Carefully selected *E. citriodora* clones for eucalyptus oil was reported to raise oil content from 0.5-2% to 3.5% and oil yeild from 200 liters/ha to 600 liters/ha (Gupta *et al.*, 1981). However, growing environment might diverge the properties of clones (van Wyk *et al.*, 1988). Although the eucalypt plantation in Thailand has rapidly changed from seedling to clonal plantations, there were not many clones, have been commercially planted. More clones were needed to prevent from monoculture disaster. In 1989 the Faculty of Forestry, Kasetsart University had carried out a research project on the Improvement of Timber Yeild of Eucalyptus Plantation which aimed to be the research model to efficiently produce elite clones for future clonal plantations.

This paper was aimed to analyse growth characteristics of *Eucalyptus camaldulensis* clones in the clonal test plot of the above project.

## MATERIALS AND METHODS

The data used were from the eucalyptus clonal test plot at Sakaew Plantation of the Forest Industry Organization (FIO) in Sakaew province. The clonal test plot was carried out by the project entitled Application of Vegetative Propagation to Improve Timber Yield of River Red Gum *Eucalyptus camaldulensis* during 1989-1993 sponsored by Science Technology Development Board (STDB-USAID Loan), Ministry of Science and Technology, Thailand (Siripatanadilok and Thaiutsa, 1989). Seventeen clones which produced through *in vitro* culture were compared to the trees produced from seeds of two sources, local seed from Sakaew Plantation (Seed) and imported seeds (Shell) by Shell Company. Four replications of 24 individuals for each replication were assigned for Completely Random Design. Diameter at breast height (dbh) and total height (Ht) were measured annually until five years old which was the harvesting age (rotation). At five years of age, 5 sampled trees were felled, total height and merchantable height (Hm, height up to diameter  $\geq 5$  cm) were measured. The stem taper of each felled tree was determined from the ratio of diameter at 6.10 m height to the diameter at breast height. Logs of 2 m were subdivided from felled merchantable trunk started from the stump end to the top. All 2 m logs were weighed for fresh weight. Sample disks, 10 cm thick, were latter cut at the base of each 2 m logs to use as sample disks. The sample disks were weighed for fresh weight. The diameter with bark and without bark of each sample disk was measured to determine the bark thickness and latter oven

dry weight at 105°C of each disk was weighed to determine moisture content. The data obtained were statistically analyzed to compared growth and some log characteristics between the clones and the trees planted from seeds.

## RESULTS AND DISCUSSION

### Diameter Growth

Diameter (dbh) growth at different ages was shown in Figure 1. Rapidly increase in dbh was pronounced up to two years while the average dbh at one and two years old were 2.98-4.95 cm and 8.10-12.43 cm, respectively. From two to five year of age, the dbh was much declined while the average dbh of three and four years old trees were 10.12-14.56 cm and 11.32-16.31 cm, respectively. At five years old, the trees could be classified basing on dbh into 3 groups, fast-diameter growth (Figure 1 a), moderate-diameter growth (Figure 1 b) and slow-diameter growth (Figure 1 c). There were 5 clones in the fast growth group, namely K2, T5, S9, Y2, and Kitti of which the averages dbh were 18.43, 17.67, 17.40, 17.27 and 16.88 cm, respectively (Table 1). However, trees growing from seeds were in the slow-diameter growth group which were 13.10 cm for local seed and 13.72 cm for Shell (imported seeds by Shell Company, Thailand).

### Total Height Growth

Total height (Ht) growth at different ages was shown in Figure 2. The height growth pattern was similar to the diameter growth. The average height growth was rapidly increased up to two years of age. The average height of one and two-year-old trees were 3.80-5.78 m and 8.77-12.62 m, respectively. The height growth was much declined from age greater than two to five

years old. At five years old, the trees could be classified basing on the height growth into 3 groups, fast-height growth (Figure 2a) moderate-height growth (Figure 2b) and slow-height growth (Figure 2c). At least 50% of the studied clones remained in the same group as the diameter growth. The clones in the fast-height growth were Kitti, T5, Y2, K2, P9, and Shell which their height were 20.40, 20.32, 19.99, 18.89, 18.30 and 18.23 m, respectively (Table 1). The first 4 clones were also of the fast-diameter growth. The height of five years old trees grown from the local seeds were in the moderate-height groups. It was interesting that the trees grown from the import seed source (Shell) shown very distinct height, averaged 18.23 m which was in the fast-height growth. Kageyama and Kibuti (1988) found that the growth *E. grandis* of progenies from open-pollination were significantly greater than those of the clones selected from the same population. Therefore, the trees grown from good seed sources might possible to grow better than the trees grown from superior clones.

### Annual Increment

Annual dbh increment was somewhat high at age one and two years of which the dbh increment rates were 2.98-4.97 cm/yr and 4.95-7.56 cm/yr, respectively (Table 3). The dbh increment of two years old showed coincident with the growth rate group where it was pronouncely larger increment in the fast dbh group which was larger than 7 cm/yr. However, the increment of trees originated from seeds (shell and local seed) were 5.57 cm/yr and 4.95 cm/yr which felt in the slow dbh growth group. The annual dbh increment of all trees gradually declined to be less than 2 cm/yr. However, the increment of the fast dbh growth group was still larger than the others.

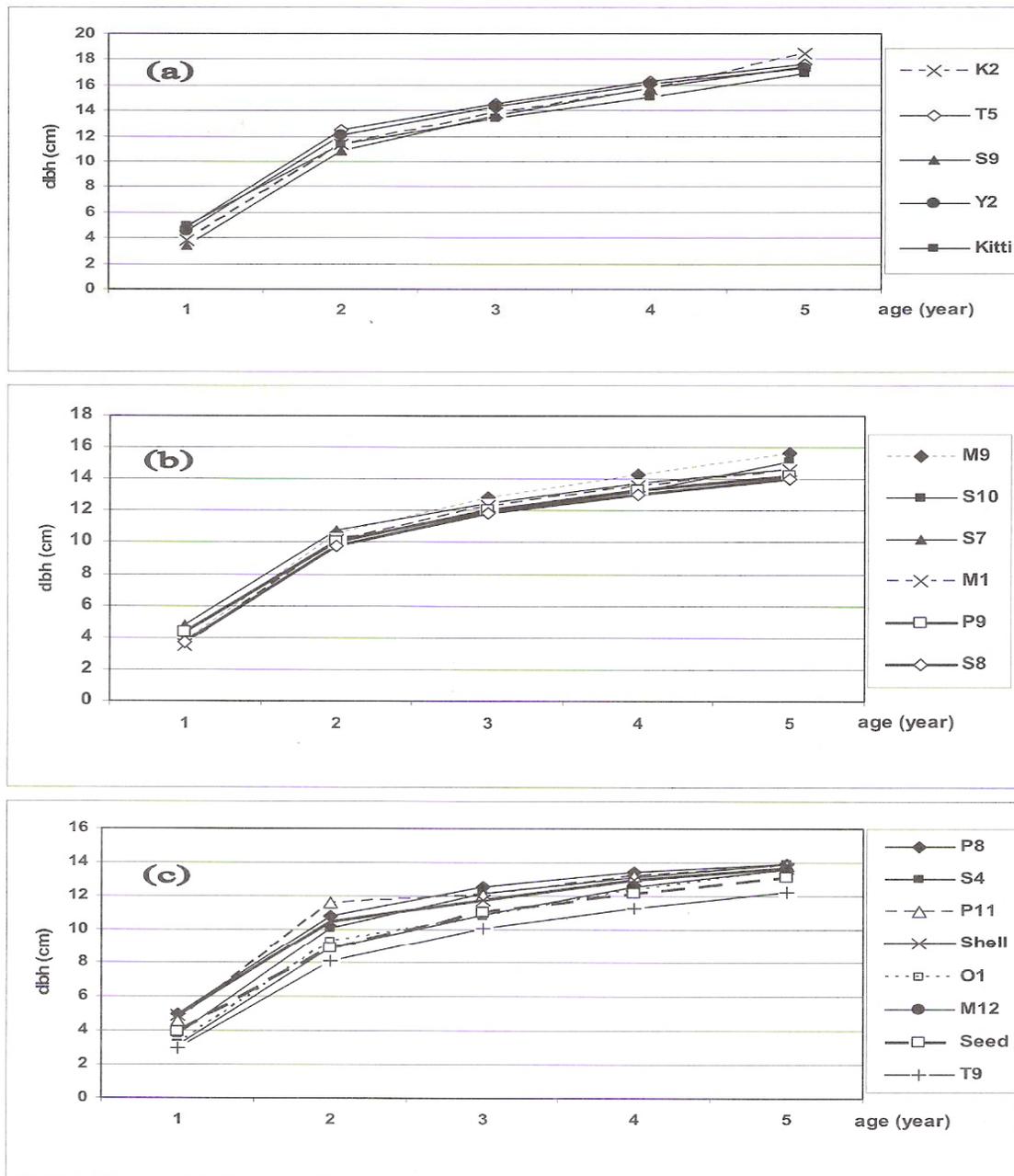


Figure 1. Diameter (dbh) of *Eucalyptus camaldulensis* clones (K2, T5, S9, Y2, Kitti, M9, S10, S7, M1, P9, S8, P8, S4, P11, O1, M12, T9) and the trees originated from seeds (Seed, Shell). (a) fast-dbh growth, (b) moderate-dbh growth, (c) slow-dbh growth

**Table 1. Growth characteristics of *Eucalyptus camaldulensis* including diameter (dbh), total height (Ht), merchantable height (Hm), Hm/Ht ratio and stem taper at 6.10 m height (Tp)**

Clones	dbh (cm)	Ht (m)	Hm (m)	Hm/Ht	Tp
K2	18.43 ± 0.78a	18.89 ± 1.47abc	15.10 ± 1.27abc	0.800 ± 0.017abc	0.75 ± 0.01bcde
T5	17.67 ± 1.00a	20.32 ± 0.60a	16.47 ± 0.10ab	0.813 ± 0.020abc	0.78 ± 0.02abcd
S9	17.40 ± 1.41a	17.86 ± 1.05bcd	14.40 ± 1.02bcde	0.806 ± 0.032abc	0.71 ± 0.02cde
Y2	17.27 ± 0.82a	19.99 ± 0.86ab	16.41 ± 0.84ab	0.820 ± 0.010abc	0.78 ± 0.02abcd
Kitti	16.88 ± 0.51ab	20.40 ± 0.65a	17.27 ± 0.55a	0.847 ± 0.023a	0.82 ± 0.01ab
M9	15.63 ± 0.28bc	16.10 ± 1.20de	12.46 ± 0.97defg	0.773 ± 0.057bcde	0.69 ± 0.06e
S10	15.12 ± 2.17cd	16.72 ± 1.01cde	12.81 ± 1.69cdefg	0.763 ± 0.055cde	0.78 ± 0.06abcd
S7	14.63 ± 1.05cde	15.26 ± 1.54ef	12.32 ± 1.50efgh	0.803 ± 0.020abc	0.67 ± 0.05e
M1	14.58 ± 1.36cde	17.28 ± 0.93cde	13.93 ± 1.08cdef	0.803 ± 0.020abc	0.74 ± 0.02bcde
P9	14.20 ± 0.34cde	18.30 ± 1.11abcd	14.89 ± 1.26bc	0.810 ± 0.020abc	0.78 ± 0.01abcd
S8	14.05 ± 0.84cde	16.32 ± 1.03de	12.80 ± 0.85cdefg	0.783 ± 0.057bcde	0.73 ± 0.03cde
P8	13.95 ± 0.26cde	17.84 ± 0.32bcd	14.79 ± 0.20bcd	0.830 ± 0.010ab	0.84 ± 0.03a
S4	13.90 ± 0.53de	15.48 ± 0.78ef	11.91 ± 1.16fgh	0.770 ± 0.036cde	0.72 ± 0.05cde
P11	13.87 ± 0.75de	16.77 ± 0.74cde	13.06 ± 0.61cdefg	0.780 ± 0.000bcde	0.70 ± 0.03de
Shell	13.72 ± 0.32def	18.23 ± 1.50abcd	14.63 ± 1.84bcde	0.796 ± 0.041abcd	0.71 ± 0.04cde
O1	13.58 ± 14.36 defg	15.25 ± 1.84ef	12.26 ± 1.93efgh	0.803 ± 0.037abc	0.70 ± 0.03de
M12	13.58 ± 0.66defg	15.33 ± 1.09ef	10.64 ± 1.18gh	0.693 ± 0.030f	0.75 ± 0.09bcde
Seed	13.10 ± 1.52efg	16.61 ± 0.55cde	12.33 ± 0.65efgh	0.743 ± 0.011def	0.70 ± 0.09de
T9	12.23 ± 0.48fg	13.55 ± 2.37f	9.97 ± 2.53h	0.730 ± 0.062ef	0.78 ± 0.03abcd

Values in each column, followed by the same letters are not significantly different from one another, at  $p \leq 0.05$  by DMRT.

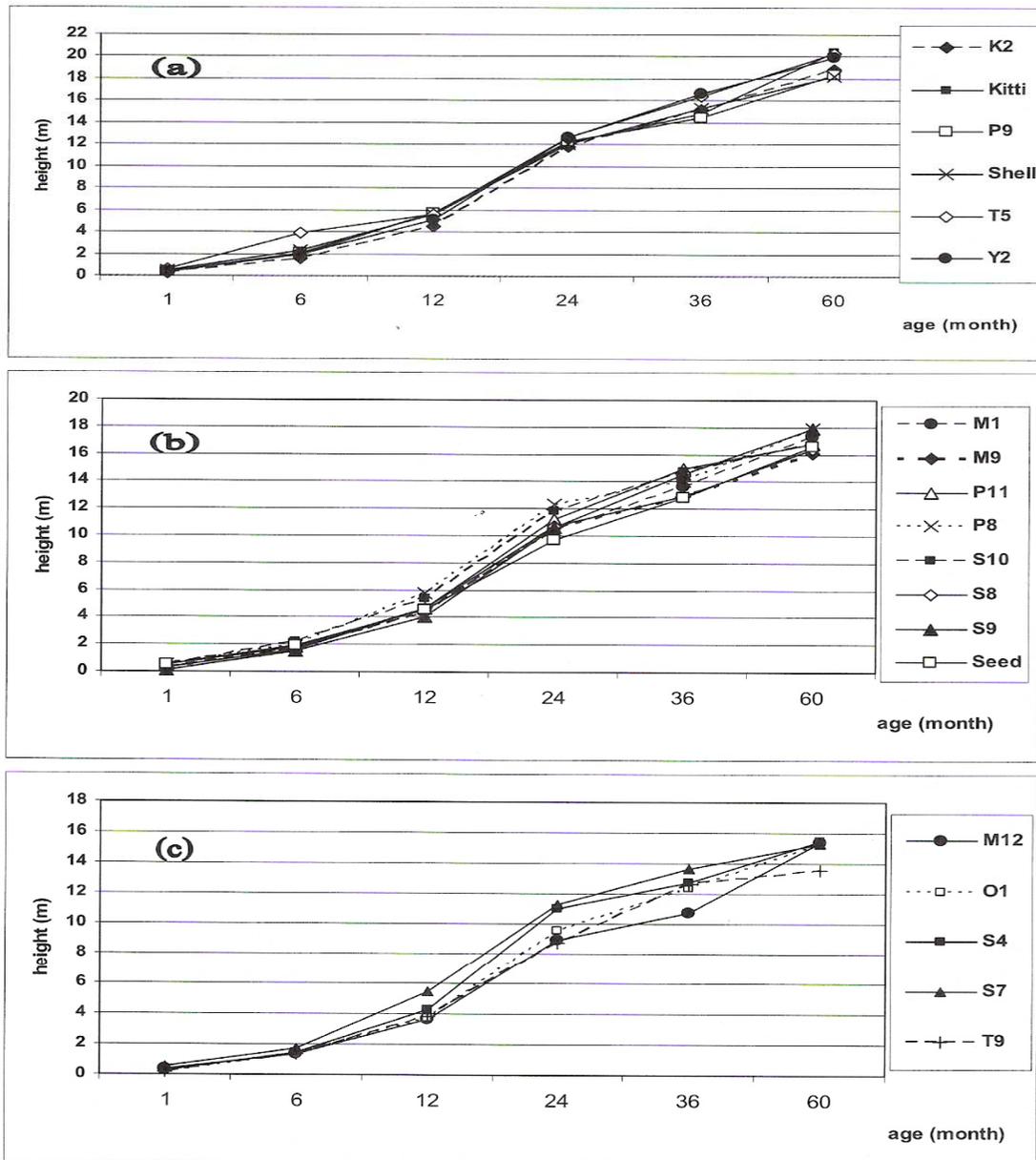


Figure 2. Height of *Eucalyptus camaldulensis* clones (K2, Kitti, P9, T5, Y2, M1, M9, P11, P8, S10, S8, S9, M12, O1, S4, S7, T9) and the trees originated from seeds (Seed, Shell). (a) fast-height growth, (b) moderate- height growth, (c) slow-height growth

Annual height increment of the trees was the same pattern as the dbh increment (Table 4). The first year and second year increment were 3.62 to 5.78 m/yr and 4.97 to 7.50 m/yr, respectively. The height increment of the trees at age two years old was the greatest. The height increment of some clones in the fast dbh growth group (clone K2,T5,Y2) at two years old was greater than 7 m/yr. However, the annual height increment was abruptly reduced at age three to five years. Mainly, the annual height increment at age of five was smaller than 2 m/yr. It must be pointed out that most of the clones which were in the fast-height increment were also in the fast dbh increment group.

Zobel and Talbert (1984) mentioned that each clone would have different growth curves and developmental patterns. When they were intermixly grown, the slower-starting clones would be severely suppressed by the faster-starting clones, but if they were grown separately as a monoclonal their growth might be caught up at certain age. However, planting site might be limited factors. Some clones performed well only at some sites which indicated that there was a certain degree of genotype and environment interaction, but many clones might be very stable in growth performance of different sites (van Wyk *et al.*, 1988). The clone T5 which was in the fast growth group in this study also showed the top performance at other sites (Aramsri, 1999).

### Stem Characteristics

Merchantable height (Hm), Hm/Ht and stem taper were significantly different between clones (Table 1). The Hm was greatest in the fast growing group and highly related to Ht ( $r=0.9788$ ) (Table 5).

Hm/Ht was also high in the fast growing group ranged from 0.800 to 0.847, but smallest in the trees originated from local seed and clone T9 which were 0.743 and 0.730, respectively. Hm/Ht was higher correlated to Hm ( $r=0.84$ ) than Ht ( $r=0.71$ ). The value of Hm/Ht explained the proportion of the stem which could be used as industrial materials and non-industrial materials. Therefore, the greater ratio of Hm/Ht indicated the better characteristic of the preferable clones.

The tapers of stems were significantly different between clones and the trees originated from seeds (Table 1). The tapers were varied depending on clones and had lower correlated to dbh ( $r=0.20$ ), Ht ( $r=0.45$ ) and Hm ( $r=0.46$ ). It could be specific characteristics of each individual clone. Of the fast growing group, the taper figure of Kitti clone was the largest (0.82) and of clone S9 was the smallest (0.71). While, those of the trees originated from local seeds, M9 and S7 were in the smallest taper group which were 0.70, 0.69 and 0.67, respectively. The larger taper figure indicated the less taper log, leading to better characteristics of the clones.

### Bark and Wood Characteristics

Averaged bark thickness at dbh (Table 2) varied between clones from 0.70 cm to 1.03 cm, but were not significantly different. The trees in the fast dbh growing group showed moderate bark thickness which varied from 0.77 cm to 0.84 cm except Kitti clone whose bark thickness was the greatest (1.03 cm). The bark thickness of the trees originated from local seed source was 0.96 cm and from Shell seed source was thin, 0.72 cm. Compinhos *et al.* (1988) have also reported wide variation of the bark content of *E. pellita* grown at Aracruz in Brazil which varied from 6 to 11% with an average

of 8.92%. The higher bark content must consist of thicker bark.

Moisture content of the sample disks which included both wood and bark varied between clones from 106.33% to 152.00% and were not statistically different (Table 2). They also widely varied between the clones within the fast growing group from 108.67 % to 139.33%. While those of the trees originated from seeds were in the same range, 117.00% for trees from Shell seed source and 130.67 % for trees from local seed source.

The bark thickness and moisture content would be the characteristics of each individual clone but did not correlated to the size or growth rate of the trees.

### CONCLUSION

1. Growth characteristics : diameter at breast height (dbh), total height (Ht), merchantable height (Hm), Hm/Ht and stem taper (Tp) were significantly different between clones and trees originated from seeds.

2. Based on dbh, it could be classified the studied trees into 3 groups; fast growth (dbh >16.00 cm), moderate growth (dbh 14.00-16.00 cm) and slow growth (dbh < 14.00 cm).

3. Growth characteristics : diameter at breast height (dbh), total height (Ht), merchantable height (Hm), Hm/Ht and stem taper (Tp) were significantly different between clones and trees originated from seeds.

4. The fast dbh growth clones were K2 (18.43 cm), T5 (17.67 cm), S9 (17.40 cm), Y2 (17.27 cm), and Kitti (16.88 cm). The dbh of the trees originated from seeds were in the slow growing group having dbh of 13.72 cm for Shell (imported seeds) and 13.10 cm for the local seeds.

5. Correlation (r) between dbh and Ht was 0.757. Mainly, the trees in the larger dbh class were also taller than the trees in the lower dbh class.

6. Bark thickness and moisture content were the characteristics of each individual clone, did not correlate to size and growth rate of trees.

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**Table 2. Bark thickness(bt) and wood moisture content (mc) of five-year-old *Eucalyptus camaldulensis* clones in different dbh groups**

Clones	dbh groups	bt (cm)	mc (%)
K2		0.77 ± 0.05	111.00 ± 12.16
T5		0.84 ± 0.10	115.00 ± 10.82
S9	fast	0.82 ± 0.01	139.33 ± 8.14
Y2		0.82 ± 0.11	108.67 ± 14.43
Kitti		1.03 ± 0.20	131.00 ± 18.52
M9		0.81 ± 0.12	132.00 ± 5.56
S10		0.75 ± 0.02	112.00 ± 15.87
S7		0.82 ± 0.03	125.33 ± 5.13
M1	moderate	0.95 ± 0.10	118.33 ± 35.00
P9		0.91 ± 0.04	124.00 ± 13.85
S8		0.94 ± 0.10	117.67 ± 22.94
P8		0.71 ± 0.20	138.33 ± 9.01
S4		1.00 ± 0.08	106.33 ± 7.57
P11		0.70 ± 0.06	145.67 ± 25.54
Shell		0.72 ± 0.08	117.00 ± 11.26
O1	slow	0.97 ± 0.13	152.00 ± 35.00
M12		0.79 ± 0.10	112.67 ± 22.73
Seed		0.96 ± 0.43	130.67 ± 10.06
T9		0.98 ± 0.14	125.67 ± 14.15

**Table 3. Annual dbh increment (cm/yr) of *Eucalyptus camaldulensis* clones at different ages**

Clones	Age (years)				
	1	2	3	4	5
K2	3.80	7.51	2.50	1.83	2.59
T5	4.87	7.56	2.13	1.75	1.29
S9	3.44	7.40	2.79	2.15	1.47
Y2	4.51	7.51	2.29	1.75	1.37
Kitti	4.97	6.36	2.12	1.60	1.12
M9	3.76	6.78	2.29	1.49	1.41
S10	4.31	5.82	1.84	1.24	1.19
S7	4.79	6.01	1.68	1.30	1.42
M1	3.50	6.64	2.13	1.29	1.46
P9	4.32	5.71	2.02	1.23	1.22
S8	3.70	6.08	2.11	1.11	1.26
P8	4.94	5.89	1.71	0.89	0.58
S4	3.75	6.30	2.13	0.98	1.05
P11	4.58	7.00	0.53	1.08	0.51
Shell	4.88	5.57	1.34	1.19	1.04
O1	3.19	6.12	1.48	1.62	1.32
M12	3.10	5.80	2.00	1.69	1.06
Seed	3.91	4.95	2.15	1.19	2.34
T9	2.98	5.12	2.02	1.20	1.25

**Table 4. Annual height increment (m/yr) of *Eucalyptus camaldulensis* clones at different ages**

clones	Age (years)			
	1	2	3	5*
K2	4.52	7.31	3.37	2.16
T5	5.60	7.02	3.78	2.20
S9	4.03	6.61	3.92	1.51
Y2	5.11	7.50	4.05	1.53
Kitti	5.66	6.49	2.65	2.50
M9	4.47	6.18	2.30	1.68
S10	5.37	6.45	2.93	1.01
S7	5.43	5.84	2.38	1.14
M1	4.31	6.10	3.21	1.74
P9	5.77	6.47	2.19	1.96
S8	4.66	6.06	2.25	1.69
P8	5.78	6.52	1.69	1.93
S4	4.26	6.75	1.75	1.49
P11	4.61	6.56	3.78	0.96
Shell	5.61	6.42	3.23	1.61
O1	3.73	5.81	2.78	1.34
M12	3.62	5.28	1.83	2.58
Seed	4.56	5.10	3.19	1.69
T9	3.80	4.97	3.86	0.39

\* averaged of two years increment, from age 3 to age 5, since height at age 4 was not measured.

**Table 5. Correlation coefficient (r) of growth characteristics and some log characteristics of five-year-old *Eucalyptus camaldulensis* clones**

R	dbh cm	Ht m	Hm m	Tp	Hm/Ht	bt	mc %	dw/wt
dbh	1.000	0.7575	0.7571	0.2032	0.5414	0.1875	0.2267	0.1815
Ht	0.7575	1.000	0.9788	0.4553	0.7135	0.1794	0.1849	0.1393
Hm	0.7571	0.9788	1.000	0.4624	0.8371	0.1272	0.0849	0.0361

dbh = diameter at breast height, Ht = total height, Hm = merchantable height  
 Tp = taper at 6.10 m height, bt = bark thickness, mc = moisture content  
 dw = dry weight, wt = wet weight