

# The Influence of Genotype and Environment on Wood Properties of Juvenile *Eucalyptus camaldulensis* Dehn.

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## Introduction

Many papers describe variations in cell size of the wood of trees but few relate these to genotypic or environmental variability.

Whilst a negative relationship has often been demonstrated between cell length and ring width no relation or positive relationships have also been reported. DINWOODIE (1960) concluded there was generally a negative relationship between cell length and ring width for between-tree studies but could not separate differences due to genotype. Complementary observational and experimental research is required to resolve this problem.

Working independently with Sitka spruce DINWOODIE (1960) and ELLIOTT (1963) concluded that ring width was only effective in controlling tracheid length in mature wood whilst age was more important in early tree growth. HARTLEY (1960) and DINWOODIE and RICHARDSON (1961) demonstrated for young trees a positive relationship between tracheid length and growth rate measured by height growth. Similarly KENNEDY (1957), CECH, KENNEDY and SMITH (1960) and SAUCIER and TARAS (1966) found positive relationships between tracheid length and growth rate for hardwood seedlings and coppice stems. DINWOODIE (1963) suggested the positive cell length-height growth and negative cell length-diameter growth relationships for Sitka spruce occur with severe nutrient competition in the leading shoot, height growth being at the expense of diameter growth and giving longer cells.

Growth condition have rarely been manipulated to determine their effects on cell characteristics. RICHARDSON and DINWOODIE (1960) and DINWOODIE and RICHARDSON (1961) showed that tracheid length increased with increasing day and night temperature and with increasing daylength. They concluded that both temperature and light directly affect tracheid length.

## Cell Dimensions in Eucalypts

Despite the economic importance of eucalypts there is little fundamental knowledge of their cell characteristics. A detailed study of variation within trees in fibre length in *E. regnans* was made by BISSET and DADSWELL (1949) but unfortunately their study was restricted to a single tree. In 1950 they investigated the pattern of variation within rings for a number of eucalypts. Further studies of this latter type were made by AMOS, BISSET and DADSWELL (1950) on *E. gigantea* (syn. *E. delegatensis*) and by SCARAMUZZI (1960, 1961). Within-tree studies have also been made of density for *E. grandis* by BAMBER and HUMPHREYS (1963) and of fibre dimensions by RANATUNGA (1964), of fibre dimensions in *E. gomphocephala* and *E. deglupta* by PETROFF (1965) and of fibre length and density in *E. deglupta* by CAMERON (1966, see DAVIDSON, 1968). PETROFF also examined other species of eucalypts. These studies give a related but in-

complete picture of within-tree variations in fibre length whilst other cell characters were largely neglected. A detailed study of the variations in fibre length and density within and between trees of *E. regnans* has been made by RUDMAN and HIGGS (in preparation).

PRYOR, CHATTAWAY and KLOOT (1956) and PRYOR and DADSWELL (1964) showed fibre length and density in eucalypt hybrids could be intermediate between those of the parent species. *E. gomphocephala* grown in the arid interior of Israel had shorter fibres than when grown quickly in the coastal region (STERN-COHEN and FAHN, 1964), but RANATUNGA (1964) found no such relationship in *E. grandis*.

In eucalypt tree improvement Programmes the effect of genotype and of environmental variations on cell parameters must be determined. Assessment of the breeding potential of the parent trees by examining the progeny at the seedling stage is desirable. If fast growth at the seedling stage were able to confer a lasting increase in fibre length this could be of immense importance to the paper industry. This report presents data obtained in a study of juvenile clones of *E. camaldulensis* growing under two controlled environmental conditions in an attempt to understand genotypic and environmental responses.

## Materials and Methods

Young (less than one year of age) but large (5 to 8 feet in height) plants of *Eucalyptus camaldulensis* DEHN, grown in phytotron glasshouse at a constant 27° C with normal daylength supplemented to 16 hours, were placed in a darkened room at 22° C for 23 hours on each of 14 successive days. Cuttings (4 cm. long) from these plants encompassing the first to the tenth nodes were then placed in a mixture of equal parts of peat moss and coarse-river gravel and kept moist by mist-spray every 20 minutes in a chamber made from transparent polythene with a day temperature of 24° C, night temperature of 19° C, daylength supplemented to 16 hours and a relative humidity of 90%. After 3 weeks the rooted cuttings were transplanted to a mixture of equal parts of vermiculite and perlite and watered daily with liquid Hoaglands solution, relative humidity being maintained at 45 to 65%. Normal growth commenced after two weeks but considerable between-plant variation occurred in rooting ability, the overall success of transplanting being 40%.

To resolve the effects of environment and genotype, between-clone variation was studied using seven clones each with two plants matched for initial height, the member of each pair being grown in different environments. Variation within a clone was studied for one clone of ten plants, one small, three medium and one large plant being grown in each environment; this clone was not included in the between clone experiment.

Though widely different, the environments chosen are within the natural range of *Eucalyptus camaldulensis* being (a) day temperature 18° C, night temperature 13° C, and (b) day temperature 27° C, night temperature 22° C. (These are later referred to as 18/13 and 27/22). Normal daylight

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was supplemented to 16 hours with artificial low intensity lighting in both cases, and humidity was not controlled but remained within the region 40% to 70%.

The plants were grown for 23 weeks during which time their development was recorded at fortnightly intervals and plant distribution in the phytotron was varied randomly. The stems were supported to reduce tension wood formation. Internode number, mean internode length, stem radius and the number and dimensions of cells at 15 percent of final height were determined as well as the radial variation in fibre length.

Stem radii, fibre diameter and fibre numbers were measured using microtome sections, measurements being made on two opposing radii. Fibre length was determined on small samples delignified by heating in a mixture of equal parts of glacial acetic acid and hundred volumes hydrogen peroxide for 2 to 3 hours at 90° C. The delignified wood was gently agitated and the individual fibres washed and stained with safranin. Using a projection microscope, 25 fibres were measured on each of four slides for each plant.

### Results

The means of the measurements made on the plants are given in Table 1. The mean growth curves followed the

usual pattern and logarithmic transformation over-corrected for the non-linearity of the curves. Relative growth rates were greater at the higher temperature.

The cellular dimensions (Table 1) are similar to those reported for this species (SCARAMUZZI 1961, 1963; CHUDNOFF and TISCHLER 1963).

#### Fibre length

The mean fibre length of plants was 0.58 mm at the lower temperature (18/13) and 0.64 mm at the higher temperature (27/22). This can be explained by more cells being produced at the higher temperature and if fibre length increased from pith to bark there could be a greater percentage of longer fibres. This has been examined for a number of the clones, a typical example being shown in Figure 1. Although the previous explanation is correct, a further difference is apparent. Plants grown at the higher temperature also have longer fibres in the zone adjacent to the pith. The effect of temperature on fibre length was very highly significant and marked genotypic differences were also evident (Table 2). The significant difference in the within-clone study confirms the environmental effect (Table 3). Initial height of the cuttings had no effect on fibre length.

The radial variation in fibre length in the juvenile stem is partly responsible for the different skewness found for

Table 1. — Effects of Growth Conditions on *E. camaldulensis*⁹)

Glasshouse⁹) Temp. ° C	Number of		Final Plant⁹) Height (cms)	Internodes		Cross Sectional Data⁹)			Fibre Length (mm)
	Clones	Replicates		Length (cms)	Number	Radius (mm)	Cell. No.	Cell Dia. (μ)	
18/13	7	1	144	7.3	19.7	2.81	217	12.9	0.58
27/22	7	1	246	7.5	33.0	3.34	354	9.4	0.64
18/13	1	5	169	8.78	19.2	2.81	241	12.0	0.56
27/22	1	5	236	7.66	31.2	3.09	295	10.6	0.63

Notes: ¹) Mean values.  
²) Environmental conditions are detailed in the text.  
³) After 157 days.  
⁹) Measurements made at the position of 15 percent of final height.

Table 2. — Effects of Environment on Fibre Length in *E. camaldulensis*.

Source of variation	D. F.	M. S.	F Value
Temperature	1	0.0193	24.95***
Clone	6	0.0080	10.32***
Temp. × Clone	6	0.0013	1.77
Residual	42	0.007	

\*\*\* Significant at the 0.1% level.

Table 3. — Effects of Environment on Within Clone Variation in Fibre Length in *E. camaldulensis*¹).

Source of Variation	D. F.	M. S.	F Value²)
Temperature	1	0.0466*	8.14*
Size	2	0.0111	2.93
Temp. × size	2	0.0027	
Plants × Temp. × Size	4	0.0043	
Samples × Plants	30	0.0009	

Notes: ¹) Five rooted cuttings of the one clone were used at each of the two temperatures; these were allocated to the environments according to size (see text).  
²) Significance at 5% level indicated by \*.

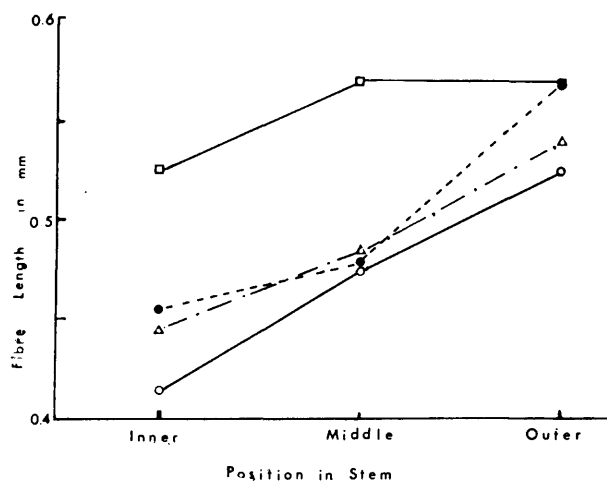


Figure 1. — Radial variation in fibre length in seedling *E. camaldulensis* —□— clone 9, 27/22° C; ---●--- Clone 9, 18/13° C; ---△--- clone 14, 27/22° C; —○— clone 14, 18/13° C.

the fibre length distribution curves for the two environments (Figure 2). The distribution curves for the lower temperature emphasises the greater numbers of short fibres.

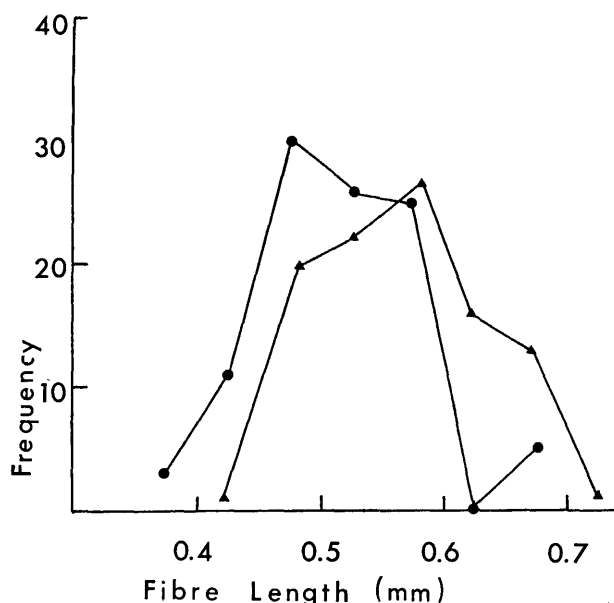


Figure 2. — Frequency distribution curves for fibre length in seedling *E. camaldulensis* at 27/22° C and 18/13° C; the higher temperature regime was associated with longer fibres.

Table 4. — Effects of Environment on Stem Dimension in *E. camaldulensis*.

Source of Variation	D. F.	M. S.	F Value
<i>Stem Radius</i>			
Temperature	1	1.0261	1.81
Clone	6	0.9586	1.69
Residual	6	0.5663	
<i>Cell diameter</i>			
Temperature	1	0.2744	4.70
Clone	6	0.0150	0.26
Residual	6	0.0584	
<i>Cell number</i>			
Temperature	1	133170	9.96*
Clone	6	17943	5.08*
Temp. × Clone	6	13375	8.30**
Radius	1	322	0.09
Radius × Clone	6	3530	
Residual	7	1611	
<i>Internode Length</i>			
Temperature	1	0.0457	0.11
Clone	6	1.0948	2.72
Residual	6	0.4024	
<i>Internode Number</i>			
Temperature	1	604.57	21.48**
Clone	6	36.14	1.28
Residual	6	28.14	

Notes: \* Significant at the 5% level, \*\* Significant at the 1% level.

#### Stem Cross-Sectional Data

Although the plants grown at the higher temperature tended to produce thicker stems (measured at 15% of final height), the differences were not statistically significant (Tables 1, 4 and 5). An increase in stem diameter may be due to increased cell diameter or increased cell number or both factors acting together. At the higher temperature the cell diameters were found to be less, although the differences were not statistically significant (Tables 1, 4 and 5). In the between-clone study increasing the temperature significantly increased the number of cells in the stem radius. In the within-clone study the difference was highly

Table 5. — Effects of Environment on Within Clone Variation in Stem Dimensions in *E. camaldulensis*.

Source of Variation	D. F.	M. S.	F Value
<i>Stem Radius</i>			
Temperature	1	0.2016	0.60
Plant	4	0.5667	2.19
Residual	4	0.2583	
<i>Cell Diameter</i>			
Temperature	1	0.0504	2.40
Plant	4	0.0499	2.37
Residual	4	0.0210	
<i>Cell Number</i>			
Temperature	1	14688.2	15.58**
Plant	4	16415.8	56.23***
Temperature × Plant	4	1539.7	3.31
Radius	1	135.2	0.46
Radius × Plant	4	291.9	
Residual	5	464.7	
<i>Internode Length</i>			
Temperature	1	0.484	8.96*
Plant	4	0.086	7.59
Residual	4	0.054	
<i>Internode Number</i>			
Temperature	1	336.40	22.70**
Plant	4	6.75	0.09
Residual	4	16.15	

Note: \*\*\* Significant at the 0.1% level; \*\* Significant at the 1% level; \* Significant at the 5% level.

significant (Tables 4, 5). Significant differences existed between clones and even between replicates in the single clone study. The important clone-temperature interaction recorded in Table 4 results largely from the effects of one clone, thus although not common, such interactions can be large.

#### Internode Length and Internode Number

The increased height growth noted at the higher temperature may be associated with an increase in internode number or an increase in internode length or both factors acting together. In the within-clone study the difference in internode length was statistically significant, but when a number of clones are considered the different responses of the individual clones result in no change in the mean. Internode number very largely accounts for the increased height growth brought about by the higher temperature (Table 1) and the differences recorded in the between-clone study are highly significant (Table 4). In the within-clone study height differences were also associated with highly significant differences in internode number (Table 5).

#### Correlations

The correlation coefficients which are statistically significant are recorded in Tables 6 and 7. Data obtained in the within-clone experiment have been excluded from the between-clone analyses. The between-clone study is represented by the seven clones referred to previously, but in the experimental work a further clone had been included whose higher temperature plant exhibited plagiotropism. This necessitated the complete exclusion of this clone from all the previous analyses, but since the plant growing at 18/13 was normal it was included. These repeat correlations are included in brackets in Table 6; in all cases they confirm and extend the original data.

Table 6. — Correlation Coefficients for Between-Clone Studies.

	18/13° C	27/22° C
Radius — No. of cells	0.95** (0.95***)	0.82*
Radius — Final height	0.89** (0.90**)	0.71
No. of cells — final height	0.82* (0.84**)	0.54
Cell diameter — radius	0.78* (0.80*)	-0.58
Cell diameter — No. of cells	0.54 (0.53)	-0.94**
Internode length — radius	0.77* (0.80*)	0.07
Internode length — final height	0.93** (0.94***)	0.52
Internode length — cell diameter	0.82* (0.81*)	0.00
Internode No. — final height	0.46 (0.54)	0.64

Note: \* Significant at 5%; \*\* Significant at 1%; \*\*\* Significant at 0.1%.

Based on the results for seven clones except for the figures in brackets which are based on eight clones, one member of each clone being grown at each temperature.

Between-clone correlations (Table 6) are more significant for the lower temperature plants and this is probably associated with more normal growth conditions at this temperature. Difference in final height of plants grown at 18/13 was associated with differences in the internode number and the internode length, the correlation of internode length with final height being highly significant. Conversely, the radial growth of the plant was achieved by an increase in cell numbers rather than cell size with the correlations being highly significant. Cell diameter was also significantly correlated with stem radius.

Few correlations were found for the 27/22 between-clone study. A correlation between stem radius and either cell number or cell diameter could be expected; that with cell numbers was significant. Surprisingly, height was not correlated with either internode number or length, indicating a very variable pattern. Of interest are the changes from positive to negative relationships for cell diameter with stem radius and with number of cells as one progresses from 18/13 to 27/22, the latter correlation being highly significant.

Perhaps the most noteworthy correlations were those involving fibre length; all six (with stem radius, cell diameter, cell number, final height, internode number and internode length) were not significant. Within-clone correlations can be quite unrelated to between-clone correlations, and the pattern exhibited by individual clones may vary widely. Consequently the data presented in Table 7 should be interpreted cautiously. Within this clone at either temperature the final height was significantly correlated with the number of internodes and not with internode length. As for the between-clone study, the stem radius is correlated more with cell numbers rather than cell diameter when the growing temperature is high. However, at the lower temperature neither is significantly correlated with stem radius.

The correlations of fibre length were all not significant except for the fibre length-final height correlation for the higher temperature which was negatively correlated.

Table 7. — Correlation Coefficients for Within-Clone Study.

	18/13° C	27/22° C
Fibre length — Final height	0.37	-0.97**
No. of cells — radius	0.81	0.92*
No. of internodes — final height	0.90*	0.88*

Note: \* Significant at 5%; \*\* Significant at 1% based on the results for one clone, five members of the clone being grown at each temperature.

## Discussion

### Environmental Variations

Differences were obtained in morphological and wood characters in response to the two environmental regimes. Comparison of the clones grown at the higher temperature with those at the lower shows an increased height increment of sixty percent, an increase in the number of internodes of fifty five percent, an increase in the number of cells in the stem radius of fifty seven percent, a stem increment of only eight percent, a fibre radius decrement of nine percent, and a fibre length increment of ten percent. The mean internode length changed little with individual results showing both increases and decreases.

The important temperature response in fibre length is similar to that recorded for coniferous species (genetic relationships of seedlings being unknown) by RICHARDSON and DINWOODIE (1960) and DINWOODIE and RICHARDSON (1961). They proposed that 'increasing the temperature increases the plasticity of the cell wall during intrusive growth and, thus, increases the amount of intrusive growth'. This hypothesis may be further modified by consideration of lignin contents and lignification. WARDROP (1957, 1965) suggested that the time of initiation of lignification may serve to limit the growth of differentiating cells by immobilizing the matrix components of the cell wall. Such a limitation would occur if lignification in part involves active cytoplasmic participation of the cell. Thus growth at lower temperatures could be associated with an earlier onset of lignification, and a higher lignin content. Support for this comes from the work of WILSON and WELLWOOD (1965), who found in four out of five coniferous species, the lignin content was higher in the earlywood (shorter tracheids) than in the latewood, the peak being reached after the onset of earlywood formation. In the present work with *E. camaldulensis* lignin analyses have been made (BLAND and RUDMAN, in preparation) and correlated with various characters. The Klason lignin was inversely correlated with temperature. Since eighty percent of the lignin is external to the primary wall in hardwoods, this increased lignin content is spread over the cellular surface of a smaller number of larger cells. Calculations show that the amount of lignin per unit surface area will be greater at the lower temperature than at the higher temperature. Thus the fibres could be shorter both because of immobilisation by such matrix components as lignin, hemicelluloses and calcium pectate and also the lower net assimilation, so supporting the suggestion of WARDROP (1957) and (not necessarily for the same reasons) that of RICHARDSON and DINWOODIE (1960).

The present work provides further information about the relationship between cell length and height growth. No significant relationships were found for *E. camaldulensis* at either temperature in the between-clone study (-0.19 and -0.58 for 18/13 and 27/22° C respectively); in the within clone study no relationship (+0.37) was found for the clone when grown at the lower temperature, but at the higher temperature a highly significant negative relationship was demonstrated (-0.97). Variability at the lower temperature is indicated by the low values of the correlation coefficients and the differing signs, but the increase in magnitude and the negative relationship demonstrated for the plants grown at the higher temperature are important.

These negative responses could be associated with genotype, environment and genotype × environment interactions. They occur in both within- and between-clone studies and the evidence suggests these are differences due

to the environment. From the within-clone study (Table 3) no important difference could be attributed to the differences in initial size of the rooted cuttings. Since no interactions were noted we can assume genotypic uniformity. Nevertheless, at the higher temperature a highly significant negative correlation occurred between final height and fibre length, the regression of initial height on final height being very highly significant up to the 120th day and significant thereafter. Thus the fact that some rooted cuttings were bigger than others at the start of the experiment resulted in an advantage at the higher temperature which was reflected in greater absolute growth (that is the dominant remained the dominant) which was in turn associated with a shorter fibre. It should be noted (Table 3) that a relationship between initial plant height and fibre length could not be demonstrated. The genotypic differences tended to obscure this relationship in the between-clone study at the higher temperature but assumed greater importance at the lower temperature.

Studies of this type emphasise the need to separate various possible responses into within and between family and within and between environment components. Even in such rigorously controlled experiments, difficulties in interpretation arise. The present results are interpreted as indicating a positive cell length-plant height relationship for young plants, both within and between clones, if the effects of two environmental conditions are being compared. If only one environmental condition is used, the relationship may be positive or negative, according to the environment and genetic relationship existing between the plants. Since the genetical relationship and environmental conditions exert a marked effect upon the relationship between fibre length and height growth the data obtained by earlier investigators should be re-interpreted. HARTLEY (1960) used one family of half-sib seedlings and grew them under one environmental condition. He obtained a positive correlation coefficient of only 0.29, significant at the five percent level. KENNEDY (1957) and CECH, KENNEDY and SMITH (1960) used hardwood coppiced stems (therefore the same clone) whereas DINWOODIE and RICHARDSON (1961) derived a positive relationship for three coniferous species by combining the height growths obtained under three different temperature regimes or daylength regimes using seedlings of unspecified genetic relationship.

#### Cell Length and Number Relationships

Interest has centred on whether (1) a plant grows in height by having more internodes or greater internode length, (2) increase in fibre length accommodates the increased height growth, (3) more fibres are placed end to end. Similarly is stem diameter increased by fibre numbers rather than size?

Considerable relevant information is available now for *E. camaldulensis*. The height increment associated with higher temperature is due to the production of more fibres rather than an increase in fibre length. An increase in the latter of nine percent, even if the fibre overlap were reduced to zero, could not account for a height increment of sixty percent. Similarly, stem diameter increment was achieved by greater cell numbers and not by an increase in cell diameter (actually a decrease in cell diameter was recorded). Even within an environment, fibre numbers were more important than fibre length and diameter.

As with fibre length, differences in the importance of internode length and internode number are related to the nature of the environment and whether studies are being made within or between clones. Height increment brought

about by a higher temperature is associated with an increase in internode number rather than length. With an individual clone in a single environment, the taller plants have more internodes. For a group of unrelated plants in a single environment, the relative importance of internode length and number is dependent upon the environment. At a lower temperature internode length appears to be of greater importance, whereas at a higher temperature both internode length and number contribute to height growth.

Consequently fibre number and internode number are more important than their respective sizes in accounting for a growth increment. Under certain circumstances size can significantly change but the magnitude is still far less than changes in numbers.

#### Genotypic Variation

Another aspect of this study was to determine if eucalypts exhibited marked genotypic differences in certain wood characters within species. It might be inferred from the work of PRYOR *et al.* (1956) and PRYOR and DADSWELL (1964) and the differences found within a species when mechanical and density examinations have been made, that genotypic differences would be found. In the present between-clone study, the use of controlled glasshouse environments to reduce micro-environmental differences such as would occur in a forest or uncontrolled glasshouse-test enabled this to be tested. Using only seven randomly chosen clones, very highly significant differences in fibre length were demonstrated, with the clone possessing the shortest fibres at the lower temperature (0.55 mm) having the shortest fibres at the higher temperature (0.56 mm) and the clone with the longest fibres at the lower temperature (0.62 mm) also having the longest at the higher temperature (0.66 mm). Because the two temperature regimes chosen for this work encompass the range naturally encountered by *Eucalyptus camaldulensis* this genotypic variation suggests that selection for fibre length could be satisfactorily achieved in juvenile plants. Whether such gains would be maintained as the plant matures is not known. The work of RANATUNGA (1964) with *E. grandis*, CAMERON (1966) with *E. deglupta* and RUDMAN and HIGGS (unpublished) with *E. regnans* suggests seedlings with long fibres tend to produce trees with long fibres, but changes could occur.

Genotypic differences were noted also in the number of cells in the plant stem radius, but not in the cell diameter. Cell number is one of four cellular features which influences density.

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#### Summary

Clones of *Eucalyptus camaldulensis* were grown under controlled environmental conditions in two phytotron glasshouses. Morphological and wood characters were measured, and the data resolved into genetic and environmental components. Marked differences between clones in fibre length were demonstrated, and to a lesser extent for cell numbers in stem radius. Higher temperatures produced a higher growth rate, greater number of internodes and longer fibres. Height growth was positively correlated with fibre length both within and between-clones if more than one environment was used, but within a single environ-

ment, the correlations tended to depend upon the nature of the environment and whether the plants are genetically related. A highly significant negative correlation between height growth and fibre length was demonstrated to exist within one clone. The interpretation of earlier work is discussed.

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# Trees Grown from Cuttings Compared with Trees Grown from Seed (*Pinus radiata* D. Don)

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## 1. Introduction

A plantation programme based on rooted cuttings, if practicable, offers possibilities of large genetic improvements through the selection of superior clones. Also, there is the possibility of further improvements because of differences between trees grown from cuttings and trees grown from seed — differences associated with the method of propagation itself.

In the Australian Capital Territory (A. C. T.), rooted cuttings of *Pinus radiata* D. Don have been planted on an experimental scale almost annually since 1938, and a lot of material is therefore available for studying differences between cuttings and seedlings.

Some clones compared with seedlings in this paper had been raised from trees selected for fast growth rate, trunk straightness and small, wide-angled branches. Such selection can be expected to have had an appreciable effect on branch size and angle and on related branching characteristics such as the number of whorls of branches on the annual shoot: selection for small branches tends to reject trees with only few whorls of branches, and the number of whorls of branches on the annual shoot is related to the number of branches in the whorl (FIELDING, 1967). It is postulated however that the selection has not had an important effect on the other characteristics studied (bark thickness, taper and foliage), because as far as is known, such characteristics are not related to those which were under selection.

It is considered that, except for the particular branching characteristics of the selected clones discussed in the previous paragraph, the differences discussed in this paper between cuttings and seedlings are basically a result of the difference in the propagation method and that they are effects of cyclophysis. Cyclophysis (BÜSGEN and MÜNCH, 1929) may be defined as the expression in the vegetatively propagated individual of properties associated with the age of

the parent plant or the developmental stage of the shoot used as the cutting or scion.

Changes associated with aging and development appear to be universal in woody species (SCHAFFALITZKY, 1959), and there are numerous examples of the carryover of such changes into vegetatively propagated progenies.

The cuttings and seedlings compared in this paper differ in physiological age by only a few years, but it is not entirely surprising that such a small age difference should be associated with distinct differences in many characters, because rapid changes are obvious during the first 5—7 years of the life of the seedlings — changes in buds, foliage, branching, crown shape and flowering.

Some of the differences between cuttings and seedlings are very marked in the case of cuttings raised from older trees. For example, in *Figures 2 and 3* the smooth bark, low taper, and small branches of the clones which had been raised from 16-yr.-old seedling trees make the trees of these clones strikingly different from trees of seedling origin.

Very little information is available on the influence of the properties of the shoot on the characteristics of the tree grown vegetatively from the shoot. Many results in this paper are preliminary in nature. The subject deserves intensive study since changes so induced in a tree provide the forester with another possible means (in addition to improvements by cultural methods and breeding) of developing trees of greater or special value.

## 2. Definitions

In this paper the term "cutting" refers not only to a shoot cut from the tree and set in the nursery but also to any tree raised from a cutting, including large, mature trees.

Cuttings from seedling ortets are referred to as "first-propagation cuttings", cuttings from which are referred to as "second-propagation cuttings".