IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Growth Behaviour of Three Species of Rajasthan in Relation to Salinity and Changes in Ionic Composition of Leaves

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Abstract

For rehabilitation of soils rendered barren owing to salinity, adaptation to site conditions and multiple uses form important criteria of tree selection. Seeds of preferred multipurpose tree species *Acacia nilotica, Albizzia lebbeck*,and *Prosopis cineraria* were sown in pots to study the growth behavior of seedlings during the initial year of establishment. Germination, Survival, height, stem diameter and biomass production were determined at three levels of saline water irrigation. *Acacia nilotica* showed moderate tolerance under medium levels of salinity of irrigation water whereas *Albizzia lebbeck* and *Prosopis cineraria* showed moderate tolerance upto low salinity level. Under different levels of saline water irrigation response breadth for height growth and total biomass was widest for *A. nilotica* followed by *A. lebbeck*. This pattern indicates that *A. nilotica* can grow in wider range of saline water conditions compared to other two species. The leaf sodium, calcium and magnesium content increased with increasing salinity conditions in *Albizzia lebbeck* and *Acacia nilotica* being maximum in *Acacia nilotica,* however K, Ca and Mg content decreased in *Prosopis cineraria* with increasing salinity levels. The ratios of Na/K, Na/Ca and Na/Mg increased with increasing salinity levels but in case of *Acacia nilotica* Na/ Mg increased upto medium level and decreased thereafter. At the end of experiment, the soil Na^+, K^+, Ca^+ and Mg^+ content increased with increasing salinity levels and was maximum in *Prosopis cineraria,* whereas the organic carbon content in the soil was maximum under *Albizzia lebbeck* at highest level of salinity of irrigation water. These results suggests that the growth of *Acacia nilotica* and *Prosopis cineraria* seedlings was greatly promoted under the stress conditions of salinity and resulting much more balanced growth in terms of biomass, which is vital for plants growing in the harsh arid environments where concentration of salts is much more.

Keywords: Adaptation, Barren, Germination, Harsh, Survival, Stress

Introduction

On a world scale, there is an area of about 380 million hectares that is potentially usable for agriculture, but where production is severely restricted by salinity (Flowers, 1977). A large area in the world (952 million ha) is affected with salinity or alkalinity or both (Gupta and Gupta, 1984). In India nearly 9.38 million ha area is occupied by salt-affected soils out of which 5.5 million ha are saline soils (including coastal) .In India, the deterioration of agricultural productive lands in the arid and semi arid zones can be directly attributed to the evolution of salinity (Pieri et al., 1996). In India ground water is major source of irrigation to supplement the water requirement of plants in arid and semiarid regions but the quality of majority ground water encountered in these regions is invariably poor (Yadav, 1980). A part from such lands that were adversely affected with arid climate or scarcity of water, lands adversely affected with excess of salts (NaCl) were called as 'Reh' by geologists in mid nineteenth century.

Application of such poor quality water makes the soil saline in nature which affects the plant growth adversely. These saline soils are a wide spread element of the landscapes of arid zones and soil salinization is one of the main processes responsible for the degradation and reduced productivity of agricultural lands in these regions. Poor infiltration and drainage practices and expansion of irrigated agriculture lands in arid zones with huge evaporation rates are other reasons of accumulation of salinity. Saline soils, predominantly have chlorides and sulfates of Na, Ca and Mg, a saturation paste pH of <8.2 and the electrical conductivity of saturation extracts of saline soil is generally more than 4 dsm^{-1} at $25^{O}C$. Visual symptoms (leaf burn, necrosis and defoliation), sometimes occur particularly in woody species. The threefold problems of salinity are low soil water potential leading to symptoms of water stress, specific ions (Na, Cl) may be toxic, there by leading to ion imbalance (mainly calcium), leading to deficiency symptoms (Lambers *et al*., 1998).

To reclaim such degraded land of arid areas investigations on methodology and monitoring of salt affected soils is required. Afforestation under such situations can be the most remunerative proposition to improve local economy by using multipurpose tree species and establishing them with the available saline water, because forest species are know to tolerate more salt stress in comparison to the agricultural field crops and are found to grow even naturally on the salt affected soils. It is of vital importance to know precisely the composition of ground water, its effects on soil properties and plant growth, the tolerance limits of important trees and to develop suitable management practices for using salt water for irrigation without much adverse effects on soil, for deciding the suitability of species for plantation on such sites. Therefore the use of trees for salinity control, fuelwood and fodder production and environmental benefits has been a subject of renewed interest. These tree species are not only tolerant to salt and a drought stresses but also are well adapted to the local agroclimate. This has immense significance in the present situation, when there is a burgeoning demand for protection of natural resources (land, soil and water).Keeping these facts in view, the present investigations have been undertaken. The objective of this study was to evaluate the tolerance limits of saline irrigation water of the three tree species *Albizzia lebbeck, Acacia nilotica* and *Prosopis cineraria* at establishment stage through various growth parameters.

Materials and Methods

Soil used in the experiment was sandy loam with sand 89.6% silt 7.4% and clay 3%. The physio-chemical analysis of soil was done before sowing the seeds in pots which had pH of 8, ECe 1.03 dsm-1; Na 15.3 m.e.l^{-1}; K 0.2 m.e.l^{-1}; Ca 1.1 m.e.l^{-1}; Mg 1.23 m.e.l^{-1}; Zn 0.40 ppm; Fe 4.72 ppm; Cu 0.24 ppm; Mn 5.74 ppm and the available N, P and K were 169 Kg $ha^{-1,}$ 12 kg ha^{-1} and 275 kg ha^{-1} respectively, ESP was 17.2 and organic carbon content was 2.5g kg^{-1}. Healthy seeds of three multipurpose tree species of *Albizzia lebbeck*, *Acacia nilotica* and *Prosopis cineraria* soaked in distilled water overnight, were sown directly in 90 experimental earthen glazed pots at the rate of 10 seed per pot. Potting medium consisted of 10 kg normal well pulverized sandy loam soil. Experiment was conducted in three parts, in first part of experiment, saline irrigation water used was of three electrical conductivity levels, 0.52 $dsm^{-1,}$ 4 dsm^{-1} and 8 dsm^{-1}. Saline water of 4 dsm^{-1} was synthesized by equal mixing of deionized water and underground water which had EC = 8 dsm^{-1}. These levels are referred to as low, S_0 (0.52 dsm-^{1}), medium, S_1 (4 dsm^{-1}) and high, S_2 (8 dsm^{-1}) levels of salinity, having the chemical composition as given in Table 1.The experiments were initiated in the month of August and the duration of the experiments were twelve months. The experiments were laid out in randomized block design with three replications.

Table 1 : Chemical composition of underground water used with different levels of salinity

Water quality	EC_{iw}	pH_{iw}	Na (m.e.L^{-1})	Ca (m.e.L^{-1})	Mg (m.e.L^{-1})	Cl (m.e.L^{-1})	HCO_3 (m.e.L^{-1})	CO_3 (*m.e.L^{-1}*)	*RSC (m.e.L^{-1})*	SAR (mmol/L) 1/2
Good quality (S_0)	0.52	7.6	2.4	3.2	0.54	2.5	1.5	0.81	Nil	1.76
Marginal ly saline (S_1)	4.0	7.5	13.2	7	3	9.0	2.3	0.75	Nil	5.90
Saline (S_2)	8.0	7.5	26.2	14	6	18.0	5.0	0.35	Nil	8.29

BAW= best available water,EC_{iw} =electrical conductivity of irrigation water,RSC=residual sodium carbonate,SAR=sodium absorption ratio

The germination and survival percentage of the seedlings produced were evaluated. When the seedlings attained a height of 9-10cm, they were thinned to retain only one healthy seedling in each pot and care was taken to select seedlings of almost equal height. Observations for growth parameters including plant height, stem-diameter, number of leaves and leaf area were recorded monthly.At the termination of the experiment, whole

plant was uprooted from the soil, washed thoroughly with distilled water and dried in the air. Average fresh weight and oven dried weight of plants were recorded. Leaf samples were analyzed for different ions (Na, K, Ca and Mg) following standard procedures (Jackson, 1967). Soil samples at the end of experiment were analyzed to access the chemical changes that occurred due to irrigation with saline / alkaline water (Jackson, 1967).With the help of the above data, specific leaf area (SLA, Evans 1972), sturdiness (Chauhan and Sharma, 1997) and measure of response breadth (B) (Levins, 1968) were determined. Salt tolerance index (Wu and Lin, 1994)=(mean value of plant height plus mean value of salt treated plant biomass/mean value of plant height plus mean value of control plant biomass) X 100 was also determined for each species and three salt categories were assigned according to their tolerance indices:
i) Above 90% = high; ii) Above 50% and less than 90% = moderate, iii)Less than 50% = low.

Statistical Analysis: Regression analysis was done for different growth parameters with different salinity (Senedecor and Cochron, 1973).

Results

Germination and Survival percentage: Increase in salinity delayed the initiation of seed germination and decreased survival rate in all species. Germination and survival percentage was maximum (90% and 73% respectively) in *P. cineraria* at low level of salinity and minimum (34% and 20% respectively) in *A. lebbeck* under high level of salinity. The maximum reduction in germination and survival at highest level of salinity was in case of *A. lebbeck* (61% and 64% respectively) and minimum in *A. nilotica* (9% and 4% respectively), Table 6. Percent germination and survival of the two species negatively correlated to salinity, however in case of *A. nilotica* the correlation was nonsignificant (Table 7).

Growth parameters: In *A. lebbeck* and *P. cineraria*, the values of height growth of one year old seedlings decreased as the salinity level increased up to high salinity level whereas in case of A. nilotica the maximum values were recorded at medium level of salinity. Comparison between the three species indicated that *A. nilotica* attained comparatively greater height growth (100 cm) at medium salinity level than others (Fig 1).The maximum reduction in height was in *P.cineraria* (68%) at S_2 level and minimum in *A.nilotica* (18%) at S_2 level (Table 6). Height growth of all the species was negatively correlated to salinity, however in case of *A. nilotica* correlation was non-significant (Table 7). The steepest slope of the regression for height growth was in *P. cineraria* and the most gentle slope was recorded in *A. nilotica*. All the species attained less height growth in the initial months from September to February but continuous growth was observed from February to August in all the species . At highest salinity level, the maximum **stem-diameter** was recorded in *A. nilotica* (6.1 mm) and minimum in *P. cineraria* (3.0 mm). Stem-diameter of all the species was also negatively correlated to salinity though in case of *A. nilotica* correlation was non-significant. In *A. lebbeck* and *P. cineraria*, the values of total **leaf production** of one year old seedlings decreased as the salinity level increased up to high level whereas in *A. nilotica* the maximum values were recorded at medium level of salinity. Shedding of leaves was observed in all the species at S_1 and S_2 levels during February to May, 2003 (Fig 2). The maximum leaf fall was observed under high salinity levels in all the species but the maximum leaf drop occurred in case of *A. lebbeck*. At highest salinity level, the leaf area was maximum in *A. lebbeck* (1.41 cm2) and minimum in *A. nilotica* and *P. cineraria* (0.20 cm^2). The root length was maximum in *A. nilotica* (75 cm) at medium level of salinity and minimum in *A. lebbeck* (27 cm) at high level of salinity though at highest salinity level the root spread was maximum in *A. lebbeck* (5.9 cm) and minimum in *P. cineraria* (2.3 cm), Table 3.

Table 3: Growth parameters of the species at varying levels of saline water

Species	Salinity levels	Germination (%)	Survival (%)	Height (cm)	Stem diameter (mm)	Leaf area (cm^2)	Root length (cm)	Root spread
A. lebbeck	S_0	86	55	64	13.6	1.68	54	8.5
	S_1	58	43	50	7.9	1.58	38	7.1
	S_2	34	20	34	4.1	1.41	27	5.9

A. nilotica	S_0	66	50	79	7.0	0.23	63	3.0
	S_1	79	65	100	8.0	0.21	75	3.5
	S_2	60	48	65	6.1	0.20	41	2.5
P. cineraria	S_0	90	73	84	6.0	0.26	73	3.4
	S_1	75	64	45	4.2	0.24	66	3.3
	S_2	62	43	27	3.0	0.20	39	2.3

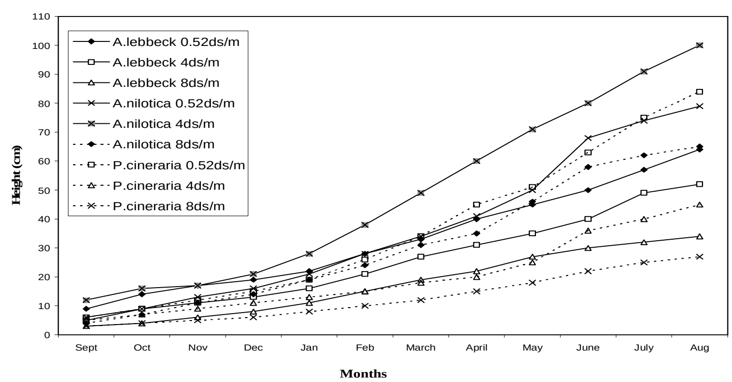

Figure 1 : Height growth of the species under different salinity levels

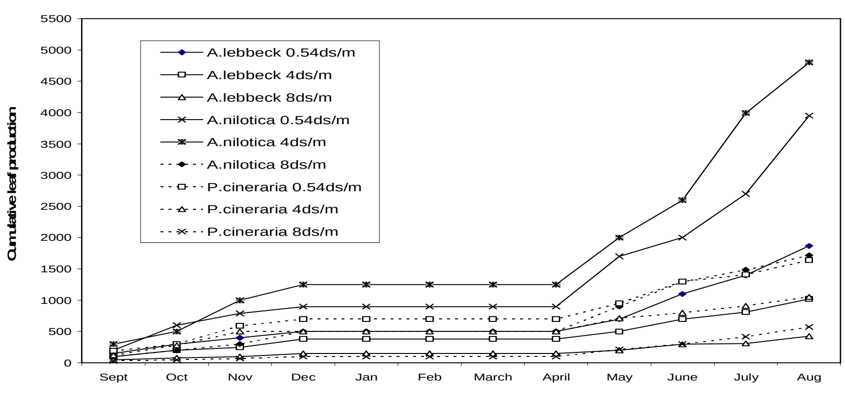

Figure 2 : Cumulative leaf production of the species under different salinity levels

Total seedling dry mass and ratios: The values of total seedling dry weight of three species under different salinity levels at the culmination of experiment are given in Table 4. Biomass production reduced in two of the species at S_2 level and only in case of *A. nilotica* maximum value was observed at medium level (41.37 g). The maximum reduction at S_2 level was in *A.lebbeck* (75%) and minimum in *A.nilotica* (13%). Total biomass of *A.lebbeck* and *P.cineraria* was significantly negatively correlated to salinity at $p<0.05$, however in case of *A. nilotica* correlation was non significant (Table 7). The proportional allocation of biomass into different components of the three species at different salinity levels is depicted in Fig 3. It is evident from figure that allocation to root component was maximum in *P. cineraria* and to stem and leaf component was higher in *A. nilotica*. In *P. cineraria* with increase in salinity, higher allocation to root component was recorded.

Table 4 : Other growth parameters and ratios of the species under different levels of saline water irrigation

Tree species	Salinity levels	Root wt (g)	Shoot wt (g)	Total biomass (g)	Root : Shoot ratio	Leaf : Stem ratio	Specific leaf area (cm^2 g^{-1})	Height :Diameter ratio
A.lebbeck	S_0	24.71	26.95	51.66	0.92	0.92	0.13	4.71
	S_1	19.64	21.56	41.20	0.91	0.87	0.16	6.32
	S_2	13.97	15.52	29.49	0.90	0.80	0.19	8.39
A.nilotica	S_0	13.78	19.95	33.73	0.70	0.99	0.02	11.0
	S_1	16.67	24.70	41.37	0.67	0.86	0.01	12.5
	S_2	12.15	17.05	29.20	0.71	0.88	0.03	10.6
P.cineraria	S_0	17.69	15.02	32.71	1.18	0.84	0.04	14.0
	S_1	11.07	9.15	20.22	1.21	0.79	0.06	10.7
	S_2	7.75	6.06	13.81	1.28	0.70	0.08	9.0

Number of nodules decreased with increasing salinity levels. At highest salinity level, the maximum number of nodules was recorded in *A.lebbeck* (10) but in case of *A.nilotica* there was no nodule formation. Dry weight of nodules followed the same pattern as that of number of nodules (Table 5).The maximum **root: shoot ratio** and minimum **leaf: stem ratio** was recorded in *P. cineraria* at S_2 level (1.28 and 0.70 respectively). The minimum root: shoot ratio and maximum leaf: stem ratio was recorded in *A.nilotica* at S_2 level (0.67) and S_1 level (0.99) respectively. **Specific leaf area** followed the same trend as that of leaf area (Table 4).The maximum value for SLA was observed in A.lebbeck (0.19 cm^2g^{-1}) at S_2 level and low in *A.nilotica* (0.01 cm^2g^{-1}) at S_1 level.The maximum value for **sturdiness** (height: diameter ratio) was observed in *P. cineraria* (14) at S_1 level and minimum in *A. lebbeck* (6.32) at S_2 level (Table 4).

Table 5 : Number of nodules and their dry weight for two species under different salinity levels

Tree species	Salinity levels	Number of nodules per seedling	Dry weight (g) per seedling
A. lebbeck	S_0	39.00	2.80
	S_1	20.00	2.01
	S_2	10.00	1.00
P. cineraria	S_0	10.00	0.09
	S_1	5.00	0.02
	S_2	2.00	0.001

Table 6 : Percent reduction or increase in different growth parameters of the species relative to control (S_0, with no salinity stress)

Tree species	Salinity levels	Germination (%)	Survival (%)	Height (cm)	Total biomass (g)
A.lebbeck	S_1	-32.6	-21.8	-21.9	-20.2
	S_2	-60.5	-63.6	-46.9	-42.9
A.nilotica	S_1	+19.7	+30.0	+26.6	+26.7
	S_2	-9.1	-4.0	-17.7	-13.4
P.cineraria	S_1	-16.7	-12.3	-46.4	-38.2
	S_2	-31.0	-41.1	-67.9	-57.8

Response breadth : Response breadth for total biomass and height growth under different salinity levels was widest in *A. nilotica* and narrower for *P. cineraria* (Table 8).

Salt tolerance index: The salt tolerance index calculated over the one year study period varied for the species (Table 9). *A. lebbeck* showed moderate tolerance under medium and highest salinity levels, *P. cineraria* showed moderate tolerance at medium level and low tolerance at high level whereas *A. nilotica* showed high tolerance at medium level, but moderate tolerance at high level of salinit

Table 7 : Regression equations between salinity levels and growth parameters of the species

Trees Species	Germination (%)	Survival (%)	Height growth (cm)	Stem-diameter (mm)	Total biomass (g)
A. lebbeck	Y=88.2– 6.92X r = -0.99* t=7.02	Y=58.9–4.70X r =-0.99* t=7.02	Y=66.1–4.01X r = -0.97* t=3.99	Y=13.8–1.26X r = - 0.92* t=2.35	Y=53.1 – 2.96 X r = -0.98* t=4.92
A. nilotica	Y=72.1– 0.89 X r = -0.33 t=0.35	Y=55.9–0.36X r = -0.03 t=0.03	Y=89.9–2.04X r = -0.42 t=0.46	Y=7.57–0.13X r = -0.53 t=0.63	Y=37.5 – 0.66 X r = -0.41 t=0.45
P.cineraria	Y=91.3–3.73 X r = -0.99* t=7.02	Y=76.8–4.04X r = -0.98* t=4.92	Y=83.5–7.54X r = -0.98* t=4.92	Y=6.06– 0.39X r = -0.91* t=2.19	Y=32.7 – 2.50 X r = -0.94* t=2.76

* significant at 5% level of probability

Table 8: Response breadth pattern of the species along the salinity gradient

Tree Species	Response breadth	
	Height	Total biomass
A. lebbeck	0.942	0.950
A. nilotica	0.969	0.983
P. cineraria	0.829	0.893

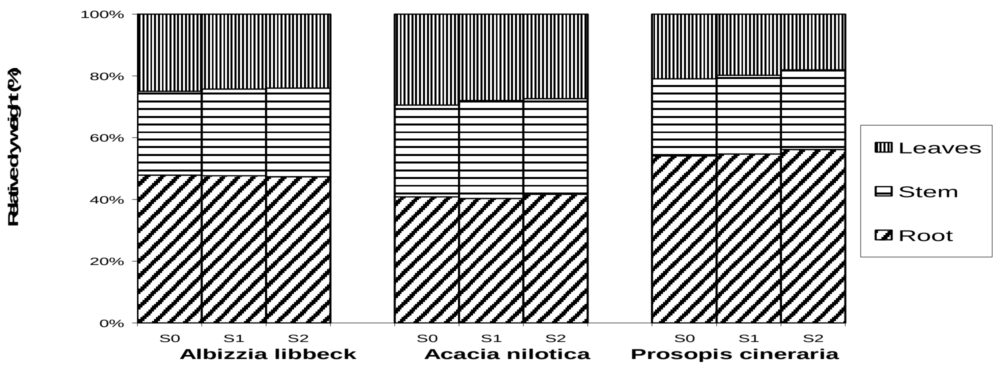

Figure 3 : Proportional allocation of biomass of the species into different components at different salinity levels

Ionic composition of leaves: In all the species maximum percentage of sodium ions was observed in leaves at the highest level of salinity. Amongst the species, maximum Na content was recorded in *A. nilotica* at high salinity level (Table 10). However the K content was maximum at the lowest level of salinity in *A. lebbeck* and *P. cineraria* and only in *A. nilotica* the maximum content was observed at S_1 level. The Ca and Mg content of *A. lebbeck* and *A. nilotica* increased with increase in salinity level but in *P. cineraria* it decreased with increase in salinity level. The maximum Na/K ratio was recorded in *A. lebbeck* (0.855) at S_2 level and minimum in *P. cineraria* (0.225) at S_0 level, Na/Ca was maximum in *A. nilotica* (0.251) at S_2 level and minimum in *A. lebbeck* (0.092) at S_0 level where as Na/Mg ratio was maximum in *A. nilotica* (1.016) at S_1 level and minimum in *P. cineraria* (0.247) at S_0 level.

Changes in soil properties: At the culmination of the experiment pHs was maximum in soil under *P. cineraria* (8.2) at low level and minimum in A. lebbeck (7.7) at high level of salinity. The ECe was maximum in P. cineraria (23.79 dsm^{-1}) at S_2 level and minimum in *A. lebbeck* (14.83 dsm^{-1}) at S_1 level. The maximum total values and highest increase in Na, K, Ca and Mg content in soil was recorded for *P.cineraria* at the highest level of salinity and minimum values of Na, Ca and Mg in *A .lebbeck* at this level (Table 11).The maximum value for SAR was recorded in *P .cineraria* (54) at high salinity level and minimum for *A.lebbeck* (16.5) at low salinity level. The organic carbon content of soil was maximum under *A.lebbeck* (5.4 g/kg) at S_2 level and minimum in soil under *A.nilotica* (4.3 g /kg) under S_1 level.

Table 9: Salt tolerance of the species under varying levels of saline water irrigation relative to lowest salt level (0.52 dsm^{-1})

Tree Species	EC_{iw} S_1 (4 dsm^{-1})	EC_{iw} S_2 (8.0 dsm^{-1})
	78.9 (Moderate)	54.9 (Moderate)
A. nilotica	125.3 (High)	83.6 (Moderate)
P. cineraria	55.9 (Moderate)	34.9 (Low)

Table 10: Ionic composition of leaves and their ratios under varying levels of saline water irrigation

	Salinity levels	Na (%)	K (%)	Ca (%)	Mg (%)	Na/K	Na/Ca	Na/Mg

A. lebbeck	S_0 S_1 S_2	0.32 0.50 0.59	0.92 0.88 0.69	3.47 3.83 3.92	1.06 1.18 1.27	0.348 0.568 0.855	0.092 0.131 0.151	0.309 0.424 0.465
A. nilotica	S_0 S_1 S_2	0.50 0.62 0.69	1.11 1.16 0.94	2.26 2.51 2.75	0.50 0.61 0.71	0.45 0.534 0.734	0.221 0.247 0.251	1.00 1.016 0.972
P. cineraria	S_0 S_1 S_2	0.20 0.31 0.41	0.89 0.73 0.61	3.59 3.26 3.08	0.81 0.69 0.53	0.225 0.425 0.672	0.055 0.095 0.133	0.247 0.584 0.594

Table 11: Effect of saline water irrigation on soil properties

	EC_{iw} (dsm^{-1})	**pHs**		*Water soluble cations* **(m.e/L)**					**Organic carbon (g/kg)**
			Initail Values						
			ECe	**Na^+**	**K^+**	**Ca^{++}**	**Mg^{++}**	**SAR**	
			1.03	15.3	0.2	1.1	1.2		2.5
A. lebbeck	0.52	7.8	2.14 (+1.11)	23.7 (+8.4)	0.3 (+0.1)	1.3 (+1.2)	2.8 (+1.6)	16.5	5.3 (+2.8)
	4.0	7.8	14.83 (+13.8)	134.1 (+118.8)	0.4 (+0.2)	6.3 (+5.2)	12.6 (+11.4)	43.6	4.9 (+2.4)
	8.0	7.7	21.24 (+22.2)	227.4 (+212.1)	0.6 (+0.4)	15.0 (+13.9)	32.0 (+30.8)	46.9	5.4 (+2.9)
A. nilotica	0.52	7.9	2.01 (+0.98)	20.8 (+5)	0.4 (+0.2)	1.1 (+0.0)	1.4 (+0.2)	18.6	5.1 (+2.6)
	4.0	8.0	15.85 (+14.82)	140.5 (+125.2)	0.5 (+0.3)	8.5 (+7.4)	15.3 (+14.1)	40.7	4.3 (+1.8)
	8.0	7.9	21.87 (+20.84)	239.1 (+223.8)	0.5 (+0.3)	17.8 (+16.7)	32.4 (+31.2)	47.7	5.2 (+2.7)
P. cineraria	0.52	8.2	2.35 (+1.32)	28.5 (+13.2)	0.4 (+0.2)	1.1 (+0.0)	1.5 (+0.2)	2.51	4.4 (+1.9)
	4.0	7.7	17.04 (+16.01)	183.4 (+168.1)	0.5 (+0.3)	9.0 (+7.9)	17.0 (+15.8)	50.9	4.6 (+2.1)
	8.0	7.7	23.79 (+22.76)	281.5 (+266.2)	0.6 (+0.4)	18.8 (+17.7)	35.6 (+34.4)	54.0	4.8 (+2.3)

Discussion

For the rehabilitation of soils rendered barren owing to salinity problems adaption to site conditions and their multiple uses, form important criteria for tree selection. Establishing salt tolerant tree plantations utilizing the saline ground water may provide for an economic use of abandoned arid lands. The initial establishment of transplanted tree saplings is critical for raising tree plantation in salt affected soils, which provide stressful conditions for salts. stress. It is difficult to make an objective assessment of salt tolerance of the tree species raised in this experiment but overall plant growth and survival do indicate this response.In the absence of clear and unambiguous procedure for assessment of tree species for suitability to site condition, an effort was made to rank the tree species on the basis of three criteria. The first was the germination and survival percentage on the basis of which the salt tolerance is often described (Marcar *et al.*, 1993). As the second criterion, the tree species were simply ranked on the basis of their height growth, leaf production and biomass produced by these tree species. The third ranking was based on response breadth (in terms of dry weight and height growth) and the salt tolerance of these tree species.

Increase in salinity delayed the initiation of seed germination and decreased survival rate in all species. Salt tolerance during germination and early seedling growth is critical for plants survival in saline soils. The tolerance of forest tree species greatly varies at germination and seedlings stage (Tomar and Yadav, 1980). In case of germination and survival *A. nilotica* showed the tolerance up to medium level of salinity. Paliwal (1972) has reported that the emergence time was delayed and percent germination decreased as the degree of salinity increased. Similar results have been reported by Tomar and Yadav (1980). This reduction could be attributed to the osmotic effect of NaCl limiting seed hydration and to the toxic effect of NaCl on seed embryo or endosperm cell membranes (Bliss *et al*., 1986).

All the growth parameters showed the maximum value at low salinity level and the value declined thereafter at high levels of stress but only in case of *A. nilotica* growth parameters increased up to medium level of salinity and decreased thereafter. The effect of highest tested level of saline water irrigation was most pronounced in *A. lebbeck* but least in *A.nilotica* thereby indicating the good tolerance of *A. nilotica* to high salt stress. Similar findings on some forest species were also reported by Singh *et al*., (1991). In all the three species leaf area decreased with increase in soil salinity stress. Under chronic stress, plant often can adjust osmotically and maintain turgor, but leaf area production, photosynthesis and yield are often considerably reduced in spite of this adjustment. Both root length and spread differed in response to salt levels. In *A. nilotica* and *P. cineraria* the value for root length was maximum but spread was minimum but in *A. lebbeck* root length was minimum whereas root spread was maximum at low salinity level. Roots are directly in contact with the salts and are potentially the first line of defense. In *A. nilotica* and *P. cineraria* the deep vertical roots penetrating up to 75 cm depth, reach lower water levels and enhance the chances of survival in dry habitat, since salts are known to be concentrated on upper crusts of soil. However, in *A. lebbeck* the horizontal growth was more and root length was minimum, resulting in decline in tolerance to salinity.

In case of salinity stress biomass production got reduced in two of the species and only in case of *A. nilotica* maximum value was observed at medium level. The most likely factor causing these differences in salt tolerance may be the rate of salt transport to the shoots adversely affecting the leaf expansion, reducing the photosynthetic efficiency of plant, further reducing the dry matter production. Inherently slow growth is associated with species characteristic of saline environments (Ball and Pidsley, 1995). The maximum root : shoot ratio at all the salt treatments were observed in *P. cineraria*, whereas leaf : stem ratio was observed maximum at all the salts treatments in *A. nilotica*. In *A.lebbeck* and *P.cineraria*, the number of nodules and its dry weight decreased with increasing salinity stress, whereas in *A. nilotica*, there was no nodule formation. Salinity inhibit nodulation depending upon the degree of salt stress (Garg and Gupta, 1997). The salt tolerance index was moderate for *A. lebbeck* and *P. cineraria* and high for *A. nilotica* at medium level of salinity. The property of salt tolerance may change with the development of plant and may also change with the type of salinity (Strongonov, 1964).

Plants that tolerate high external ion concentration of salts invariably do so with high internal concentration, particularly in the leaves (Garg and Gupta, 1997). Maximum percentage of sodium ions was observed in leaves of all the species at the highest level of salinity. At highest salinity level, the maximum content of sodium and potassium was recorded in *A. nilotica*. Very high Na accompanied by lower K appears to be the primary reason of the poor growth and yield of sensitive varieties (Garg and Gupta, 1997). The effect of Na on K is twofold. At low concentrations Na may actually increase K uptake though decreasing it at higher concentrations (Levitt, 1980). The calcium and magnesium content of *A. lebbeck* and *A. nilotica* increased with increase in salt levels but in *P. cineraria* it decreased with increase in salinity. This was due to higher absorption of Na which had an antagonistic effect on absorption of Mg. Mehrota and Dass (1973) also reported decrease in Mg content. Sodium induced calcium deficiencies have notorious growth distorting effects in developing leaves. The uptake of calcium from the soil solution may decrease because of sodium ion strength that reduces the activity of calcium. These combined effects are mainly responsible for reduced yield under saline conditions (Bernstein, 1975) .The toxicity of specific ions may lead to Ca deficiency due to ionic imbalance (Rengel 1992a) e.g. in the present case of *P. cineraria,* which is less tolerant to salinity. It has also been reported by Dhir *et al.* (1993) that the *P. cineraria* is less tolerant as compared to other species. These data related to salinity suggest that owing to higher uptake of sodium, Na/K, Na/Ca and Na/Mg ratios increased with increase in salinity level. Tolerant species selectively absorb potassium over sodium and thus make adjustment in the Na/k ratio to counteract the salt effect (Levitt, 1980).

With the use of saline waters, a depression in soil pH in the treatment of high EC irrigation water can be attributed to the high electrolyte concentrations. The ECe of the soil increased with the increase in salinity. The increase in soil salinization in the case of irrigation water of 8 mmhos/cm EC was of lesser magnitude as compared to that with water of 4 mmhos/cm EC. The Na, K Ca and Mg content of soil extract also increased with increasing salinity levels in all the species. Enhanced ability to exclude salts or Na from shoots and roots has been considered to be the most important mechanism operating in salt tolerant woody tree species (Marcar and Khanna, 1997). The sodium absorption ratio (SAR) of the irrigation water increased as RSC increased from 0.9 to 14 m.e.l-1 and this caused sodiumlisation of the soil.. The SAR value of the irrigation water did not adversely affect the growth of the species at lower RSC values, nevertheless, the adverse effect became evident at the higher RSC value. The reduction in growth and total biomass accumulation with increase in pH of soil could be attributed to increase in concentration of hydroxyl ions, increased corrosiveness upon cells or tissues of roots, inhibiting cell-division.The organic carbon content of soil with saline water irrigation was maximum under *A. lebbeck* .The greater increase in organic carbon in the soil under *A. lebbeck* is ascribed to greater addition of leaf fall at highest salinity level and may be due to faster decomposition of leaf litter, leading increase of 2.5 g kg^{-1} in organic carbon content over the initial value. The horizontal root spread of this species in lower depths may be another reason for high content of organic matter. The difference observed in organic carbon status of soil under different tree species after one year study period, clearly indicates the contribution of leaf litter and other by products of trees in improving the fertility status in the semiarid environment. Our present findings are also similar to the previous studies which suggested that about 20-25% of the total living biomass of trees is in roots (Armson, 1977) and there is constant addition of organic matter to the soil through dead and decaying roots, and significant improvement in status of soil under different tree species has also been reported by Lahiri (1984).

Three important growth criterions, along with ionic composition of leaves and changes in soil properties produced different rankings and these criterions were later combined to give a final ranking. Following this procedure the tree species in order of preferred choice for arid areas with saline levels should be *A. nilotica*, *A. lebbeck* and *P. cineraria*. During the past few decades, a number of well-designed species evaluation trails were established on saline water logged soils (Ahmad and Ismail, 1992). Our evaluation trail has shown that *A. nilotica* at arid land is suitable for higher wood production at medium level of salinity. It has been reported that favored species of foresters (e.g. *Dalbergia sissoo*) should not be recommended for saline soils because of its sensitivity to the presence of salts during initial establishment stages (Singh *et al*., 1991) whereas *A. nilotica* should be recommended for saline soils at medium level of salinity because of its tolerance to the presence of salts.

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