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# Growth and foliar variation among provenances of *Eucalyptus camaldulensis* Dehn. grown at Dehradun

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**Abstract.** Results of provenance trial of *Eucalyptus camaldulensis*, established at New Forest, Dehradun, are discussed. Highly significant differences were observed among the provenances for growth ($P=0{\cdot}001$) and foliar ($P=0{\cdot}01$) characteristics. The provenances of Katherine, NT (S3); Hughendon, Queensland (S7) and Petford, Queensland (S1) from Australia proved best at the site of introduction with mean height 12·97, 13·63 and 12·69 m and mean diameter 10·39, 9·47 and 8·49 cm respectively. Selection of provenances has been advocated on the basis of their comparative performance and within provenance variability. Overall performance of northern and southern populations, having a line of discrimination somewhere between 21° S and 23° S latitude, has been discussed. For the first time statistically significant provenance difference has been explored at stomatal level. Significant negative correlations were obtained between provenance latitude and height ($r=-0{\cdot}64$), diameter ($r=-0{\cdot}73$) and stomata length ($r=0{\cdot}84$). The impact of maximum temperature of the provenance on height and leaf length was observed to be positive and significant ($r=0{\cdot}824$ and $0{\cdot}710$ respectively).

**Keywords.** Provenance; latitude; coefficient of variation; correlation; northern and southern populations.

## 1. Introduction

In recent years provenance variation has attracted attention of the forest researchers all over the world. Eucalypts, being a fast growing species and having a wide range of adaptability, have become one of the most studied genera. Studies have been carried out on *Eucalypts camaldulensis* by Bank and Hillis (1969), Hallam and Chambers (1970), Pryor and Byrne (1969), Karschon and Lydia (1971), Burley *et al* (1971), Siddiqui *et al* (1979), Ghosh *et al* (1977) and Venkatesh and Vakshasya (1979).

To assess the performance of different provenances of *E. camaldulensis*, a trial was initiated at New Forest Campus (altitude 640·08 M, latitude 30° 20′ 40″ N, longitude 77° 52′ 12″ E, annual rainfall 216 mm and mean maximum temperature 27·5° C), of the Institute in July 1967. Observations were recorded in 1972 on different growth and foliar parameters.

## 2. Materials and methods

### 2.1 *Materials*

Seeds of 12 provenances of *E. camaldulensis*, from 14° 25′ S to 34° 9′ S, were obtained from Australia (table 1) and seedlings were raised in nursery in polybags. Later these seedlings were outplanted in 1967 in a complete randomised design.

**Table 1.** Seed origin of *E. camaldulensis*.

| Local code No. | Seed lot No. | Origin | Latitude | Max. temp. | No. of plants |
|---|---|---|---|---|---|
| S1 | 6953 | Petford, Queensland | 17°20′ | 94·7 | 48 |
| S2 | 7116 | Goodairs Creek, NT | 19°0′ | 99·8 | 48 |
| S3 | 6869 | Katherine, NT | 14°25′ | 100·4 | 24 |
| S4 | 7080 | Newcastle Waters Creek, NT | 17°30′ | 99·4 | 24 |
| S5 | 6956 | Lachlan River, Forbes, NSW | 33°20′ | 91·9 | 24 |
| S6 | 6955 | Barrnedman, Wyalong, NSW | 34°9′ | 87·1 | 24 |
| S7 | 6949 | 29 km north of Hughendon, Queensland | 20°43′ | 99·4 | 12 |
| S8 | 6957 | Macquaris river, Dubho, NSW | 32°11′ | 92·1 | 12 |
| S9 | 6960 | 103 km north of Charleville, Queensland | 26°50′ | 97·6 | 12 |
| S10 | 6870 | 3 km along Quilpie, Eulo, Queensland | 28°4′ | 97·4 | 12 |
| S11 | 6788 | Bed of Todd River 7 km SE of Alice Spring, NT | 23°38′ | 95·3 | 12 |
| S12 | 3052 | 31 km south of Agnew, West Australia | 28°15′ | 96·7 | 12 |

## 2.2 *Methods*

Measurements were recorded on the trees of 12 provenances of *E. camaldulensis* in 1972.

2.2a *Height and diameter*: Height and diameter at breast height (DBH) of all the available trees were recorded. S12 provenance was not studied due to the large number of damaged trees.

2.2b *Leaf length and leaf width*: Twenty five mature leaves were sampled from the middle of the first persisting branch from 5 different trees of each provenance. Leaves were measured for length, along the midrib and maximum width.

2.2c *Stomata length and width*: For this study 5 leaves were randomly sampled from each of the 5 trees of each provenance. The basal region of the lamina was cut and treated for 12 h in 1:1 ratio of 10% HCl and 10% $H_2CrO_4$ at room temperature (30°C ± 2). The abaxial epidermal peel separated by this treatment was stained in safranin and mounted in 30% glycerine. One slide was prepared from each leaf. Ten stomata were measured from 5 different microscopic fields under high power (10 × 40) from each epidermal peel prepared. Data on leaf size for 8 provenances and stomata size for 7 provenances could not be taken due to some difficulties.

2.2d *Statistical analysis*: The experiment was laid out in a completely randomised design with varying number of plants per provenance as mentioned in table 1.

Mean (M), standard deviation (SD) and coefficient of variation (CV) were calculated for height and diameter. Standard error also was calculated for the foliar characters as the material was sampled from a population (table 2).

To understand provenance differences emphasis was given to one way analysis of variance and differences between pairs of means for each characteristic were tested by calculating least significant difference (LSD). For height and diameter number of trees per provenance had varied resulting in many values of LSD and hence the bar

**Table 2.** Statistical constants for height (Ht), diameter (Dia), leaf length (LL), leaf width (LW), stomata length (SL) and stomata width (SW). Values with mean (M), standard deviation (SD), standard error (SE) and coefficient of variation (CV).

| Provenance code<br>Latitude | | $S_3$<br>14°25′ | $S_1$<br>17°20′ | $S_4$<br>17°30′ | $S_2$<br>19°0′ | $S_7$<br>20°43′ | $S_{11}$<br>23°38′ | $S_9$<br>26°50′ | $S_{10}$<br>28°4′ | $S_{12}$<br>28°15′ | $S_8$<br>32°11′ | $S_5$<br>33°20′ | $S_6$<br>34°9′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | 12·97 | 12·69 | 10·19 | 8·07 | 13·63 | 5·66 | 7·83 | 8·97 | | 6·90 | 7·76 | 8·58 |
| Ht | SD | 2·547 | 3·433 | 1·845 | 2·139 | 2·631 | 2·514 | 3·985 | 2·649 | — | 1·507 | 3·146 | 1·923 |
| (M) | CV | 19·63 | 27·05 | 18·10 | 26·50 | 19·30 | 44·42 | 50·89 | 29·53 | | 21·84 | 40·54 | 22·41 |
| | M | 10·39 | 8·49 | 7·52 | 5·43 | 9·47 | 4·15 | 5·70 | 6·07 | | 4·40 | 5·36 | 5·22 |
| Dia | SD | 2·387 | 3·037 | 1·586 | 1·416 | 2·195 | 1·046 | 2·827 | 2·384 | — | 0·946 | 2·489 | 1·379 |
| (cm) | CV | 22·97 | 35·77 | 21·09 | 26·08 | 23·18 | 25·21 | 49·60 | 39·27 | | 21·51 | 46·44 | 26·42 |
| | M | 20·10 | 17·50 | | 17·60 | | 12·10 | | 19·00 | 13·10 | | 15·10 | 11·30 |
| | SD | 1·093 | 1·720 | — | 1·784 | — | 1·096 | — | 1·100 | 0·260 | — | 1·452 | 0·710 |
| LL | SE | 1·049 | 0·771 | | 0·800 | | 0·491 | | 0·493 | 0·117 | | 0·651 | 0·318 |
| (cm) | CV | 5·437 | 9·828 | | 10·136 | | 9·042 | | 5·789 | 19·847 | | 9·615 | 6·255 |
| | M | 3·90 | 5·00 | | 3·00 | | 3·72 | | 3·66 | 4·86 | | 4·06 | 4·06 |
| | SD | 0·543 | 0·200 | — | 0·213 | — | 0·117 | — | 0·234 | 0·166 | — | 0·244 | 0·213 |
| LW | SE | 0·243 | 0·089 | | 0·095 | | 0·052 | | 0·104 | 0·074 | | 0·109 | 0·095 |
| (cm) | CV | 13·923 | 4·000 | | 7·100 | | 3·145 | | 6·393 | 3·415 | | 6·009 | 5·246 |
| | M | 25·10 | 26·61 | | 25·85 | | 26·17 | | 24·47 | | | 22·45 | 22·76 |
| | SD | 1·450 | 1·255 | — | 2·870 | — | 0·770 | — | 1·190 | — | — | 0·485 | 0·846 |
| SL | SE | 0·650 | 0·562 | | 1·286 | | 0·345 | | 0·533 | | | 0·217 | 0·379 |
| ($\mu$) | CV | 5·776 | 4·716 | | 11·101 | | 2·942 | | 4·863 | | | 2·160 | 3·717 |
| | M | 17·72 | 18·98 | | 19·99 | | 20·30 | | 18·16 | | | 16·90 | 16·46 |
| | SD | 0·682 | 1·629 | — | 2·367 | — | 0·716 | — | 0·907 | — | — | 0·571 | 0·685 |
| SW | SE | 0·306 | 0·726 | | 1·058 | | 0·321 | | 0·406 | | | 0·256 | 0·307 |
| ($\mu$) | CV | 3·848 | 8·582 | | 11·840 | | 3·527 | | 4·994 | | | 3·378 | 4·161 |

diagrams were drawn. However values of LSD have been mentioned for foliar characteristics (table 3). Coefficient of correlation was calculated between the variables studied and geographical factors and between possible pairs of studied variables (tables 4 and 5). All calculations have been carried out as per the formulae given by Snedecor and Cochran (1967).

## 3. Result and discussion

### 3.1 *Growth characteristics*

The measurements recorded on height and diameter showed that the mean height and diameter varied from 5·66 m (S11) to 13·63 m (S7) and from 4·15 cm (S11) to 10·39 cm (S3) respectively. Maximum variability was observed in S9 for height (CV 50·89%) and diameter (CV 49·60%), whereas minimum variability was noticed in the case of S4 for height and diameter (CV 18·10%) and (CV 21·09%) respectively (table 2). This aspect of range and within provenance variability provides the base for provenance selection to raise homogeneous population with acceptable rate of growth. Analysis of variance carried out on height and diameter showed that the differences among the provenances were highly significant. It was observed that provenances S7 (Hughendon), S3 (Katherine) and S1 (Petford) were superior amongst the provenances under test. Bar diagrams drawn on the basis of LSD showed that S1, S3, S4 and S7 are the main contributors for the significant differences between the provenances whereas the performance of rest of the provenances was almost similar thus forming a separate group (table 3).

The natural distribution of *E. camaldulensis* has been grouped into northern and southern populations on the basis of some physiological and morphological features (Pryor and Byrne 1969). The present study also indicated the existence of northern and southern populations on the basis of growth differences. The diameter was found to be a better discriminator with shifting of a single provenance (S2) from the expected position. If a line of delimitation is to be drawn on the basis of bar diagrams obtained as indicated by the result of the present investigation, it will fall somewhere between 21° S and 23° S latitude. In this experiment the northern populations are those north of 21° S latitude and southern populations are those south of 23° S latitude.

The northerly populations were less variable and grew faster than the southern populations. This reflects a better stability and proportional adaptability of low latitude population lending the way for safer selection of some provenance from northern region of Australia. The performance of the best 3 provenances assessed in this study confirms this.

The findings of Siddiqui *et al* (1979) on the comparative performance of *E. camaldulensis* at 6 and 10 years of age were in agreement with the present studies, as the ranking of the provenances at 5 years (the present study) and at 8 years (Gosh *et al* 1977) remained unchanged. This showed that there are possibilities of evaluating the provenances at an early age.

### 3.2 *Leaf characteristics*

The range of variation in leaf length was observed from 11·30–20·10 cm (S6 and S3)

**Table 3.** Mean values of the characters studied together with their significance and bar diagram.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ht | Provenance | $S_7$ | $S_3$ | $S_1$ | $S_4$ | $S_{10}$ | $S_6$ | $S_2$ | $S_9$ | $S_5$ | $S_8$ | $S_{11}$ | Sig. | LSD |
| | Mean | 13·63 | 12·97 | 12·69 | 10·10 | 8·97 | 8·58 | 8·07 | 7·83 | 7·76 | 6·90 | 5·66 | ** | LSD differs as numbers of trees varied |
| Dia | Provenance | $S_3$ | $S_7$ | $S_1$ | $S_4$ | $S_{10}$ | $S_9$ | $S_2$ | $S_5$ | $S_6$ | $S_8$ | $S_{11}$ | | |
| | Mean | 10·39 | 9·47 | 8·49 | 7·52 | 6·07 | 5·70 | 5·43 | 5·36 | 5·22 | 4·40 | 4·15 | | |
| Bar diagram for Ht | | $S_7$ $S_3$ $S_1$ | | | $S_4$ $S_{10}$ | | $S_6$ $S_2$ | | $S_9$ $S_5$ | | $S_8$ $S_{11}$ | | | |
| Bar diagram for dia | | $S_3$ $S_7$ | $S_1$ | $S_4$ | $S_{10}$ | $S_9$ | $S_2$ | $S_5$ | $S_6$ | $S_8$ | $S_{11}$ | | | |
| LL | Provenance | $S_3$ | $S_{10}$ | $S_2$ | $S_1$ | $S_5$ | $S_{12}$ | $S_{11}$ | $S_6$ | | | | | |
| | Mean | 20·10 | 19·00 | 17·60 | 17·50 | 15·10 | 13·10 | 12·10 | 11·30 | | | | * | 1·67 |
| LW | Provenance | $S_1$ | $S_{12}$ | $S_5$ | $S_6$ | $S_3$ | $S_{11}$ | $S_{10}$ | $S_2$ | | | | | |
| | Mean | 5·00 | 4·86 | 4·06 | 4·06 | 3·90 | 3·72 | 3·66 | 3·00 | | | | * | 0·44 |
| St | Provenance | $S_1$ | $S_{11}$ | $S_2$ | $S_3$ | $S_{10}$ | $S_6$ | $S_5$ | | | | | | |
| | Mean | 26·61 | 26·17 | 25·85 | 25·10 | 24·47 | 22·76 | 22·45 | | | | | * | 2·37 |
| St W | Provenance | $S_{11}$ | $S_2$ | $S_1$ | $S_{10}$ | $S_3$ | $S_5$ | $S_6$ | | | | | | |
| | Mean | 20·30 | 19·99 | 18·98 | 18·16 | 17·72 | 16·90 | 16·46 | | | | | * | 1·58 |

* Significant at 1% of probability. ** Significant at 0·1% of probability.

**Table 4.** Correlation between independent and dependent variables.

| | Ht | Dia | Leaf length | Leaf width | St. length | St. width |
|---|---|---|---|---|---|---|
| Latitude | −0·644* | −0·728** | −0·645 NS | 0·075 NS | −0·841* | −0·587 NS |
| Max. temp. | 0·824** | 0·508 NS | 0·710* | −0·296 NS | 0·637 NS | 0·568 NS |

**Table 5.** Correlation among variables studied.

| | Ht | Dia | Leaf length | Leaf width | St. length | St. width |
|---|---|---|---|---|---|---|
| Ht | | 0·966** | 0·695 NS | 0·314 NS | 0·234 NS | 0·239 NS |
| Dia | | | 0·737* | 0·259 NS | 0·271 NS | −0·174 NS |
| Leaf length | | | | −0·210 NS | 0·331 NS | 0·100 NS |
| Leaf width | | | | | −0·402 NS | 0·306 NS |
| St. length | | | | | | 0·207 NS |

*Significant at 5% level of probability. **Significant at 1% level of probability. NS. Not significant.

and width from 3–5 cm (S2 and S1) respectively (table 2). The differences between the provenances were highly significant (table 3). The leaf size was found to be a good indicator for the identification of northern and southern populations. Long and narrow leaves are the distinct features of northern populations whereas southern populations are characterised by shorter and broader leaves. There was much less variation in leaf width in their respective provenances exhibiting more stability in this character as compared to leaf length.

Mean stomata length and width ranged from 22·45 (S5) to 26·65 (S1) and 16·46 (S6) to 20·30 $\mu$ (S11). Variability was more in northern forms in comparison to the southern forms. Maximum variation was observed in S2, a northern provenance and minimum in S5, a southern provenance (table 2). Analysis of variance showed highly significant differences between provenances (table 3). The two latitudinally extreme provenances were distinctly different in foliar characters. The leaf and stomata size of the southernmost populations i.e. the New South Wales (S5 and S6), were found to be the smallest.

### 3.3 *Correlations*

The coefficient of correlation was calculated between the characters studied (dependent variables) and latitude and maximum temperature of the seed source (independent variables) separately. Height, diameter and stomata length were found to be negatively correlated with the latitude ($r = -0{\cdot}64$, $-0{\cdot}73$ and $-0{\cdot}84$ respectively). The association of maximum temperature of the seed source with height and leaf length was positive and significant (table 4). The results of the present study were found in accordance with the findings of Pryor and Byrne (1969) who have reported a trend of height increase with decrease in latitude for 6 months old seedlings. In addition the DBH also showed negative correlation with the latitude of respective provenances. The correlation coefficient was calculated for 15 pairs of variables also. There was significant correlation between height and diameter and diameter and leaf length (table 5).

Burley *et al* (1971) observed the leaf length to be positively correlated with the maximum temperature of seed source rather than with latitude and the reverse for leaf width. In the present study the leaf width was found to be related neither with the latitude nor with the maximum temperature of the seed source. The leaf length was observed on the other hand, to be correlated with the maximum temperature of the seed source but very near to significant level in respect of latitude (table 4). A significant negative correlation was observed between stomata length and latitude of the provenance. On the basis of high values obtained for other characters also which are near to significance level the incorporation of more provenances, in such studies to understand the pattern more precisely, is required.

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## References

Bank C J S and Hillis W E 1969 The characteristics of populations of *Eucalyptus camaldulensis* by chemical features; *Aust. J. Bot.* **17** 133–146

Burley J, Wood P J and Hans A S 1971 Variation in leaf characteristics among provenances of *Eucalyptus camaldulensis* Dehn. grown in Zambia; *Aust. J. Bot.* **19** 237–249

Gosh R C, Gupta B N and Sheda M D 1977 Provenance trial of *Eucalyptus camaldulensis* Dehn.; *Indian For.* **103** 441–453

Karschon R and Lydia P 1971 Variation in heat resistance of ecotypes of *Eucalyptus camaldulensis* Dehn. and their significance; *Aust. J. Bot.* **19** 161–272

Pryor L D and Byrne O R 1969 Variation and taxonomy in *Eucalyptus camaldulensis*; *Silvae Genet.* **18** 64–71

Siddiqui K M, Khan M and Akhtar S 1979 Results of 10 year old *Eucalyptus camaldulensis* Dehn. provenance study at Peshawar; *Silvae Genet.* **28** 24–26

Hallam N D and Chambers T C 1970 The leaf waxes of the genus *Eucalyptus* L Heritier; *Aust. J. Bot.* **18** 335–386

Snedecor G W and Cochran W G 1967 *Statistical methods*, 6th edition (New Delhi: Oxford and IBH Publishing Co.)

Venkatesh C S and Rajnish K Vakshasya 1979 Provenance variation in some floral characters of *Eucalyptus camaldulensis* Dehn.; *Indian J. For.* **2** 61–64