Survival and growth responses of Australian provenances of *Eucalyptus tereticornis* and *Eucalyptus camaldulensis* in soils of different salinities in North-West India

S.K. Dhanda and O.P. Toky[1]
CCS Haryana Agricultural University Krishi Vigyan Kendra, Jind-126102 (Haryana), India

ABSTRACT : Seeds of eight Australian provenances of *Eucalyptus camaldulensis* and *Eucalyptus tereticornis*, received from the CSIRO, Australia were tested on three saline soils (0.45, 2.16 and 3.97 dS m^{-1}) in field conditions in Haryana located in north-west India. One local Indian seed source of *Eucalyptus tereticornis* was also included in the study for comparison. The growth of two years old plants varied significantly ($P<0.05$) among the provenances. The height of plants ranged from 210 to 447 cm, the collar diameter from 35 mm to 91 mm and dry weight from 1.98 kg to 3.41 kg/plant. Growth was adversely affected by the salinity. However, the root length of the plant increased significantly as the salinity levels arises indicating that more biomass was allocated to the underground parts under stress conditions. The maximum growth was attained by *Eucalyptus camaldulensis* of Emu Creek, Petford followed by Laura River, Qld and minimum in *Eucalyptus tereticornis* (of Indian local source). *Eucalyptus tereticornis* NW Mt. Molloy, QLD (Australia) performed better as compared to *Eucalyptus tereticornis* (of Indian local source) in three levels of salinity. The results are important since eucalypts are preferred by the farmers on saline soils in north-west India.

Key words: Provenance, *Eucalyptus*, Growth, Diameter, Salinity

1. INTRODUCTION

Salinization of non–irrigated soil is a serious problem in many areas of the world (Madsen & Mulligan, 2006). The total area of salt-affected soils is more than 7% of world's total surface area. In India 6.73 m ha area has been reported to be salt-affected out of which about 50% (2.98 m ha) occurs in the states of Rajasthan (0.38 m ha), Gujarat (2.22 m ha), Haryana and Punjab (0.38 m ha) (Sharma *et al.,* 2004). Bhargava (2005) classified the extent of salt affected saline soils occurring in different states into 6 classes on the basis of ECe (dS/m) by procuring the Soil Resource Maps. Salinity in the area of the study *i.e.* Haryana, north-west India, is increasing at an alarming rate due to rising level of watertable. These lands are mostly lying barren and pose a serious problem from afforestation point of view. *Eucalyptus* have unique ability to adapt to a wide range of sites at the same time grow more rapidly than other species (Desingh & Reddy, 2005). Among eucalypts *Eucalyptus camaldulensis* is tolerant to prolonged periods of drought, light frosts, relatively high temperatures and can grow on a wide range of soils (Boland, 1980).

Extensive provenance trials have been made on *Eucalyptus* species in many parts of the world, and a wide range of variation existed among provenances under different climatic and soil conditions. Marcar *et al.* (1995) conducted two provenance trials of *Eucalyptus camaldulensis* with 13 Australian provenances. They established significant differences between provenances. The best provenances were Gvale, Petford and Gibb. river. Significant intra-specific variation for salt tolerance has been reported for several species including *Eucalyptus camaldulensis* and *Eucalyptus grandis* and *Eucalyptus globulus* .

2. MATERIALS AND METHODS

The present study was conducted at the Experimental Farm of Krishi Vigyan Kendra at Jind in Haryana state of north-west India (29.03´ and 29.51´ north latitude and 75.53´ and 76.47´ east latitude). The study area represents a typical sub-tropical and semi-arid type of climate characterized by a dry and hot spring/early summer, a hot rainy season , a warm autumn and a cool winter. The average rainfall is about 500 mm with 80% rains received between June-September. The temperature starts rising from February onwards and exceeds 45°C in May or June. Three fields of different salinity levels were selected; their soils were analyzed up to a depth of 90 cm (Table 1).

Seeds of eight provenances of *Eucalyptus* (Table 2) were received from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia through Forest Research Institute, Dehradun (India) during 2001. Seeds of one local provenance of *Eucalyptus tereticornis* was collected from the trees growing at Jind (Haryana) for comparison. Seeds were sown in the mother beds in February 2001. Germination of seeds in the bed was above 90%. Seedlings were pricked out in polythene bags of 9" X 6" size at four leaf stage in June 2001. Each field was divided into

[1]Address for correspondence:
Forestry Department, CCS Haryana Agricultural University, Hisar-125004, Haryana (India) E-mail: optoky@gmail.com

two equal size sub-plots (replications) and each sub-plot was having 10 seedlings of each provenance following randomized block design. Therefore, for each provenance there were 20 plants in each salinity level.

Table 1. Soil properties of 3 fields of saline soils at Jind

Salinity level	pH (1:2)	Salt concentration (1:2) dS m^{-1}	Organic carbon (%)	Available P	Available K (kg ha^{-1})	Texture
S_1	8.2	0.45	0.45	36	345	Sandy-loam
S_2	7.8	2.16	0.23	25	594	Sandy
S_3	8.0	3.92	0.21	20	480	Sandy-loam

Table 2. Details of different provenances of *Eucalyptus*

	Seed lot	Species/ssp	Provenance
P_1	18276	*Eucalyptus camaldulensis* spp. *simulata*	Laura River, QLD
P_2	18548	*Eucalyptus camaldulensis* var. *Obtusa*	Emu Creek, Petford
P_3	18658	*Eucalyptus camaldulensis* var. *Obtusa*	Degrey River, WA
P_4	18912	*Eucalyptus camaldulensis* var. *Obtusa*	Gibb. River, WA
P_5	18943	*Eucalyptus camaldulensis* var. *Obtusa*	Wiluna, WA
P_6	19105	*Eucalyptus camaldulensis* var. *Obtusa*	Morehead River, QLD
P_7	20231	*Eucalyptus camaldulensis* var. *Obtusa*	Kennedy River, QLD
P_8	19095	*Eucalyptus tereticornis*	NW Mt. Molloy, QLD
P_9	Local	*Eucalyptus tereticornis*	Jind (Haryana)

Pits of 60x120cm (width x depth) size were prepared with a tractor drawn auger at a spacing of 1x1m in the field to transplant the seedlings. The pits were treated with chlorophyriphos @ 2 ml/litre to avoid the termite damage to the seedlings. The seedlings (30-35 cm in height) were transplanted in the fields of different salinities *i.e.* 0.45, 2.16 and 3.92 dSm^{-1} in June, 2001. After transplanting, the pits were filled with original soil.The plants were irrigated with bucket (10 litres/plant) for two months and with tubewell water having average EC of 4.2dS m^{-1}. Plants were regularly irrigated once in a month during winter and twice in a month during summer. Weeding and hoeing were done after every two months. The survival of plants was 100 per cent in the fields at three levels of salinities.

Total height, branch free height, collar diameter, number of branches, leaves, root length and dry biomass (oven dried at 80°C for 15 days) were recorded after 2 years on four plants of each provenance in one type of soil salinity. In total, 60 plants of each provenance were observed.

Statistical analysis:

The data were subjected to statistical analysis using Genstat 5 Release 3.2 (PC/Windows NT) Copyright 1995, Lawes Agricultural Trust (Rothamsted Experimental Station) to analyse the data.

3. RESULTS AND DISCUSSION

Plants of nine provenances survived well under 3 levels of salinities having no mortality. The growth of provenances P_2, P_1, P_7 and P_6 in terms of plant height & collar diameter (Table 3) was better than average (height & collar diameter) of the provenances, whereas provenance P_4, P_5, P_8 and P_9 performed poorly in all three soils except provenance P_3 in case of plant height. A wide range of variation existed among the provenances. Nevertheless, provenance P_8 performed better in plant height and collar diameter as compared to P_9 (a local provenance). The plant height and collar diameter reduced drastically as the salinity increased. The minimum reduction (21.7%) in plant height was observed in P_1 and the maximum reduction (32.6%) in provenance P_9 whereas minimum reduction in collar diameter was recorded in provenance P_2 (21.9%) and maximum in P_9 (36.2%) as the salinity increased from S_1 to S_3. The inhibitive effect of salinity on plant height and collar diameter was the greatest in provenances P_9, P_8, P_5 and P_4, whereas provenance P_2, P_1, P_7, and P_6 were resistant even at S_3 level of salinity. The differences in plant height & collar diameter in three levels of salinity for the nine provenances were statistically significant ($P<0.05$). The combine effect of salinity and provenances for plant height & collar diameter was found significant & non-significant ($P>0.05$),

respectively. Inhibition of plant growth may be due to the osmotic effect exerted by salt solutions reflected in the availability of soil moisture for plant growth and or to the accumulation of specific ions within the plant which may upset its normal metabolism or may be toxic in some other way (Marcar *et al.,* 1995).The early growth of seedlings is a critical phase because only a small reserve of accumulated assimilates and water are available to enable it to survive periods of stress. Plants take up inorganic chemicals from the soil solution and these include those essential for growth plus others, which are even toxic such as salts (Lambert and Turner, 2000).

The maximum clear bole height was recorded in P_2 (110.8 cm), while the minimum was in provenance P_9 (68.0 cm) at S_1 level of salinity (Table 3). The maximum root length (189.2 cm) was observed in provenance P_2 followed by P_7 (183.4 cm) and P_1 (183.2 cm) at salinity level S_1 while the minimum root length (140.8 cm) was in provenance P_9 (Table 3). In S_3 soils, the maximum root length (163.9 cm) was recorded in P_2 provenance followed by P_1 (160.9 cm), while the minimum (117 cm) was in provenance P_9. All the provenances and interaction of provenances and salinity differed significantly ($P<0.05$) at all salinity levels for clear bole height & root length. The ratio of root length/shoot length showed inverse relationship in all the provenances with increasing level of salinity indicating that more growth is allocated to root than shoot under stress conditions in plants. Lambert and Turner (2000) concluded that in case of high salinity there was a rapid uncontrolled uptake of salt by the roots of *Eucalyptus camaldulensis.*

The number of branches/plant ranged from 43 to 87 with maximum number in P_2 provenance and the minimum in P_9 at all levels of salinity (Table 3). The maximum reduction in branches occurred in S_3 salinity that ranged from 19 per cent in P_2 provenance to 28 per cent in P_9 as compared to the branches in S_1 soil. The maximum number of leaves/plant was observed in provenance P_2 followed by P_1 and least number was in provenance P_9 at all levels of salinities (Table 3). The number of leaves decreased with increasing level of salinity. The maximum reduction (39.8 %) was observed in P_9 provenance, while the minimum reduction (25%) was in P_2 provenance as the salinity increased. Differences among provenances were found to be statistically significant ($P<0.05$) at all levels of salinity for number of branches and leaves/plant. The combined effect of salinity and provenances for number of leaves was also significant ($P<0.05$).

Above-ground dry biomass ranged from 1.98 kg per plant in provenance P_9 to 3.41 kg per plant in P_2 at S_1 level of salinity (Table3). As the salinity increased the above-ground dry biomass decreased. Minimum reduction (11%, 12%, 13%) was in P_2, P_1 and P_7 provenances, respectively, while maximum reduction (23%) was observed in provenance P_9 as salinity increased. Significant differences were observed in provenance P_8 (*Eucalyptus tereticornis* from Australia) and P_9 (*Eucalyptus tereticornis* from local Indian source) for aboveground dry biomass. A wide range of significant variation existed among the provenances. The interaction of salinity and provenance was significant ($P<0.05$).

In the present study, plant growth was markedly reduced in all provenances as the salinity increased although significant variation existed among provenances except for collar diameter and number of branches. Similarly, root growth was also inversely related to salt concentration. High concentration of Na might have reduced Mg and micronutrient concentration in seedlings potentially affecting root and leaf growth. (Bhati and Singh, 2003).Inhibition of the uptake of essential nutrients may also contribute to the reduction of dry matter accumulation. Salt affected soils contain excessive concentration of either soluble salts or exchangeable sodium or both and impair plant growth. (Khajanchi Lal, 2007).

Several studies identified the best Australian provenance of *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* for commercial plantation on saline and non-saline soils. Two salt tolerant tree species, *Combretum quadrangulare* and *Eucalyptus camaldulensis* were compared in the field (NaCl salinity) and green house (non-saline) and it was suggested that *Eucalyptus camaldulensis* showed better salt-tolerance followed by *Eucalyptus tereticornis* (Marcar *et al.,* 2000).

Other scientists also revealed that *Eucalyptus camaldulensis* performed best on saline soil followed by *Eucalyptus tereticornis* while the local provenance gave the poorest growth. (Marcar *et al.*, 2003, Adams *et al.,* 2005). They also observed a wide range of variation among the Australian provenances. If total quantity of salts in the irrigation water is high enough, then availability of water to the plant is decreased and plant growth is affected. Saline soils cotains a concentration of neutral soluble salts sufficient to interfere with the growth of most plants (CSSRI, 2004). Scope for improvement in the productivity of *Eucalyptus* plantation in India through raising the stock from the seed from better-selected Australian natural stands (Boland,1980). He also suggested that *Eucalyptus tereticornis* and *Eucalyptus camaldulensis* are the species for most site in India provided the correct provenance are chosen. Results of the present trial also support the above view.

Table 3. Variation in growth among provenances in different levels of salinity

Salinity level	Provenance									Mean
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	
Plant height (cm)										
S_1	438.6	447.0	403.6	393.6	387.0	421.8	429.2	353.2	312.0	398.4
S_2	373.8	384.8	333.4	321.2	310.6	353.8	363.4	274.8	236.8	328.0
S_3	343.2	354.6	300.8	289.0	281.6	324.6	333.6	248.0	210.2	298.4
MEAN	385.2	395.4	345.9	334 .6	326.4	366 .7	375 .4	292 .0	253.0	
L.S.D	Provenance 2 .009, Salinity 1 .160, Provenance X Salinity 3 .480									
	Collar diameter (mm)									
S_1	87.7	91.1	76.1	77.8	74.1	86.6	83.8	65.9	55.5	77.6
S_2	74.7	78.3	61.9	64.4	59.4	72.6	70.2	52.5	41.7	64.0
S_3	68.0	71.1	58.2	59.7	55.3	66.4	65.7	46.7	35.4	58.5
MEAN	76 .8	80.2	65.4	67.3	62.9	75.2	73.2	55.0	44.2	
L.S.D	Provenance 1.134, Salinity 0.655, Provenance X Salinity 1.965									
	Clear-bole height (cm)									
S_1	100.0	110.8	93.4	92.4	86.0	98.4	95.8	79.0	68.0	91.5
S_2	84.7	95.0	73.6	70.0	66.8	82.4	80.8	59.2	50.8	73.7
S_3	78.6	86.2	65.4	61.2	55.1	74.4	74.6	47.2	39.8	64.7
MEAN	87.7	97.3	77.4	74.5	69.3	85.0	83.7	61.8	52.8	
L.S.D	Provenance 1.852, Salinity 1.069, Provenance X Salinity 3.208									
	Root length (cm)									
S_1	183.2	189.2	174.2	170.6	168.9	180.8	183.4	155.4	140.8	171.8
S_2	170.8	174.3	157.2	151.6	147.8	162.8	166.0	136.1	124.4	154.5
S_3	160.9	163.9	148.0	144.2	143.0	154.7	157.6	128.2	117.0	146.4
MEAN	171.6	175.8	159.8	155.4	153.2	166.1	169.0	139.9	127.4	
L.S.D	Provenance 1.507, Salinity 0.870, Provenance X Salinity 2.610									
	Branches/plant									
S_1	84.0	87.4	76.4	73.0	71.8	82.2	85.8	66.0	59.2	76.2
S_2	75.8	78.0	67.2	64.4	62.4	73.4	77.2	57.0	50.3	67.3
S_3	66.9	70.8	59.4	56.8	54.2	65.8	68.2	48.3	42.7	59.2
MEAN	75.5	78.7	67.6	64.7	62.8	73.8	77.0	57.1	50.7	
L.S.D	Provenance 1.098, Salinity 0.634, Provenance X Salinity 1.903									
	Leaves/plant									
S_1	6488	6980	4959	4401	3929	5836	6364	3226	2623	4978
S_2	5428	6052	4146	3674	3242	4914	5286	2530	1956	4136
S_3	4624	5234	3466	2921	2646	4207	4598	2024	1578	3478
MEAN	5514	6089	4190	3665	3272	4986	5416	2593	2052	
L.S.D	Provenance 54.35, Salinity 38.38, Provenance X Salinity 94.13									
	Above-ground dry biomass (Kg/plant)									
S_1	3.38	3.41	3.14	3.07	3.02	3.29	3.32	2.78	2.56	3.11
S_2	3.10	3.17	2.80	2.71	2.64	2.96	3.02	2.38	2.16	2.77
S_3	2.96	3.02	2.64	2.56	2.50	2.83	2.88	2.24	1.98	2.62
MEAN	3.14	3.20	2.86	2.78	2.72	3.03	3.08	2.47	2.23	
L.S.D	Provenance 0.0207, Salinity 0.0119, Provenance X Salinity 0.0358									

4. CONCLUSION

1. Wide range of variation in Australian seed sources and Indian local sources of *Eucalyptus tereticornis* was observed after two years of growth. The provenances of *Eucalyptus camaldulensis* from Emucreek, Petford and Laura River, Qld were superior in height, collar diameter and weight of plant, while lesser growth was observed in *Eucalyptus tereticornis* of Indian local source.
2. Among the Australian provenance, *Eucalyptus camaldulensis* was found to be more salt tolerant than *Eucalyptus tereticornis*. Australian provenance of *Eucalyptus tereticornis* was superior than Indian local source of this species.

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