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Survival and Growth Rate of Tree Saplings Planted under Salt Affected and Hypoxia Conditions

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Abstract: An Investigation was carried out to note the survival and growth rate of eucalyptus saplings planted in salt affected and hypoxia areas with plastic container bags totally removed compared to base only removed. The soil used was highly saline sodic in nature with wide variation in electrical conductivity of the saturation extract (EC_e), pH_s and sodium adsorption rate (SAR) within the field. At Basti Thabal, Pindi Bhattian site half acre of eucalyptus was transplanted with bigger bags, half acre with original smaller bags and three and half kanals of eucalyptus were transplanted at Jalalpur Kangra. Survival rate data was collected fifteen days after transplanting of tree seedlings. While height and girth data was recorded within 15-25 days after transplantation. The results showed that survival rate of eucalyptus was more than 82% at Jalalpur Kangra while survival rate was more in smaller bags than bigger bags at Pindi Bhattian site. The treatment effect remained nonsignificant. The gain in height was more than 84 cm in case of bigger bags at Pindi Bhattian, more than 73 cm at Jalalpur Kangra and more than 47 cm incase of smaller bags at Pindi Bhattian site. However treatment effect remained nonsignificant at all the sites. The gain in girth was more than 1.20 cm at Jalalpur Kangra, 0.90 cm in case of bigger bags while more than 0.34 cm in case of smaller bags at Pindi Bhattian site. The treatment effect was again nonsignificant at all the sites. In case of root proliferation, tap root length was more at Jalalpur Kangra and Pindi Bhattian (bigger bags) while lateral root length was more in case of smaller bags at Pindi Bhattian site and treatment was observed nonsignificant. There was a slight improvement in EC_e, pH_s and SAR of soil in the plough layer only indicating that salts were leached down only at Jalalpur Kangra. While at Pindi Bhattian site the EC_e, pH_s and SAR were increased due to the eroded soil by rain that brought salt to this low lying area. The results lead to conclude that eucalyptus plantation in salt affected soils has some ameliorative effects on soil chemical characteristics.

Key words: Salt affected soil, hypoxic conditions and eucalyptus growth parameters

Introduction

The salt-affected soils exist mostly under arid and semi arid climates, in more than 100 countries of all the continents except Antarctica. These soils cover about 955 million hectares (Szabolcs, 1991). In Pakistan salt-affected lands are estimated at about 6.8 m ha (Khan, 1998). Salinity and water logging (water table within 2 meters) co-exist in an area of 1.013 m ha (Rafiq, 1975).According to earlier estimates, out of 5.8 m ha salt-affected area, 3.16 m ha are within the canal command area (CCA) and 2.64 m ha are outside the CCA, while 2.93 m ha are cultivated (Rafiq, 1990) and half of salt-affected area is waste land (Qureshi, 1993). Salt affected soils can be categorized into slightly (S_1) moderately (S_2) highly (S_3) and very highly (S_4) affected depending upon degree of salinity/sodicity. The problem of salinity and water logging can be tackled through engineering and chemical reclamation approaches. The other approach (Saline Agriculture) that is based on growing salt tolerant plant species and use of saline waters to utilize salt-affected soils has been explored to a lesser extent (Qureshi and Barrett-Lennard, 1998).

Eucalyptus is one of many tree species that has been planted successfully under a variety of ecological conditions of Pakistan (Siddiqui *et al.*, 1984) and its survival up to 42 d Sm^{-1} in both aerobic and water-logged conditions (Van der Moezel *et al.*, 1988) have been reported. Moreover, in an adaptation trial near Faisalabad, *Eucalyptus camaldulensis* performed better than 11 other tree species over seven and a half years (Qureshi, 1993). The $CaCO_3$ in sodic/saline sodic soil could be mobilized to release Ca^{2+} through the root action of certain plants which are more tolerant to salinity/sodicity than the most field crops (Qadir *et al.*, 1992). There are some planting methods suited to salty soils. These are; help replace exchangeable sodium with calcium down to deeper soil layers, reclaim more soil volume for proper root growth, maintain low salinity in the root zone, reduce water application costs, help in site conservation of rainwater and at the same time alleviate water-logging problems, help in breaking the hard kankar layer if present, loosens the soil deep into the profile, encourage and train deep rooting and cost effective (Gupta *et al.*, 1995).

It has usually been observed that survival rate on affected soils is very low. Besides many other factors like poor management after transplantation, presence of a hard layer in the profile and salt level beyond the tolerance limit and placing method of saplings affect tree growth. Among the placement techniques one question "whether the plastic container is totally removed or base should only be cut" is always controversial. The foresters consider that leaving most of the plastic bag on the sapling unduly restricts its root growth and development in early days and hence its performance to maturity. The soil scientists counter this with the argument that the saplings are being placed in a hostile salt affected environment in the early stages of growth. The plastic container acts as a temporary membrane that prevents the migration of salts from the surroundings towards the plant roots. They claim that this protection can last until the sapling is established to withstand the prevailing salinity/sodicity level. Hence this issue needs to be investigated and resolved so that farmers should be encouraged to follow the best method. This study was started to answer the issue and establish a best-suited technique and to compare the effect of complete removal against cutting only the lower part of plastic bag of saplings on survival and growth rate in salt affected and water-logged soils.

Materials and Methods

The study was started in Pindi Bhattian at Basti Thabal (Ghabrica) site and in Sahiwal, Sargodha at Jalalpur Kangra site in December, 2000. All the fields were selected and handed over by IWASRI, which were ultra salt affected and not cultivated for many years. After taking possession of all the fields, these were levelled, chieselled and disking was done to break the hard pan and cultivation was done for pulverization of soils. All the fields were surveyed in detail for salinity/sodicity/water logging by digging pits up to 150 cm depth and nature of profiles were studied at each site. Further 30 samples from 15 selected locations from each site were also taken from 0-15 and 15-30 cm depths. The minimum, maximum and mean values of different soil characteristics are given in Tables 1 and 2. Ridges were drawn by ridger operated mechanically and then pits of 60x90 cm^2 size were dug manually at the shoulder of ridges except at Basti Thabal (Ghabrica) where in half acre pits of small size i.e. 45x45 cm^2 were dug on the shoulder of ridges. The pits were simply filled with silt (Bhall), which was free of salinity/sodicity. Eucalyptus trees were transplanted at both the sites I. e. Pindi Bhattian, Basti Thabal (Ghabrica) and Sahiwal, Sargodha, Jalalpur Kangra. There was three treatments which were;

T_1 = Plastic container bag totally removed, T_2 = Plastic container bag's base only removed and T_3 = Plastic container bag unremoved. At Pindi Bhattian, Basti Thabal (Ghabrica) in half acre, plastic bags of bigger size were used at the time of transplanting and in other half-acre original bags were used**.** Plant to plant distance was 6 feet while **r**ow to row distance was 10 feet. Number of plants in each replications were 33 and system of layout was randomized complete block design (RCBD) with three replications in case of bigger and smaller (original) bags**.** Total area used was one acre. In case of Sahiwal, Sargodha, Jalalpur Kangra site plastic bags of bigger size were used at the time of transplanting replacing the original small ones. Plant to plant distance was 5 feet while row to row distance was 10 feet. There were 20 plants in each replication. The system of layout was randomized complete block design (RCBD) with three replications and total area used was three and half kanals. It was kept in mind at the time of selection of plants that these should be of same age and size. Although size was variable in spite of best efforts. The plant height and girth data were recorded 15-25 days after transplanting when plants were established; plant survival rate was also noted. Same cultural practices were applied to all sites. At Jalalpur Kangra, water-logged conditions were created artificially by applying water to see the effect of water logging on growth of eucalyptus plants in salt affected heavy textured soil. Urea fertilizer was applied to plants twice in the whole course of study. First split was applied before on set of monsoon and 2nd after monsoon. The rate of application was 15 Kg urea $acre^{-1}$ in single split. Ridges at Basti Thabal (Ghabrica) were again drawn manually after monsoon season, because rainwater from surrounding area traveled to this site and disturbed the ridges and deposited eroded soil and salts collected from the area and increased the salt status of fields. At the end of the study, final plant height and girth data were recorded in December 2001 to calculate the difference in height and girth attained by the plants during the course of study. Root proliferation was also studied by uprooting the two plants from each treatment. The pits were dug up to the length of tap roots and lateral roots were also explored with Khurpa up to their length. The height of plants and length of roots were measured by meter rod while girth of plant at the base near soil surface was measured by vernier caliper.

Table 1: Original soil analyses of Basti Thabal (Ghabrica) and Jalalpur site

	Ec_e (dSm^{-1})			pH_s			Sodium adsorption ratio ($M\ mol^{-1}$)			Gypsum requirement (tons $acre^{-1}$)		
Tree	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Basti Thabal (Ghabrica)												
Eucalyptus	11.5	13.2	12.2	10.0	10.30	10.18	29.4	140.5	90.6	3.1	4.2	3.7
Jalalpur												
Eucalyptus	13.50	16.72	14.60	8.87	9.10	9.52	20.18	37.6	29.28	4.50	5.85	5.30
Guava	12.50	14.30	13.70	8.70	9.20	8.96	22.5	28.6	25.70	4.30	5.90	5.40

Mean is average of 15 figures.

Table 2: Profile characteristics of Pindi Bhattian site (Thabal Ghabrica)

Depth (cm)	pH_s	EC_e (dSm^{-1})	Sodium Adsorption Ratio ($m\ mol^{-1}$)^{½}	$CaCO_3$
0-15	10.10	12.80	120.80	Traces
15-30	9.89	11.50	107.84	Traces
30-60	9.58	6.97	71.62	Traces
60-90	9.22	6.81	57.45	Kankers
90-120	8.92	2.68	22.8	Kankers
120-150	8.91	2.51	20.17	Kankers
Profile characteristics of Sahiwal site Jalalpur Kangra				
0-15	8.91	15.61	33.45	Traces
15-30	8.95	13.50	30.60	Traces
30-60	8.99	10.90	26.52	Traces
60-90	9.01	10.82	25.91	Traces
90-120	9.03	7.30	22.33	Traces
120-150	9.01	6.50	21.65	Kankers

Table 3: Water analyses

Name of site	EC ($dS\ m^{-1}$)	Sodium Adsorption Ratio (SAR) ($m\ mol\ l^{-1}$)^{½}	Residual Sodium Carbonate (RSC)($me\ l^{-1}$)
Pindi Bhattian Basti Thabal (Ghabrica)	1.78	7.29	4.4
Sahiwal Jalalpur Kangra	1.45	7.59	3.1

All the soil analyses were done by using methods of Anonymous (1954). The plant height, girth and plant survival data were analyzed statistically by using randomized complete block design (Steel and Torrie, 1980).

Results

Soil characteristics: The fields allotted for the conduct of project at all the sites were highly saline sodic in nature with pure saline or sodic patches. The soil characteristics of Basti Thabal (Ghabrica) Pindi Bhattian site showed that EC_e ($dS\ m^{-1}$) ranged between 11.5 to 13.2 with a mean value of 12.2, pH_s ranged between 10.0 to 10.30 with a mean value of 10.18, SAR ($m\ moll^{-1}$)^{½} ranged between 29.4 to 140.5 with an average of 90.6 and gypsum requirement of this field ranged between 3.1-4.2 with an average of 3.7 tons $acre^{-1}$ (Table 1).

Mean is average of 15 figures. The second site was at Jalalpur Kangra, Sahiwal whose characteristics showed that the EC_e ($d\ Sm^{-1}$) remained from 13.50 to 16.72 with a mean value of 14.60, pH_s 8.87 to 9.10 with an average of 9.52, SAR ($m.mol\ l^{-1}$)^{½} ranged 20.18 to 37.6 with a mean value of 29.18 and gypsum requirement was 4.50 to 5.85 with an average of 5.30 tons $acre^{-1}$ (Table 1).

Profile study of Basti Thabal (Ghabrica) Pindi Bhattian site (Table 2) showed that pH_s, EC_e (dSm^{-1}) and SAR ($m.mol\ l^{-1}$)^{½} decreased continuously from surface to 150 cm depth. Calcium carbonates traces were also present at surface, which increased in concentrations with depth and at 60 cm kankers were observed up to 150 cm depth. This soil was calcareous saline sodic with sandy loam texture in upper 60 cm and beneath it there was compacted soil. The profile analysis of Jalalpur Kangra, Sahiwal area (Table 2) showed that pH_s increased from surface to 120 cm depth and then decreased while EC_e (dSm^{-1}) and SAR ($m\ moll^{-1}$)^{½} decreased with depth from surface to 150 cm. Calcium carbonates were also present in this field and kankers were observed at 150 cm depth. This soil was also calcareous saline sodic with clay loam texture.

Table 4: Survival of eucalyptus plants at Basti Thabal (Ghabrica) small and bigger bags and Jalalpur Kangra

Replications	T1	T2	T3
	Basti Thabal (Ghabrica) small bags		
R_1	31 (93.94)	29 (87.88)	32 (96.97)
R_2	25 (75.76)	22 (66.67)	25 (75.76)
R_3	16 (48.48)	20 (60.61)	20 (60.61)
Mean	24 (72.73)	23.67 (77.73)	25.67 (77.79)
	Basti Thabal (Ghabrica) bigger bags		
R_1	23 (69.70)	13 (39.39)	12 (36.36)
R_2	23 (69.70)	29 (87.88)	26 (78.79)
R_3	20 (60.61)	21 (63.64)	23 (69.70)
R_4	25 (75.76)	22 (66.67)	28 (84.85)
Mean	22.75 (68.94)	21.25 (64.39)	22.25 (67.42)
	Jalalpur Kangra		
R_1	18 (90)	18 (90)	16 (80)
R_2	14 (70)	19 (95)	15 (75)
R_3	19 (95)	17 (85)	16 (80)
R_4	20 (100)	19 (95)	19 (95)
Mean	17.75 (88.75)	18.25 (91.25)	16.5 (82.5)

Figures within parenthesis are percentage of survival Plant height of eucalyptus

Table 5: Gain in eucalyptus plant height (cm) at Basti Thabal (Ghabrica) small and bigger bags and at Jalalpur Kangra

Replication	T_1	T_2	T_3
	Basti Thabal (Ghabrica) small bags		
R_1	60.1	124.6	99.7
R_2	45.3	61.8	57.8
R_3	37.5	34.5	38.2
Mean	47.63	73.63	65.23
	Basti Thabal (Ghabrica) bigger bags		
R_1	79.20	50.9	48.1
R_2	98.2	90.0	64.1
R_3	86.2	113.3	116.5
R_4	121.7	92.5	108.3
Mean	96.325	86.675	84.25
	Jalalpur Kangra		
R_1	85.9	67.6	68.9
R_2	64.8	65.8	66.9
R_3	56.4	91.3	90.9
R_4	119.7	90.6	66.7
Mean	81.7	78.825	73.35

(Treatments)

Characteristics of irrigation waters: Brackish ground water was available at all the sites. The water used for growing of Eucalyptus plants at Basti Thabal (ghabrica) Pindi Bhattian site have EC 1.780 dS cm^{-1}, Sodium Adsorption Ratio (SAR) 7.29 (m mol l^{-1})^{½} and residual sodium carbonate(RSC) 4.4 me l^{-1}. The tube well water used at Jalalpur Kangra, Sahiwal project area have EC 1.450 dS cm^{-1}, SAR 7.59 (m.mol l^{-1})^{½} and RSC 3.1 me l^{-1} (Table 3).

Survival of eucalyptus plants: Eucalyptus was transplanted at Basti Thabal (Ghabrica) and Jalalpur Kangra site. Survival rate of Eucalyptus plants at all sites was recorded 15 days after transplanting of plants (Table 4). The effect of treatment was non-significant at all the sites. At Jalalpur Kangra the survival rate remained between 91.25 (bag's base only removed) to 82.5% (bag unremoved). At Basti Thabal (ghabrica), the survival rate after Monsoon was again recorded because many of plants were damaged by the saltish soil transported from surroundings by rainwater to this site (Table 4). The plants survival rate was more in smaller bags, which ranged from 77.79 (bag unremoved) to 71.01% (bag's base on (removed) than bigger bags where it ranged between 68.94 (bag totally removed) to 64.39 % (bag's base only removed).

Plant height of eucalyptus was recorded first time after 15-25 days of transplanting and then in December, 2001 after about 9 months at the end of study at all the sites i.e. Basti Thabal (Ghabrica) and Jalalpur Kangra. Difference between final plant height and initial were calculated to determine the gain in height of plants attained during the course of study (Table 5). The effect of treatment remained non significant at all the sites. The maximum gain in eucalyptus plant height was recorded at Basti Thabal (Ghabrica) bigger bags which ranged 84.25 (bag unremoved) to 96.32 cm (bag totally removed). Then maximum gain in height was recorded at Jalalpur Kangra which was 73.35 (bag unremoved) to 81.7 cm (bag totally removed). The least maximum gain in height was observed at Basti Thabal (Ghabrica) small bags, which ranged between 47.63 (bag totally removed) to 73.63 cm (bag's base only removed). Although the treatment effect was non-significant on gain in plant height attained by eucalyptus during 9 months period yet it was interesting to note that bag totally removed treatment gave the maximum gain in plant height at all the sites though non significantly except Basti Thabal (Ghabrica) small bags. The reason for this site may be the eroded soil and salt brought here by rain water from surrounding area resulting in increase of salinity/sodicity level and more damage to bag totally removed plants compared to bag's base or bag unremoved plant because bag protected them from direct effect of high concentration of salts.

Girth of eucalyptus plants: The girth of eucalyptus plants at all sites was recorded initially after 15-25 days of transplanting with the help of vernier caliper. The final girth of plants was recorded in the month of December 2001 after about 9 months at the end of project. The gain in girth of eucalyptus plants was calculated. The data (Table 6) showed that difference in all the treatments were at par statistically at all the sites. However, maximum gain in girth was recorded at Basti Thabal (bigger bags) which ranged between 0.90 (bag's base only removed) to 0.945 cm (bag totally removed). After that maximum gain in girth was recorded at Jalalpur Kangra site where it ranged between 0.805 (bag unremoved) to 0.923 cm (bag totally removed). The least maximum gain in girth was observed at Basti Thabal Ghabrica (small bag's), which was from 0.347 (bag totally removed) to 0.727 cm (bag's base only removed).

Roots proliferation of eucalyptus plants: Roots proliferation was also studied at all the sites by selecting two eucalyptus plants in each treatment (Table 7). The pits were dug up to the length of tap root vertically. Among the lateral roots, one root was selected and exposed with the help of "Khurpa" to its length. The root length at Basti Thabal (Ghabrica) smaller bag's measured longer than bigger bags plants although height of bigger bags plants was greater than smaller bags. In case of

Table 6: Gain in eucalyptus plant girth (cm) at Basti Thabal (Ghabrica) small and bigger bags and at Jalalpur Kangra

Replication	T1	T2	T3
	Basti Thabal (Ghabrica) small bags		
R1	0.65	1.63	1.06
R2	0.29	0.37	0.46
R3	0.10	0.18	0.20
Mean	0.347	0.727	0.573
	Basti Thabal (Ghabrica) bigger bags		
R1	0.78	0.33	0.50
R2	0.92	0.99	0.65
R3	0.79	1.22	1.28
R4	1.29	1.06	1.24
Mean	0.945	0.90	0.918
	Jalalpur Kangra		
R1	1.13	0.56	0.68
R2	0.50	0.67	0.73
R3	0.62	1.24	0.98
R4	1.44	1.02	0.83
Mean	0.923	0.873	0.805

Table 7: Roots proliferation of eucalyptus plants at Basti Thabal (Ghabrica) and Jalalpur Kangra

Treatments	Basti Thabal (Ghabrica) (Smaller bags)		Basti Thabal (Ghbrica) (Bigger Bags)		Jalalpur Kangra	
	Top root (cm)	Lateral root (cm)	Top root (cm)	Lateral root (cm)	Top root (cm)	Litral root (cm)
Bag totally removed	170	228	23	276	60	40
Bag's base only removed	133	323	103	70	70	80
Bag unremoved	130	115	36	62.3	125	40

Table 8: Soil analyses at Basti Thabal (Ghabrica) and Jalalpur Kangra sites (after 9 months)

Tree	EC_e (dSm^{-1})	pH_s	SAR $(mmol\ l^{-1})^{1/2}$	G.R.(tacre^{-1} 6″)
	Basti Thabal (Ghabrica)			
Eucalyptus (Small bags)	20.5-25.6	10.62-10.72	27.46-139.6	3.15-4.25
Eucalyptus (bigger bags)	11.68-26.7	9.97-10.25	16.31-140.5	3.10-4.10
	Jalalpur Kangra			
Eucalyptus	10.54-12.11	8.63-9.10	88.5-34.93	4.25-5.60

Changes in these parameters were also noted at Basti Thabal. It was further noted that ECe, pHs and SAR were continuously decreased (Table 10) at both sites i.e. bigger and small bags sites.

smaller bags the length of tap root ranged between 130 (bag unremoved) to 170 cm (bag totally removed) while length of lateral roots remained between 115 (bag unremoved) to 323 cm (bag's base only removed). In case of bigger bags, the length of tap root varied from 23 (bag totally removed) to 103 cm (bag's base only removed) while lateral roots ranged between 62.3 (bag unremoved) to 276 cm (bag totally removed). In case of Jalalpur Kangra tap roots were found between 60 (bag totally removed) to 125 cm (bag unremoved) while lateral roots 40 (bag totally/unremoved) to 80 cm (bag's base only removed). These results further indicated that at Basti Thabal (Ghabrica) both bigger and smaller bags produced tap root length shorter compared to lateral roots while at Jalalpur Kangra site tap roots were longer than lateral roots. The reason might be that at Basti Thabal (Ghabrica) after 60 cm, there was hard calcite clay mixed layers in which root penetration was difficult. Due to which plants established lateral roots in search of water and nutrients in comparatively porous horizontal medium. In case of Jalalpur Kangra site although the texture was heavy (clay loam) yet no hard layer was found, so plants established longer tap roots which is main root vertically for obtaining water and nutrients instead of lateral roots.

Table 9: Soil analysis of the profile at Pindi Bhattian Basti Thabal (Ghabrica) site (Eucalyptus plants) small and bigger bags and Jalalpur Kangra

Depth (cm)	pH_s	EC_e(dSm^{-1})	SAR $(m.mol\ l^{-1})^{1/2}$	$CaCO_3$
	Basti Thabal (Ghabrica) small bags			
0-15	10.67	24.3	99.40	Traces
15-30	10.48	21.9	87.66	Traces
30-60	10.21	11.50	66.70	Traces
60-90	9.20	7.60	44.88	Kankers
90-120	9.10	7.80	47.60	Kankers
120-150	9.01	6.85	39.41	Kankers
	Basti Thabal (Ghabrica) bigger bags			
0-15	10.47	19.60	88.90	Traces
15-30	10.41	17.67	81.77	Traces
30-60	10.22	10.44	60.17	Traces
60-90	9.16	6.90	41.41	Kankers
90-120	9.03	6.60	38.17	Kankers
120-150	8.89	6.41	33.45	Kankers
	Jalalpur Kangra			
0-15	8.88	10.13	30.95	Traces
15-30	8.90	9.64	29.62	Traces
30-60	8.93	8.67	27.65	Traces
60-90	8.99	10.21	31.64	Traces
90-120	9.04	8.40	28.67	Traces
120-150	9.03	8.70	29.41	Kankers

The post study analysis showed that there was a slight decrease in EC_e, pH_s, SAR and gypsum requirement at Jalalpur Kangra site (Table 8) while at Basti Thabal (Ghabrica) these parameters increased (Table 8). The reason for decrease of these parameters might be that EC_e was decreased due to shading effect (reduced capillary action) in eucalyptus plants field at Jalalpur Kangra. The decrease in pH and SAR might be due to root action i.e. more development of roots and their exudates which infect enhanced solubility of precipitated calcium as calcium sulphate/calcium bicarbonate or calcium carbonate that replaced Na ions simultaneously resulted in lowering of soil pH and SAR. The reason for increase of these soil parameters at Basti Thabal (Ghabrica) is the addition of salts by rainwater, which eroded soil and salts from the surrounding area to this site, resultantly increased ECe, pH_s, SAR and gypsum requirement of this site. A minor change in soil EC_e and SAR up to 120 cm depths were noted at Jalalpur Kangra site (Table 9). Changes in pH_s was negligible.

Discussion

The results regarding height, girth and root length are in accordance with earlier studies conducted on Eucalyptus (Qureshi**,** 1993; Marcar *et al*., 1995). The typical response of plants to salts in the root medium is the growth inhibition (Flowers *et al.,* 1991). As salt concentration increases above a threshold level, both the rate of growth and the vigour of plant species are progressively decreased; shoot growth is more severely affected than root (Lone, 1988; Aslam *et al*., 1991).

The salinity/sodicity level of Basti Thabal (Ghabrica) was increased by eroded soil and salts brought by rainwater to this site resulting in higher mortality, stunted growth (height and girth was reduced). However Van der Moezel and Bell (1990) observed that *Eucalyptus camaldulensis* provenances had a tolerance to water salinities between 1000-4200 u Sm^{-1} and can with stand EC_e of soil over 30 d Sm^{-1} (Choukr-Allah, 1996).

There are a number of plants, soil, water and environmental factors including temperature and humidity which determine growth behavior of a plant under salt affected conditions (Aslam *et al*., 1993, 1996). Deterioration of soil structure because of dispersion of soil particles in saline sodic/sodic soils is a common phenomenon; crusting of surface soils under such conditions aggravate the adverse effect of sodicity and may result in poor seed germination, whereas occurrence of compact layer at lower horizon in saline-sodic/sodic soil because of downward clay movement is not conducive for root development. In salt affected soils plant often experiences a number of stresses including compaction therefore, their growth in this field is not uniform. In medium to heavy textured salt-affected waste lands saturated with Na and not cultivated to crops for a longer period, movement of surface clay to lower horizons through pores with rain water is a common phenomenon. This is specifically true when these soils are exposed to natural environmental factors for more than a decade, presence of compact layers because of down ward movement of clay increase denseness and compaction in the lower horizon. Because of the compact layer, existing at lower horizon, these soils when brought under for growing crops/trees which possess high degree of salt tolerance and are able to grow on salt affected soils also fail to give satisfactory performance because of poor soil structure (Nawaz, 1993). In the case of present study less root proliferation was observed in compacted as compared to non-compacted salt affected soils. This clearly demonstrates the negative effects of soil compaction on root penetration (Marschner, 1995). The plant roots subjected to poor aeration because of less gaseous exchange and resultant low uptake of nutrients and water (Martinez *et al*., 1992) this is specifically true if compact soil is wet (Kirkegaard *et.al*., 1992). Not only root length but plant height was also reduced. As was observed at Jalalpur Kangra site. It is believed that the root under compact soil environment perhaps was not able to transport appreciable amounts of water and nutrients to shoot, which ultimately resulted in shorter plants. Salinity in combination with water logging may have a much more deleterious effect on plant performance than the individual effect of salinity or water logging. Anaerobiosis caused by water-logging interferes with the mechanisms of salt tolerance which usually operate in aerobic conditions As a consequence plants selected to grow on salt affected soil (because of their ability to cope with salinity) may not be able to grow and survive in a saline environment subjected to periodic water- logging. In the flood sensitive species, root and shoot growth are usually quickly inhibited on flooding (Davies and Hillman, 1988) as was observed at Jalalpur Kangra. Marcar (1993) advocated that *E.camaldulensis* showed least reduction in growth and symptom development under saline, water-logged and saline-water- logged conditions. Although plant height increased with time under all adverse conditions, this trend was not evident under saline water-logged treatment. A number of studies report similar results regarding growth reduction in Eucalyptus species after fifth week of salinity water-logging stress (Van der Moezel *et al*., 1988).

The plant stand was not uniform at both Basti Thabal (Ghabrica) and Jalalpur Kangra sites where a very large variation in tree height and girth was noted. The possible reasons observed were the soil under poor plants was more compacted and hard as compared to soil under the good plants and this could be one of the reasons for poor growth, since compact soil has negative effect on nutrient availability and root penetration (Borges *et al*., 1986). Sodic soils which have high relative Na content can impede root growth due to poor aeration, high soil strength and may also create nutritional disorders/ imbalances because of elevated soil pH (Marcar and Crawford, 1996). Soil under the poor plants had similar conditions i.e. high pHs and sodicity (SAR), which ultimately resulted in severe reduction of growth in case of very poor plants (Singh and Yadav, 1985).

Another possible reason of less growth could be the ion excess in case of poor plants as opposed to good and moderate plants at both sites. This hypothesis is further strengthened when overall growth of plats at site Basti Thabal (Ghabrica) was found inferior to plants grown at Jalalpur Kangra site. Even within same field at Basti Thabal (Ghabrica) good and moderate plants were found growing progressively with time whereas, the poor plants were just surviving. Resulting in less height, girth and branches on these trees. Similar adverse effects of salinity/sodicity on plant growth are very well documented in the literature (Qureshi, 1993; Marcar and Crawford, 1996).

Ameliorative effects of Eucalyptus plantation on soil characteristics were also monitored. A minor decline in soil salinity/sodicity (EC_e, SAR and pHs) was observed after 9 months of plantation on these salt affected soils. The reduction in soil salinity could be attributed to decrease surface evaporation because of vegetative cover, consequently reverting the process of upward movement of salts through capillary fringe (Qureshi, 1993). Similar changes in soil pH were recorded by Hussain and Gull (1991). Good plants caused high reduction in soil pH through root action. Not only soil SAR was lowered, infiltration capacity under healthy plants became better which could be due to more development of roots and enhanced root exudates (Dormaar, 1988). Root exudates perhaps resulted in an increased solubility of soil Ca^{2+}, precipitated as calcium sulphate/calcium bicarbonate or calcium carbonate that replaced Na ions and simultaneously resulted in improvement of physical conditions of the soil (Shah, 1992; Hussain and Gul, 1991). The results lead to conclude that survival and growth rate of tree samplings planted under salt affected and hypoxia conditions can be increased by changing the rooting medium with silt (free of salts). There are also some ameliorative effects of Eucalyptus plantation on soil characteristics.

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