Variation of Seedling Traits of *Eucalyptus microtheca* Origins in Different Watering Regimes

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Abstract

Nine biometric characters of seedling of four *Eucalyptus microtheca* origins from Australia were studied under semi-controlled conditions. Statistically significant differences were found in some seedling traits between the origins under three watering regimes. Root/shoot ratio and foliage quantity (total leaf area, leaf dry weight)/sapwood basal area ratios in 5-month-old seedlings had adjusted to water stress. The highest root/shoot ratio and foliage quantity/sapwood basal area ratios were observed in the origin from northern Australia. In addition, root/shoot ratio and foliage quantity/sapwood basal area ratios had been associated with intrinsically the driest quarter rainfall of the natural habitats. The results suggest that there is genetic variation in term of drought adaptation mechanisms among the origins relating to their natural habitats, and the northern origin employs an adaptive strategy in response to water deficit at the initial phase of seedling growth and establishment.

Key words: Drought adaption, *Eucalyptus microtheca,* foliage quantity/sapwood basal area ratios, genetic variation, root/shoot ratio.

FDC: 165.5; 181.31; 181.525; 232.12; 176.1 *Eucalyptus microtheca;* (94).

Introduction

Eucalyptus microtheca F. MUELL. (coolibah) occurs in hot dry areas of Australia. The species has a wide geographical rang of tropical habitats with differing climatic conditions (BOLAND et al., 1984). Thus the populations with a wide diversity of habitats are often composed of ecotypes, each of which is adapted to prevailing environments. Therefore, it has been attributed to differences in the origins responses to available water. For example, the seedlings of *E. microtheca* grown in eastern Kenya from seed collected in the climatically different locations had distinctive responses to water limitation (JOHANSSON and TUOMELA, 1996).

The balance maintained by plants between the growth of their various parts may be an indicator of adaptation to site conditions. For example, foliage quantity (total leaf area, leaf dry weight)/sapwood area ratios for a plant is commonly used in physiological and ecological studies as an index of growth pattern (PEARSON et al., 1984; SHEPHERD and PRASIT, 1984; BERNINGER and NIKINMAA, 1994; MENCUCCINI and GRACE, 1995), often to draw attention to differences in pattern between species (KAUFMANN and TROENDLE, 1981; BRACK et al., 1985). In addition, several authors (SHEPHERD and PRASIT, 1984; WANG et al., 1988; GIBSON et al., 1995) had also studied the relationships between shoot and root development in some eucalypt species under different water supplies, and suggested root/shoot ratio was an important index of drought adaptation. Based on these studies, the hypothesis is that in the origins of *E. microtheca,* differences in drought adaptation can be detected at early seedling growth stages through root and leaf development, which may relate to the climatic conditions in their natural habitats. Therefore, the aim of this study is to compare seedling traits in four *E. microtheca* origins under three watering regimes, and to improve the understanding of relationship between plant structure and function in the origins from diverse habitats, which may be used for selecting origins under different environmental conditions at the initial phase of seedling growth and establishment.

Material and Methods

Seeds

Seeds from four origins of *E. microtheca* were obtained from Australian Tree Seed Centre, CSIRO, Division of Forest Research, Canberra (*Table 1*).

Growth conditions and treatments

The seeds were sown in Helsinki, Finland, on wet tissue paper in Petri dishes. After germination, the seedlings were pricked into small plastic pots and grown in a semi-controlled environment in a greenhouse within a temperature range of 17.0 °C to 35 °C. The daily temperature was allowed to fluctuate according to prevailing weather conditions. After about one month, the seedlings were transplanted into pots with 2 litres of volume (18 cm deep x 12 cm diamter). A commercial peat-sand substrate was used as growth medium in the seedling pots. One cubic metre substrate contained 0.7 kg of fertilizer (10% N, 8% P and 16% K) and 8 kg of Mg-rich limestone powder. The substrate was packed into the seedling pots with a density of about 0.4 g/cm^3. The 2-litre pots were thoroughly watered and kept in a basin partly with water overnight to let them reach field capacity before transplanting. The pots were assumed to be at field capacity and weighed after they were removed from the water basin and allowed to drain.

A completely randomised design with two factors (four origins and three watering regimes) was used. For each origin there were 45 seedlings equally divided among three watering regimes; i.e. control treatment (100% of field capacity), water stress treatments (50% and 25% of field capacity, respectively). One seedling in each pot was arranged, total 180 pots.

A two-day cyclical watering schedule was applied throughout the experiment. The water loss was estimated every second day by weighing five randomly selected pots in each origin from the control treatment. This measured water loss was completely compensated in the control treatment. The stress treatments were induced as follows: in the two stress treatments, only 50% or 25% of the measured water loss was compensated as compared with the control treatment.

Seedling measurements

At the end of the experiment (after five months), the seedlings were measured for shoot height, basal diameter, root dry weight, stem dry weight, leaf dry weight and total leaf area. Basal diameter was measured above root collar, assuming that no heartwood was formed yet, so sapwood basal area could be

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Table 1. – Details of four *E. microtheca* origins (with seedlot number indicated) used in the study[1]).

Seed-lot	Locality	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)	The driest quarter rainfall (mm)	Mean annual maximum temperature (°C)	Mean annual minimum temperature (°C)	Mean annual rainydays	Weight of 1000 seeds (g)
15074	Newcastle Waters	17°00′	134°45′	160	494	8	34.2	19.5	47	0.724
15076	Central Australia	24°30′	132°50′	490	263	27	28.7	13.8	35	0.554
15081	South West Qld	27°20′	144°35′	180	360	57	28.2	14.3	43	0.536
15085	Western Nsw	32°05′	142°45′	80	233	52	23.7	12.0	38	0.607

[1]) Climatic data from CSIRO (1979).

Table 2. – Growth related characters of seedling (means and standard errors) in four *E.microtheca* origins[1]).

Seed-lot	Treatment	Shoot height (cm)	Basal diameter (mm)	Root dry weight (g)	Leaf dry weight (g)	Total biomass (g)	Total leaf area (dm^2)
15074	25%	42.69(2.15)	4.21(0.11)	2.30(0.17)	1.80(0.08)	4.94(0.22)	2.46(0.10)
	50%	59.85(1.80) A	5.66(0.14) A	4.69(0.21) A	3.13(0.06) A	10.56(0.29) A	4.82(0.08) A
	100%	72.55(4.14)	7.39(0.37)	5.57(0.34)	4.39(0.11)	15.94(0.36)	7.29(0.18)
15076	25%	35.51(3.57)	4.34(0.16)	2.20(0.17)	1.82(0.07)	5.49(0.18)	2.59(0.11)
	50%	51.00(2.52) AB	6.33(0.23) A	4.95(0.14) AB	3.81(0.07) B	12.87(0.17) B	5.95(0.05) B
	100%	78.26(4.86)	7.80(0.26)	6.01(0.19)	5.46(0.25)	18.32(0.21)	9.12(0.41)
15081	25%	46.76(1.96)	4.25(0.14)	2.28(0.06)	2.62(0.15)	6.80(0.12)	3.73(0.22)
	50%	65.64(3.17) BC	6.01(0.19) A	5.10(0.08) BC	4.94(0.10) C	15.43(0.19) C	8.06(0.07) C
	100%	84.67(6.35)	7.68(0.67)	6.49(0.22)	6.62(0.27)	22.57(0.32)	11.32(0.43)
15085	25%	54.44(3.13)	4.38(0.17)	2.16(0.06)	2.35(0.05)	6.91(0.10)	3.36(0.07)
	50%	71.60(4.04) C	6.01(0.17) A	4.79(0.24) C	4.92(0.11) C	15.35(0.28) C	8.21(0.17) C
	100%	92.37(7.14)	7.16(0.31)	6.79(0.21)	7.19(0.24)	24.45(0.49)	12.52(0.45)

[1]) Capital letters refer to differences between the origins over all treatments. Values followed by the same letter are not statistically different at $p < 0.05$.

calculated according to basal diameter.

Analysis of data

Data were analysed using the analysis of variance. TUKEY's test was used to detect possible differences between the origins. The correlations among characters of growth were tested with correlation analysis. The relationships between root and leaf characters and climatic data of the natural habitats were tested by regression analysis. Statistical analyses were done with the SYSTAT statistical software package.

Results

Growth related characters of seedling

Statistically significant differences were found in shoot height (HT), root dry weight (RD), leaf dry weight (LD), total biomass (TB) and total leaf area (LA) between the origins, but there was no statistically significant difference in basal diameter (DR) between the origins. The southeastern origins have higher early seedling growth as compared to the northern and central origins (*Table 2*). The effect of watering on early seedling growth was very significant ($p < 0.001$). In addition, the watering x origin interaction was significant ($p < 0.01$) in HT, RD, LD, TB and LA.

Root and leaf related characters

There was a close linear relationship between foliage quantity and sapwood basal area in each origin and watering regime. Statistically significant differences in root/shoot ratio (RS), total leaf area/sapwood basal area ratio (FA) and leaf dry weight/sapwood basal area ratio (FW) between the origins were detected. The highest RS, FA and FW were observed in the origin from northern Australia (*Table 3*). Water deficit increased significantly RS, FA and FW ($p < 0.001$). In addition, the watering x origin interaction was significant ($p < 0.01$) in RS, FA and FW.

Correlation analysis

The results of correlation analysis showed that the correlations between most growth characters were highly significant under the same watering condition. In all watering treatments, root/shoot ratio (RS) was significantly correlated with total leaf area/sapwood basal area ratio (FA) and leaf dry weight/sapwood basal area ratio (FW). The relationships between root and leaf characters (RS, FA, FW) and climatic data (mean annual rainfall, MAR; the driest quarter rainfall, DQR; mean annual maximum temperature, MAXT; mean annual minimum temperature, MINT; mean annual number of rainydays, RDAY) of the natural habitats were also analysed (*Table 4*), it was found that RS, FA and FW had been associated with intrinsically DQR under three watering treatments ($p < 0.05$). In addition, there is not a close correlation between seed weight and seedling traits in all different watering regimes.

Conclusion and Discussion

Plant responses to water deficit vary temporally and spatially. Over longer time scales, structural modifications can be major indicators and growth patterns can change as a consequence of plant water stress. There are different drought adaptations to water deficit by means of structural modifications. For example, total leaf area and leaf dry weight are reduced significantly, whereas the ratio of root dry weight to shoot dry weight is increased significantly. In this study, it was found that there were statistically significant differences in some seedling traits between the origins, and root and leaf characters of early seedling growth could be of major importance in determining the capacity of seedlings to grow and survive in water stress, and hence for seedlings to overcome from water deficit damage.

Root and leaf development has usually been related with their natural habitats, statistically significant differences were found in root and leaf characters between the origins. Root and leaf characters of seedling from two southeastern origins with similar climates were similar and different from origins in the other climates. The ratios of foliage quantity (total leaf area, leaf dry weight) to sapwood basal area and the ratio of root dry weight to shoot dry weight had adjusted to water stress. The lowest foliage quantity/sapwood basal area ratios and root/shoot ratio were observed in the origins from southeastern Australia. These structural characteristics reflected acclimatization and/or genetic adaptation to transpiration requirement of growing conditions. Thus structural modification is very important indicator through physiological feedback which in turn is affected by water situation in the soil.

Water availability is the main factor that affects the ratio of root dry weight to shoot dry weight. AWE et al. (1976) suggested that the ability of *E. camaldulensis* to establish successfully in a rapidly dry soil profile was largely due to a capacity to produce a massive root system rapidy, and GIBSON et al. (1995) found that seedlings from the dry tropical and semi-arid climates had a higher allocation of dry matter to roots than seedlings from the humid tropics when water limited. Overall, trees native to arid environments often have high root/shoot ratio, the ratio of root dry weight to shoot dry weight is shifted further in favour of the roots, the greater the exposure to drought (LARCHER, 1995). Therefore, a clear conclusion is that adaptation to water deficit in *E. microtheca* involves marked change in the ratio of root dry weight to shoot dry weight.

Table 3. – Root and leaf related characters (means and standard errors) in four *E.microtheca* origins[1]).

Seed-lot	Treat-ment	Root/shoot ratio	Total leaf area/ sapwood area ratio(dm^2/mm^2)	Leaf dry weight/ sapwood area ratio(g/mm^2)
15074	25%	0.87(0.07)	0.316(0.013)	0.232(0.011)
	50%	0.80(0.03) A	0.277(0.007) A	0.180(0.004) A
	100%	0.54(0.03)	0.263(0.007)	0.158(0.004)
15076	25%	0.67(0.06)	0.273(0.008)	0.193(0.012)
	50%	0.63(0.02) B	0.256(0.008) B	0.164(0.005) B
	100%	0.49(0.03)	0.240(0.005)	0.144(0.003)
15081	25%	0.51(0.02)	0.251(0.008)	0.177(0.006)
	50%	0.49(0.01) C	0.243(0.002) C	0.149(0.002) C
	100%	0.41(0.02)	0.225(0.005)	0.131(0.003)
15085	25%	0.46(0.01)	0.245(0.007)	0.157(0.005)
	50%	0.45(0.02) C	0.245(0.002) C	0.147(0.001) C
	100%	0.38(0.01)	0.235(0.008)	0.135(0.005)

[1]) Capital letters refer to differences between the origins over all treatments. Values followed by the same letter are not statistically different at $p < 0.05$.

Table 4. – Relationships between root and leaf characters and climatic data of the natural habitats. Correlation coefficients are shown in bold, P-values in italics type[1]).

Factor	Treatment	MAR	DQR	MAXT	MINT	RDAY
RS	25%	**0.580**	**-0.948**	**0.874**	**0.828**	**0.248**
		0.238	*0.026**	*0.065*	*0.090*	*0.502*
	50%	**0.572**	**-0.952**	**0.869**	**0.822**	**0.242**
		0.244	*0.024**	*0.068*	*0.093*	*0.508*
	100%	**0.460**	**-0.932**	**0.837**	**0.711**	**0.139**
		0.322	*0.035**	*0.085*	*0.157*	*0.628*
FA	25%	**0.652**	**-0.922**	**0.871**	**0.883**	**0.334**
		0.193	*0.040**	*0.067*	*0.060*	*0.422*
	50%	**0.568**	**-0.945**	**0.775**	**0.819**	**0.283**
		0.246	*0.028**	*0.120*	*0.095*	*0.468*
	100%	**0.445**	**-0.943**	**0.586**	**0.691**	**0.233**
		0.333	*0.029**	*0.234*	*0.169*	*0.518*
FW	25%	**0.719**	**-0.918**	**0.963**	**0.912**	**0.366**
		0.152	*0.049**	*0.019**	*0.045**	*0.395*
	50%	**0.531**	**-0.971**	**0.831**	**0.791**	**0.213**
		0.271	*0.014**	*0.088*	*0.110*	*0.538*
	100%	**0.452**	**-0.974**	**0.692**	**0.722**	**0.189**
		0.328	*0.013**	*0.168*	*0.151*	*0.565*

[1]) RS, root/shoot ratio; FA, total leaf area/sapwood basal area ratio (dm^2/mm^2); FW, leaf dry weight/sapwood basal area ratio (g/mm^2); MAR, mean annual rainfall (mm); DQR, the driest quarter rainfall (mm); MAXT, mean annual maximum temperature (°C); MINT, mean annual minimum temperature (°C); RDAY, mean annual number of rainydays (day). *) Significant.

Many authors (ESPINOSA BANCALARI et al., 1987; KEANE and WEETMAN, 1987; LONG and SMITH, 1988; BERNINGER and NIKINMAA, 1994; MENCUCCINI and GRACE, 1995; TUOMELA, 1997) found that leaf dry weight or total leaf area of a woody plant and sapwood area in the stem were highly correlated. KAUFMANN and TROENDLE (1981) thought their correlations might be based upon a physiological balance between demand for water by the crown and the ability of the stem to conduct it, and found that tolerant species might be able to carry higher leaf areas per sapwood area because of lower rates of water loss per unit leaf area. These results are similar to present study, it demonstrates that different climatic conditions in native habitats may influence on the development of plant structure that the origins from higher temperature and lower the driest quarter rainfall regions have a higher foliage quantity/sapwood basal area ratio for preventing water deficit.

These differences imply that there is variation in term of drought adaptation mechanisms among the origins of *E. microtheca* relating to their natural habitats. The origins differ in their root and leaf development under water stress, and it may be possible to use these inductive plant features as criteria for selecting origins in arid and semi-arid regions. However, the present study is based in one single experiment without replication in space and time. Therefore there is no possibility to estimate the genotype x environment variance component. Thus the calculation of the magnitude of the genetic component is not possible with the applied experimental layout.

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Age Trends in Variances and Heritabilities for Diameter and Height in Maritime Pine (*Pinus pinaster* AIT.) in Western Australia

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Abstract

The inheritance of variables related to growth was studied in a progeny trial of maritime pine (*Pinus pinaster* AIT.) in Wanneroo, Western Australia. The trial consists of the progeny of three parent trees used as females and five used as males, crossed in 14 of the 15 possible combinations (full-sib families), plus a routine commercial control family. There were 108 trees/cross, planted at a spacing of 3 m x 3 m.

Certain families had consistently large diameters and were consistently tall, indicating that early selection between families may be effective. Genetic and environmental variance components of the diameters and heights were estimated using the restricted maximum likelihood (REML) method. Both phenotypic and additive-genetic variances increased as trees became older, rapidly up to age 6 years, then more gradually up to 25 years. However, the heritabilities were fairly constant, in the range 0.14 to 0.16 for diameter and 0.11 to 0.14 for height. This is in contrast to other studies of pines in which heritability increased with age, and was greater for height than for diameter.

In a principal component analysis of the diameters the first component represented an average of the successive measurements and accounted for 93% of the variation. The second component contrasted early and late measurements and accounted for only 6% of the variation, but was more heritable ($h^2 = 0.35$) than the first component ($h^2 = 0.14$). A similar pattern was found for the heights. It is concluded that selection between families at an early age for diameter or height will be effective. It is also suggested that the second principal components reflect the genetic distance between trees, and could be used to ensure retention of genetic diversity in a tree breeding program.

Key words: Genetic variance, phenotypic variance, heritability, principal component analysis, progeny trial.

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Introduction

Forest trees are typified by long rotations and long breeding cycles, and selection at early ages is therefore a common practice in the improvement of these species. The assumption is made that early performance is indicative of later performance (LAMBETH et al., 1983). However, genetic and phenotypic parameters of trees reflect growth of the tree under the varying control of the genotype, the environment, and the genotype x environment interaction during its development. Hence they are expected to change over time (VÁSQUEZ and DVORAK, 1996). Determination of trends in variances and heritabilities with age may therefore be of value in the estimation of an optimal age for early selection. Stem volume production is an important goal in silviculture and tree breeding programs, and is largely determined by height and diameter. Of the two components, height is commonly used as a selection criterion for volume growth, since it is less sensitive to competition (KREMER, 1992).

The first objective of the research presented here was to determine the trends in genetic and phenotypic parameters for height and diameter during stand development in maritime pine (*Pinus pinaster* AIT.), and hence to seek trends in the heritability of these variables. A second objective was to explore whether the deviations from the major trends over time could provide further information of value to the tree breeder.

Materials and Methods

Materials

Data were obtained from a progeny trial of maritime pine in Gnangara Plantation, Wanneroo, Western Australia (latitude 115° 50'E, longitude 31° 38'S, altitude 60 m above sea level). The site is about 50 km north of Perth. The trial consists of the progeny of three parent trees used as females and five used as males, crossed in 14 of the 15 possible combinations (full-sib families), plus a routine commercial control family, and comprises 108 trees of each family (*Table 1*). The trees were planted in 1971, at a 3 m x 3 m spacing. The experiment was arranged in three replications, each consisting of six blocks of