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GENETIC VARIATION IN *EUCALYPTUS CAMALDULENSIS* DEHNH. IN A PROVENANCE-FAMILY TRIAL ON SALINE SOIL

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Abstract

In a provenance-family trial established on marginally saline soil, 45 seedlots of *Eucalyptus camaldulensis* Dehnh., including 44 families from 11 Australian provenances and 1 family from Pakistan, were evaluated for growth and stem straightness at the age of 60 months. Significant differences were found between families as well as provenances for height, diameter at breast height (DBH) and stem straightness. The provenance from De Grey river, Western Australia (WA) showed the best growth. Some individual families from Pakistan, Fitzroy river, WA, Lennard & Baker river, WA, and NE Petford, QLD had comparable growth. Overall mean height was 9.67 m with provenance means range of 10.3 m (De Grey river, WA, NE Petford, QLD and SE Petford, QLD) to 7.2 m (Silverton, NSW). DBH also followed a similar pattern with overall mean value of 7.4 cm and provenance mean range of 9.1 cm (De Grey river, WA) to 5.0 cm for Mt Benstead creek, NT. Stem straightness (scored qualitatively on a four point scale 1-4 with four for the straightest stem) was good with a trial mean value of 2.88 (range from 3.3 for Lennard & Barker river, WA to 2.26 for Newcastle Waters, NT). This study indicates significant genetic differences among the seed sources and thus good potential to improve growth of *E. camaldulensis* on marginal soils by selection and breeding.

Introduction

Salinisation of soil is one of the major processes resulting in low agricultural productivity and desertification, particularly in arid and semi-arid regions of the world. In Pakistan, about 6.3 million hectares of agricultural land is adversely affected by soil salinity. Qureshi & Barrett-Lennard (1998) have provided a comprehensive background to the causes, economic impact and possible management options to the salinity problem in Pakistan. One of the possible options, namely Saline Agriculture Approach, aims at utilization (rather than reclamation) of salt-affected land to achieve economic production by growing suitable salt tolerant plants and also using saline water for irrigation. A number of plant species/varieties have been identified as candidates for growth on saline land and provide a range of choices depending on the environmental conditions and potential utility of the produce (Marcar *et al.*, 1999; Qureshi & Barrett-Lennard, 1998). Planting trees and shrubs is likely to be a logical choice for salt-affected land because many tree and shrub species are moderately to highly salt tolerant (Marcar *et al.*, 1995).

Results from several tree species evaluation trials in Pakistan and elsewhere have indicated the existence of significant inter- as well as intra-specific variation in survival and growth for several tree and shrub species. *Eucalyptus camaldulensis* Dehnh. and *Acacia ampliceps* Maslin proved to be the most promising among the tree species tested under saline conditions (Davidson & Galloway, 1993; Ansari *et al.*, 1998). Significant differences for growth parameters exist between different seed sources of most *Eucalyptus* spp., (Eldridge *et al.*, 1993). There are good prospects to enhance tree growth on saline land through exploitation of genetic variation within species and by using

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improved seed (Marcar, 2002). It is, therefore, considered imperative to investigate the extent of the intra-specific variation for promising tree species. With this objective, two provenance-family trials of *Eucalyptus camaldulensis* were planted on saline-sodic sites near Faisalabad and Lahore (Pakistan). The results from the trial near Faisalabad have been reported previously (Mahmood *et al.*, 2003). The present paper describes the growth performance of 45 seedlots (families) of *E. camaldulensis* included in a provenance-family trial on sodic soil near Lahore.

Materials and Methods

The trial was conducted at the Biosaline Research Station of NIAB, Faisalabad located on Bedian Road near Lahore (74° 50′ E, 31° 60′ N, elevation 214 m asl). Average annual rainfall in the area is approximately 500 mm, with majority of it (about 80%) occurring during the July to September monsoon season. Mean monthly air temperature has range of 3-25°C for minima and 20-38°C for maxima. Both summer and winter are severe, with air temperatures of up to 48°C in June and near freezing point in January. The soil is medium textured (sand 60%) with a water table 20 m below the surface. The soil (0-30 cm) in the experimental field was marginally saline ($EC_{1:1}$ 1.11±0.16 dS m^{-1}, SAR 8.7±1.8, pH 8.6±0.08; *n = 12*).

The trial comprised 45 seedlots of *Eucalyptus camaldulensis* var. *obtusa*, including 44 families representing 11 provenances from different ecological zones of Australia and one land race from Pakistan (Table 1). The Australian provenances were provided by CSIRO's Australian Tree Seed Centre, Canberra. Seeds were germinated in plastic trays filled with sand. After germination, seedlings were irrigated with 1/5 Hoagland's solution. Individual seedlings were transferred to polyethylene bags filled with a silty loam soil:sand (2:1 ratio) mix including about 5% of composted organic manure. The seedlings were propagated in the bags in a nursery for about 6 months before planting out in the field.

In the trial layout, each family (seedlot) was represented by six replications of a five-tree-row plot (i.e. 30 trees). A row and column structure provided two-dimensional blocking within replicates. Trees were spaced at 3 m distance between rows and 1.5 m spacing within rows. The trial covered an area of 0.70 ha (100 x 70.5 m); two rows of trees were planted around the border. Seedlings of uniform size (ca. 18-20 inch) were planted by hand on the sides of 45 cm high ridges in third week of July 1995. About 250 g of gypsum was mixed in the soil around each tree at the time of transplanting. Four weeks after planting, mean survival across the trial was > 90% and dead seedlings were replaced at that time. Low quality water (EC 1.4 dS m^{-1}, sodium adsorption ratio (SAR) 7.5, residual sodium carbonate (RSC) 9.5, pH 7.6) was applied to the planted trees. The trees were irrigated more frequently up to age 2 years and thereafter, only 2-3 times each year during dry periods in summer.

Height and diameter at breast height (DBH) of each tree was measured 60 months after planting. The trees were also assessed for stem straightness. Measurements were taken on all trees in each replicate. Height was estimated to the nearest 0.1 m with a height pole and DBH was measured to the nearest mm with a diameter tape. Stem straightness was scored on a scale 1-4 qualitatively as: 1 for a stem with severe bends and 4 for a perfectly straight stem. Individual conical tree volumes were calculated using the following formula:

$$V = [0.333 \times 3.14 \times (\text{DBH} \times 0.1)^2 \times (Ht \times 10)] /4$$

where V is individual tree volume in dm^3, DBH is the diameter at breast height (cm), and *Ht* is tree height (m) as described by Mahmood *et al*., (2003).

Table 1. Description of *Eucalyptus camaldulensis* provenances andfamilies included in the trial.

Provenance number	Provenance	Latitude (^{0}S)	Longitude (^{0}W)	Altitude (m)	Seedlot number*	Number of families
1	Lennard & Baker River, WA	17.33	124.75	70	15320	5
2	Fitzroy River, WA	17.67	123.60	15	14536, 15319	4
						7
3	De Grey River, WA	20.32	119.25	100	15441, 18658	3
						4
4	George River, WA	20.92	117.37	15	15440	1
5	Wiluna, WA	26.57	120.05	550	14466	2
6	E Wrotham Park, QLD	16.82	144.17	240	14778, 14798	1
						1
7	NE Petford, QLD	17.28	145.05	500	14255, 14257, 14262, 14289, 14303	5
8	SE Petford, QLD	17.37	145.20	780	14341, 14343, 14345, 14356, 14386	5
9	Newcastle Waters, NT	17.47	133.42	200	14516	1
10	Mt Benstead Creek, NT	23.57	134.35	500	17297	1
11	Silverton, NSW	31.88	141.22	210	15195	4
12	Pakistan	31.25N	73.09E	184	PFRI1	1

*Seedlot numbers provided by CSIRO's Australian Tree Seed Centre, except for PFRI1, the Pakistan land race obtained from Punjab Forestry Research Institute, Faisalabad.

Analyses of variance were carried out on plot mean data using the package GENSTAT version 5.3.2 (Payne *et al*., 1987). The outputs were used to produce ANOVA tables for testing the significance of differences among families, following procedures described by Williams & Matheson (1994).

Results and Discussion

The overall tree survival in the trial was 95 %. Most of the seedlots had survival percentage > 90 %; only five seedlots had survival in the range 80-90 %. Mean tree height and DBH were 9.67 m and 7.44 cm at age 60 months. There were significant differences in height and DBH among the provenances as well as families (Table 2). The provenance mean height ranged from 10.3 m in provenances De Grey river, WA, NE Petford, QLD and SE Petford, QLD to 7.2 m (Silverton, NSW). DBH also followed a similar pattern with provenance mean range of 9.1 cm (De Grey river, WA) to 5.0 cm for Mt Benstead creek, NT. Tree volumes differed widely with provenance means ranging from 4.96 to 28.68 dm^3 and overall trial mean 18.5 dm^3 (Table 2). The De Grey river, WA provenance had the maximum tree volume (28.68 dm^3) followed by 23.5 dm^3 for the Pakistan land race PFRI1. The provenance Mt Benstead creek, NT had the lowest (4.96 dm^3) tree volume. There were significant differences among families for stem straightness, with mean score range between 2-3 for most of the provenances (Table 2).
Significant differences among families (seedlots) were evident for height, DBH, tree volume and stem straightness (p<0.001, Table 3). Results from several trials have shown wide variations among provenances as well as families of *E. camaldulensis* from Australia under a range of geographical locations (Pinyopusarerk *et al*., 1996; Sun & Dickinson, 1997; Mahmood *et al*., 2003). The best growth was observed in the provenance De Grey river, WA represented by 7 families. One bulk collection from this provenance (seedlot 15441) has shown good performance in earlier trials in Pakistan (Hussain & Gul, 1993). Further, this provenance (De Grey river, WA represented by 25 families) was the best performing in provenance-family trial on saltland near Faisalabad (Mahmood *et al*., 2003). Other provenances (NE Petford and SE Petford from QLD) had comparable height but smaller DBH than the provenance De Grey river, WA (Table 2). Good adaptability and growth of the provenance De Grey river could probably be attributed to the similarities in the climatic conditions at the place of its origin and at the trial site. This observation is further supported by the fact that the Pakistan race seedlot (PFRI1) was the second highest with respect to tree volume (Table 2). However, in the present trial, all provenances from WA did not perform equally well as did the De Grey river provenance. The provenance Mt Benstead creek, NT (one seedlot) had the poorest growth followed by Silverton, NSW (represented by 4 families). On the other hand, the provenances NE Petford and SE Petford, QLD (each represented by 5 families) had growth performance comparable with the provenances from Western Australia (WA). This is in contrast to the results from a provenance-family trial near Faisalabad (Mahmood *et al*., 2003) where these provenances (NE Petford and SE Petford, QLD) were among the poor performing ones while the Silverton, NSW and Mt Benstead creek, NT provenances had remarkably good growth.

Table 2. Height, diameter at breast height (DBH), tree volume and stem straightness of *Eucalyptus camaldulensis* provenances and families at 60 months.

Provenance	Number of Families	Height (m)			D B H (cm)			Tree volume (dm^3)			Stem straightness		
		Prov. Mean	Family Min.	Family Max.	Prov. Mean	Family Min.	Family Max.	Prov. Mean	Family Min.	Family Max.	Prov. Mean	Family Min.	Family Max.
Lennard & Baker River, WA	5	9.99	9.00	11.18	7.49	6.66	8.82	18.88	15.37	27.49	3.30	2.83	3.54
Fitzroy River, WA	11	9.86	8.86	11.87	7.39	6.58	8.67	18.32	13.58	28.22	3.07	2.77	3.47
De Grey River, WA	7	10.30	9.28	11.18	9.11	8.01	9.75	28.68	22.86	35.96	2.82	2.28	3.27
George River, WA	1	8.72	8.72	8.72	9.03	9.03	9.03	18.63	18.63	18.63	2.84	2.84	2.84
Wiluna, WA	2	9.31	9.03	9.54	7.80	7.77	7.83	19.99	18.72	21.58	2.33	2.29	2.37
E Wrotham Park, QLD	2	9.88	9.12	10.64	7.11	6.51	7.7	16.29	14.15	18.43	2.84	2.57	3.11
NE Petford, QLD	5	10.35	9.77	11.12	7.19	6.31	8.51	16.81	9.75	23.52	3.05	2.54	3.53
SE Petford, QLD	5	10.28	9.59	10.87	7.15	6.11	7.99	17.75	12.73	21.1	2.96	2.74	3.27
Newcastle Waters, NT	1	8.27	8.27	8.27	6.65	6.65	6.65	11.53	11.53	11.53	2.26	2.26	2.26
Mt Benstead Creek, NT	1	7.50	7.50	7.50	5.04	5.04	5.04	4.96	4.96	4.96	2.28	2.28	2.28
Silverton, NSW	4	7.25	6.39	7.83	5.67	4.84	6.05	8.48	6.81	11.1	2.35	2.18	2.65
Pakistan	1	9.87	9.87	9.87	8.68	8.68	8.68	23.50	23.50	23.50	2.59	2.59	2.59
Trial mean		9.67			7.44			18.52			2.88		
Standard error of differences of provenance means:	Maximum	0.878			0.866			5.14			0.277		
	Minimum	0.294			0.286			1.69			0.092		
Average standard error of differences of family means:			0.849			0.830			4.88			0.249	

Table 3. Mean squares from analyses of variance for mean height, diameter at breast height (DBH), tree volume and stem straightness score of *Eucalyptus camaldulensis* families at 60 months in the provenance-family trial at Lahore (Pakistan).

Source of variation	Degrees of freedom	Mean squares			
		Height	DBH	Tree volume	Stem straightness
Family	43	5.61*	5.69*	196.9*	0.687*
Residual	126	1.73	1.52	54.66	0.178

*The factor (i.e. Family) proved to have significant effects at $p \leq 0.001$ in analysis of variance. The seedlot from Pakistan was excluded as it was not certain whether it is true family or a multiple parent seedlot.

The overall growth rates in the present trial are comparable with growth (2-3 m per year over a 5 year period) of *E. camaldulensis* from local seed sources on a saline (EC_e = 10 dS m^{-1}) soil near Faisalabad and irrigated with good quality canal water (Marcar, 1996) and also in provenance-family trial on moderately saline (mean ECe = 9 dS m^{-1}) irrigated with saline (EC = 4.8 dS m^{-1}) water (Mahmood *et al*., 2003). In a species trial on saline site in India, *E. camaldulensis* had relatively smaller height (5.9 m) and DBH (5.8 cm) growth after 5 years (Jain *et al*., 1985). In other studies, growth of 7-month old seedlings of 42 families of *E. camaldulensis* was not affected by exposure for 4 months to soil salinity levels of 3.47 and 5.15 dS m^{-1}, but a significant variation was found among families (Aguayo *et al.*, 1998). Marcar (2002) reported a trend of decline in height of *E. camaldulensis* (De Grey river provenance) with increase in root zone salinity. Further, despite variable salinity across the trial, the use of soil salinity as a covariate did not alter the precision of comparisons between provenances and families-within-provenances (Mahmood *et al*., 2003) indicating the genetic variations among the seed sources. In the present studies, soil salinity ($EC_{1:1}$ = 1.11±0.16 dS m^{-1}; n = 12) was uniform across the trial plot, thus the differences in growth responses are attributable to genetic variations among the seedlots (families). Variations among different seed sources of *Eucalyptus* species are well documented, however larger number of families (10-15 per provenance) is recommended for surveying genetic variation (Eldridge *et al.*, 1993). Therefore, evaluation of a large number of provenances/families is desirable to investigate the true genetic variation and potential within the species.

The differences among families (seedlots) of *E. camaldulensis* found in the present as well as other trials could be exploited to improve productivity of plantations on both saline and normal soils. The seed sources from the best performing families are the most appropriate choices for immediate future plantations in areas having conditions similar to the trial site. In the long-term, out-crossing among the best performing individuals from selected families is expected to bring genetic gains over the natural seed sources.

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