Impact of Alkaline Irrigation Water on Ion Relations and Soil Properties of Two Desert Tree Species

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ABSTRACT

The salt affected land in India is about 6.73 million ha consisting of 3.77 million ha sodic and 2.96 million ha saline soil. For rehabilitation of soils rendered barren owing to alkalinity, adaptation to site conditions and multiple uses form important criteria of tree selection. Seeds of preferred multipurpose tree species *Albizzia lebbeck* and *Acacia nilotica* were sown in pots to study the growth behavior of seedlings during the initial year of establishment. Growth attributes were determined at three levels of alkali water irrigation. *A. nilotica* and *A.lebbeck* showed moderate tolerance under intermediate and high levels of alkalinity of irrigation water. The leaf sodium content increased with increasing alkalinity conditions in all the two species, being maximum in *A. nilotica*, however K, Ca and Mg content decreased with increasing alkalinity levels of irrigation water. The ratio of Na/K, Na/Ca and Na/Mg increased with increasing alkalinity up to medium level and decreased thereafter. At the end of experiment, the soil pHs, ECe and ESP increased whereas the organic carbon content in the soil was maximum under *A. nilotica* at highest level of alkalinity of irrigation water. A well defined and strong integrated natural resource management system, particularly soil and water should be evolved to prevent, monitor and rehabilitate degraded salt affected soils for sustainable agriculture development.

Keywords: Salt, Sodic, Alkaline, Barren, Growth, Irrigation

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) and 3.88 million ha alkaline soils. In the past, all such lands which used to be unfit for agriculture were called as ‘Ushtra’. 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). Application of such poor quality water makes the soil alkaline in nature which affects the plant growth adversely. These alkaline soils are a wide spread element of the landscapes of arid zones and soil alkalinization is one of the main processes responsible for the degradation and reduced productivity of agricultural lands in these regions. Millions of hectares of land have been abandoned because of alkalinity hazards. Alkaline soils have high exchangeable sodium percentage >50% and saturated paste pH >8.2. Alkali soils frequently have poor physical properties due to high sodicity and high pH and low EC, resulting in restricted water and air movements (Acharya and Abrol, 1978). The main reason of soil getting affected by salt is the application of ground water that is often alkaline thereby resulting in enhancement of salt loads in soils. Poor infiltration and drainage practices and expansion of irrigated agriculture lands in arid zones with huge evaporation rates are other reasons of accumulation of alkalinity. The problem of alkaline soils is associated with exchangeable sodium which a part from deteriorating the physical conditions of the soils also causes nutritional imbalance in plants. Alkalinity impairs plant growth, obstructs root development, restricts water supply to the roots and results in deficiencies in phosphorus and zinc. Due to alkalinity discoloration of leaves starts occurring at tip leading to scorched appearance in more susceptible plants.

Although considerable attention has been given to the toxic limits of salt concentration but investigations on the utilization of alkaline water by developing different cultural practices are lacking. 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 alkaline 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. These tree species are not only tolerant to salt and 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 alkaline irrigation water of the two tree species *Albizzia lebbeck and Acacia nilotica* 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 two multipurpose tree species of *Albizzia lebbeck*, and *Acacia nilotica* 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..In this experiment, alkaline irrigation waters of three RSC levels 0.9 $m.e.l^{-1}$, 7 $m.e.l^{-1}$, and 14 $m.e.l^{-1}$, were used having the chemical composition as given in Table 1. Alkaline water of 7 RSC was synthesized by equal mixing of deionized water and underground water which was equivalent to 14 RSC. These levels are referred to as low A_0 (0.9 $m.e.l^{-1}$) or BAW medium, A_1 (7 $m.e.l^{-1}$) and high, A_2 (14 $m.e.l^{-1}$) levels of alkalinity. The experiments were initiated in the month of August and the duration of the experiment was twelve months. The experiments were laid out in randomized block design with three replications. The germination and survival percentage of the seedlings produced was recorded. When the seedlings attained a height of about 10 cm, they were thinned out to retain only one healthy seedling in each pot. 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 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. Dry weight was estimated by harvesting the species at the end of twelve month experimental period. For a comparison among the species, the ratio of root: shoot and leaf: stem biomass were calculated

With the help of the above data the following growth parameters i.e. specific leaf area (SLA) and sturdiness were determined.

Specific leaf area (SLA): was calculated by using the formula given by Evans (1972).

$$\text{SLA} = \frac{\text{leaf area}}{\text{unit leaf mass}}$$

Sturdiness: was calculated by using the formula suggested by Chauhan and Sharma (1997).

$$\text{Sturdiness} = \frac{\text{Height}}{\text{Diameter}}$$

Measure of response breadth (B): was calculated by using Levin's niche breadth metric (1968):

$$B = \frac{1}{\left(\sum_{i=1}^{s} P_i^{2}\right) s}$$

Where, B is niche breadth, pi is the proportion of seedling height growth or total seedling dry weight response in the state i and S is the total number of states (treatments). The resulting measure B is a scale of 0 to 1 with 1 being the widest breadth

Statistical analysis

Regression analysis was done for different growth parameter of the species after different pretreatments (Senedecor and Cochron, 1973). The data collected were categorized for two-way analysis. The source of variation was treatments and species. The data was analyzed using two way ANOVA with n observation per cell (Das and Giri, 1979).

Table 1: Chemical composition of irrigation water used with different alkalinity levels

Water quality	RSC ($m.e.l^{-1}$)	pH $_{iw}$	EC_{iw} (mmhos/ cm)	SAR	Cations ($m.e.L^{-1}$)			Anions ($m.e.L^{-1}$)		
					Ca+Mg	*Na*	K	HCO_3	CO_3	Cl
Good quality (A_0)	0.9	7.8	0.68	4.0	6.6	5.2	0.23	6.0	1.5	2.5
Marginally alkaline (A_1)	7.0	8.1	1.44	11.45	5.2	12.6	0.19	10.5	1.7	4.2
Alkaline (A_2)	14.0	8.3	2.20	22.20	3.2	20.0	0.16	15.2	2.0	5.6

BAW= best available water
EC_{iw} =electrical conductivity of irrigation water

RSC=residual sodium carbonate

SAR=sodium absorption ratio

Result

Germination and Survival : At highest alkalinity level the maximum germination and survival percentage was recorded in *A. lebbeck* (Table 2). Percent germination and survival was significantly negatively correlated to alkalinity in all the species except survival percentage of *A.lebbeck* (Table 6). Analysis of variance for germination and survival percentage under different alkalinity levels, indicated significant differences between treatments, species and their interactions at $p<0.05$.

Growth parameters : The monthly growth in height of various species under different levels of alkaline water irrigation i.e. control, low level (A_0,0.7 $m.e.l^{-1}$) medium level (A_1, 7 $m.e.l^{-1}$) and high level (A_2, 14 $m.e.l^{-1}$) during one year of study period are depicted in Fig 4. At high alkalinity level, the length of growing period was maximum in *A. nilotica* from May to August . The values of height growth decreased as the alkalinity level increased upto A_2 level in all the species . *A. nilotica* attained comparatively greater height growth (56 cm) than others species particularly at A_2 level (Table 2). Relative to lowest alkalinity level (BAW) height growth reduction was least in *A. lebbeck* (22 %) at A_2 level (Table 5). Height growth was significantly negatively correlated to alkalinity levels for all the species at $p<0.05$ (Table 6). For height growth most gentle slope was observed in *A. lebbeck*. Analysis of variance for height growth under different alkalinity level indicated, significant difference between treatments, species and their interactions at $p<0.05$. At highest alkalinity level, the maximum stem diameter was observed in *A. lebbeck* (6.0 mm) .Stem diameter of all the species was significantly negatively correlated to alkalinity at $p<0.05$ (Table 16). Analysis of variance for stem diameter under different alkalinity level indicated significant difference between treatments, species and their interaction at $p<0.05$.

The values of leaf production of one year seedling decreased, as the alkalinity level was increased up to A_2 level. The maximum number of leaves was recorded in *A. nilotica* (630) and minimum in *A.lebbeck* at A_2 level. Shedding of leaves was observed at RSC values of 7 and 14 m.e.l-1 i.e. A_1 and A_2 levels during February to May 2003. At highest alkalinity level, the value for leaf area was markedly greater in *A. lebbeck* (1.29 cm^2) and least in *A .nilotica* (0.15 cm^2). Both root length and spread differed in response to high alkalinity level In *A. lebbeck* root length was minimum (23 cm) whereas root spread was maximum (3 cm), Table 2.

Total seedling dry mass and ratios : Total seedling mass values decreased with increasing alkalinity levels in all the species (Table 3). At highest alkalinity level, the maximum dry weight was recorded in *A. lebbeck* (38.5g) and minimum in *P. cineraria* (25.94g). Root and shoot dry weight followed the same pattern as that in total dry weight. Relative to lowest alkalinity level (BAW) least reduction was observed in *A. nilotica* (23%) (Table 5). Total biomass of all the species was significantly negatively correlated to alkalinity at $p<0.05$ (Table 6). The most gentle slope was observed in *A. nilotica*. Analysis of variance for total biomass under different alkalinity levels, indicated significant differences between treatments, species and their interactions at $p<0.05$.

Table 2 : Growth parameters of the species at varying levels of alkaline water irrigation

Tree species	Alkalinity levels	Germination (%)	Survival (%)	Height (cm)	Stem diameter (mm)	Leaf area (cm^2)	Root length (cm)	Root Spread (cm)
A. lebbeck	A_0	86	55	64	13.6	1.68 ±0.326	44 ±3.110	3.3 ±0.102
	A_1	65	63	55	8.1	1.42 ±0.0.296	30 ±1.176	5.1 ±0.102
	A_2	55	40	50	6.0	1.29 ±0.0.071	23 ±1.019	3.0 ±0.059
A. nilotica	A_0	66	50	79	7.0	0.23 ±0.001	63 ±6.620	3.0 ±0.059
	A_1	56	32	66	6.9	0.18 ±0.020	53 ±2.121	2.9 ±0.102
	A_2	46	29	56	5.6	0.15 ±0.026	42 ±1.556	2.7 ±0.068

SEm = Mean standard error

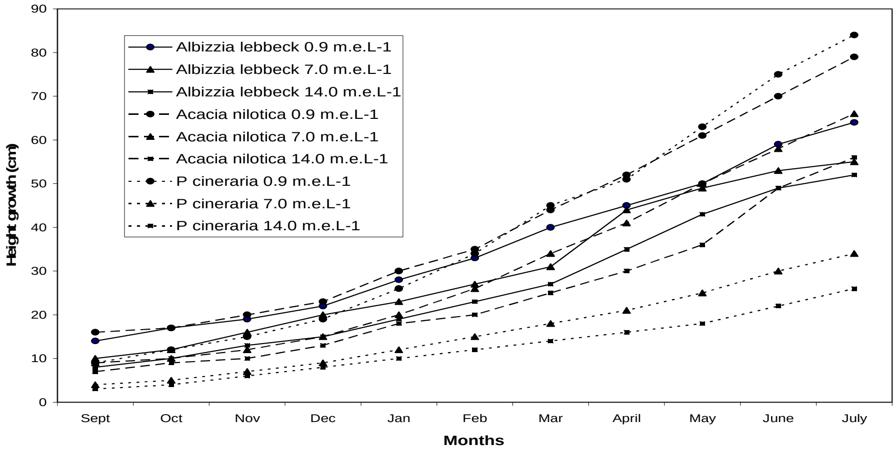

Figure 4 : Monthly height growth (cm) of seedlings at different alkalinity levels

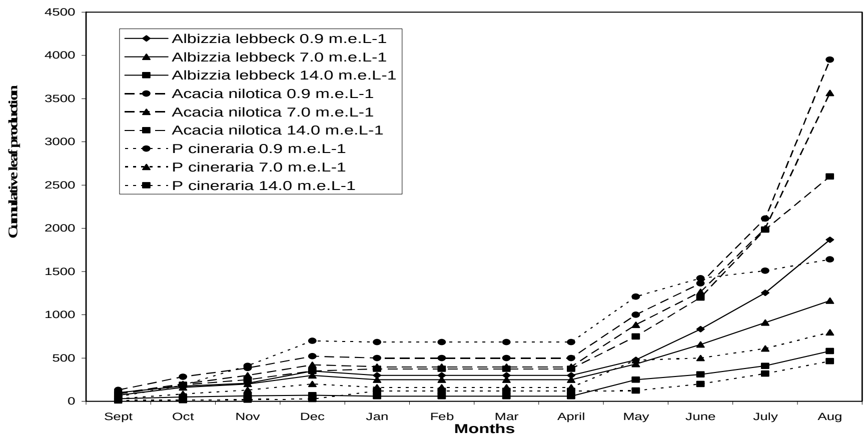

Figure 5 : Cumulative leaf production of the species under different alkalinity levels for one year study period

Table 3 : Effect of different levels of alkaline water irrigation on other growth parameters of the species

Tree species	Alkalinity levels	Root wt (g)	Shoot wt (g)	Total biomass (g)	Root: shoot ratio	Leaf: stem ratio	Specific leaf area (cm^2/g)	Height: Diameter ratio
A. lebbeck	A_0	24.71	26.95	51.66	0.917	0.918	0.130	4.706
	A_1	20.97	23.78	44.75	0.881	0.782	0.132	6.790
	A_2	18.15	20.36	38.51	0.891	0.811	0.141	8.333
A. nilotica	A_0	13.78	19.95	33.73	0.691	0.993	0.020	11.00
	A_1	12.56	18.18	30.74	0.690	0.818	0.022	9.57
	A_2	10.40	15.54	25.94	0.669	0.902	0.018	10.00

Table 4 : Number of nodules and their dry weight for two species under different alkalinity levels

Species	Alkalinity Levels	Number of nodules per seedling	Dry weight (g) per seedling
A. lebbeck	A_0 A_1 A_2	39.00 21.00 12.00	2.80 2.01 1.01

Table 5: Percent reduction or increase in different growth parameter of the species relative to control (A_0, with no alkalinity stress)

Tree species	Alkalinity levels	Germination (%)	Survival (%)	Height (cm)	Total biomass (g)
A.lebbeck	A_1	-24.4	+14.5	-14.1	-13.4
	A_2	-36.04	-27.3	-21.9	-25.5
A.nilotica	A_1	-15.2	-36.0	-16.5	-12.4
	A_2	-30.3	-42.0	-29.1	-23.1

Number of nodules decreased with increasing alkalinity levels. At highest alkalinity level, the maximum number of nodule was recorded in *A.lebbeck* (2) in case of *A .nilotica* there was no nodules formation. Dry weight of the nodules followed the same pattern as that of number of nodules (Table 4).

Table 6 : Regression equations between different alkalinity levels and growth parameters of the species

Tree species	Germination (%)	Survival (cm)	Height growth (cm)	Stem diameter (mm)	Total biomass (g)
A. lebbeck	Y=85.7-0.34X r =-0.97* t=3.99	Y=61.4-0.19X r = -0.67 t=0.90	Y=641-0.06X r = -0.98* t=4.92	Y=13.4-0.57X r = -0.96* t=3.43	Y=52.3-1.00X r = -0.99* t=7.02
A. nilotica	Y=67.1-0.57X r = -0.99* t=7.02	Y=48.0-0.41X r = -0.91* t=2.19	Y=79.8-0.74X r = -0.99* t=7.02	Y=7.29-0.11X r = -0.92* t=2.35	Y=34.5-0.59X r = -0.99* t=7.02

* significant at 5% level of probability

Table 7 : Response breadth for total biomass and height growth of the species along alkalinity gradient

Tree Species	Response breadth	
	Height	**Total biomass**
A. lebbeck	0.992	0.986
A. nilotica	0.981	0.989

Table 8 : Salt tolerance of the species under varying levels of alkaline water relative to lowest salt level (0.9 m.e.L^{-1})

Tree Species	**RSC 7.0 (m.e.L^{-1}) A$_1$**	**RSC 14.0 (m.e.L^{-1}) A$_2$**
A. lebbeck	86.2 (Moderate)	76.5 (Moderate)
A. nilotica	85.8 (Moderate)	72.7 (Moderate)

Table 9 : Ionic composition of leaves and their ratios under varying alkalinity levels of irrigation water

Tree species	**Alkaline levels**	**Na (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**Na/K**	**Na/Ca**	**Na/Mg**
A. lebbeck	A_0	0.32	0.92	3.47	1.06	0.348	0.092	0.302
	A_1	0.49	0.90	3.04	1.04	0.544	0.161	0.471
	A_2	0.57	0.70	2.89	0.91	0.814	0.197	0.626
A. nilotica	A_0	0.50	1.11	2.26	0.50	0.450	0.221	1.000
	A_1	0.78	0.87	2.06	0.46	0.897	0.378	1.182
	A_2	0.87	0.78	2.01	0.40	1.115	0.416	1.50

Table 10 : Effect of different levels of alkaline water irrigation on soil properties of the species

Tree species	**RSC (m.e.L $^{-1}$)**	***pH_s***	**ECe (dsm^{-1})**	**ESP**	**Organic carbon (g kg $^{-1}$)**
		Intial Values			
		7.7	1.07	17.2	2.5
A. lebbeck	0.9	7.8 (+0.1)	2.08 (+1.01)	22.56 (+5.36)	5.3 (+2.8)
	7.0	9.0 (+1.3)	4.66 (+4.59)	36.40 (+19.2)	4.2 (+1.7)
	14.0	9.8 (+2.1)	6.21 (+6.14)	48.47 (+31.27)	4.0 (+1.5)
A. nilotica	0.9	7.8 (+0.1)	2.27 (+1.2)	21.87 (+4.67)	5.6 (+3.1)
	7.0	9.0 (+1.3)	4.52 (+4.45)	32.42 (+15.22)	4.8 (+2.3)
	14.0	9.6 (+1.9)	6.67 (+6.00)	41.75 (+24.55)	4.2 (+1.7)

* Values in parenthesis indicate increase from initial value

At high alkalinity level, *A.lebbeck* attained the maximum root : shoot ratio (0.891) and minimum in *A. nilotica* (0.669) but *A. nilotica* attained highest leaf : stem ratio (0.902) and least in *A. lebbeck* (0.811) at this level (Table 3). At highest alkalinity level, the value for SLA was markedly greater in *A. lebbeck* (0.141 cm^2/g) and least in *A. nilotica* (0.018 cm^2/g). The maximum value of height : diameter ratio, at highest alkalinity level was recorded in *A. nilotica* (10) and least in *A. lebbeck* (8.3).

Response breadth : The response breadth for height growth along the alkalinity gradient was broadest in *A. lebbeck* but for dry weight it was broadest in *A. nilotica.* (Table 7).

Salt tolerance index : The salt tolerance index calculated over the one year study period varied for the species (Table 8). *A. lebbeck* and *A. nilotica* showed moderate tolerance at intermediate and high levels of alkalinity (72-86).

Ionic composition of leaves : Maximum percentage of sodium ions was observed in leaves of all the species at the highest level of alkalinity (A_2) being in *A. nilotica* (0.87%) and minimum in *A. lebbeck* (0.57%). Potassium content was higher in leaves of *A. nilotica* while in others it was lower (Table 9). Percent calcium was highest in *A.lebbeck*(3.47 at A_0) level and least in *A. nilotica* (2.01 at A_2 level). Magnesium was lowest in *A. nilotica* at A_2 level and highest in *A .lebbeck* at A_0 level.It appears that owing to higher content of sodium, ratios of Na/K, Na/Ca and Na/Mg increased with increase in alkalinity level. At A_2 level Na/k was maximum in *A. nilotica* (1.115) and minimum in *A. lebbeck* (0.814). Ratios of Na/Ca and Na/Mg followed the same pattern.

Changes in soil properties : At the culmination of experiment, at A_2 level the maximum values of ECe was found in soil under *A.lebbeck* and ESP values were maximum in *A. nilotica* (Table 10). The organic carbon content increased in the soil of all the species at A_0 level and decreased with increasing levels of alkali water irrigation.

DISCUSSION

For the rehabilitation of soils rendered barren owing to alkalinity problem adaption to site conditions and their multiple uses, form important criteria for tree selection. Establishing salt tolerant tree plantations utilizing the alkaline 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 of salts. In fact, for arid areas not just physical measurements of tree size and quantities of useful productivity, but also the impact of trees on its surroundings and improvement in microclimate need to be monitored. 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. Salt tolerance during germination and early seedling growth is critical for plants survival in alkaline soils. The tolerance of forest tree species greatly varies at germination and seedlings stage (Tomar and Yadav, 1980). In case of alkaline water irrigation mortality rate of all the species was higher at low and high levels. Initial seed germination was significantly affected by alkalinity levels. 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). Bicarbonates and carbonate are more harmful to germination than sulphate and chlorides ions because high amounts of carbonate and bicarbonate ions adversely affect permeability to air and water due to formation of hard surface crusts and dispersed colloidal structure of the soil (Rao *et al*., 1969).

All the growth parameters showed the maximum value at low alkalinity and the value declined thereafter at high levels of stress .Shalhevet and Hsiao (1986) showed a clear distinction between the responses of plants to salt stress in terms of incomplete osmotic adjustment under water stress. The effect of highest tested level of alkaline 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* (1992). The differences in the growth parameters under alkaline water irrigation may be due to specific ion toxicity of carbonates and bicarbonates and selective absorption of these ions by the seedlings. In all the species leaf area decreased with increase in alkalinity. 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 (McCreek, 1986). Both root length and spread differed in response to salt levels. In *A. nilotica* 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 alkalinity level. Roots are directly in contact with the salts and are potentially the first line of defense. In *A. nilotica* 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 alkaline. Root elongation can be rapidly inhibited by alkalinity depending upon the type and concentration of salt. The crust formed by the alkalinity reduces the infiltration rate causing over saturation and aeration problem and retards the root penetration.

Total seedling mass values decreased with increasing alkalinity levels in all the species. 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 leaf: stem ratio was observed maximum at all the salts treatments in *A. nilotica*. Under different levels of alkaline water irrigation although *A. lebbeck* showed the widest response breadth for height growth, *A. nilotica* again had the widest response breadth for dry mass, indicating its chances to grow along a large range of alkalinity gradient also. In case of alkaline water irrigation, the tolerance was moderate for *A.lebbeck* and *A.nilotica* at medium and high levels of alkalinity. 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 alkalinity. At highest alkalinity 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). 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 sodic conditions . These data related to alkalinity suggest that owing to higher uptake of sodium, Na/K, Na/Ca and Na/Mg ratios increased with increase in alkalinity level. Tolerant species selectively absorb potassium over sodium and thus make adjustment in the Na/k ratio to counteract the salt effect (Levitt, 1980). At end of experiment the pHs and ESP of the soil increased with the increase in RSC values of irrigation water, whereas ECe decreased in all the species. 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. Alkalinisation of the soil can therefore be ascribed to the combined effect of RSC and SAR. 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 alkaline water irrigation was maximum under *A. nilotica*. 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 alkaline irrigation should be *A. lebbeck and A. nilotica* . Our evaluation trail has shown that *A.lebbeck* may be recommended for its moderate tolerance to medium and high levels of alkaline water irrigation.

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