EFFECT OF VARIOUS SODICITY LEVELS ON GROWTH PARAMETERS OF *ACACIA AMPLICEPS*

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ABSTRACT

A pot study was conducted at Soil Salinity Research Institute, Pindi Bhattian, Pakistan during the year 2005 and 2006. The objective was to assess tolerance limits of *Acacia ampliceps* against different levels of sodicity ranging 10-70 mmol/l$^{1/2}$. It was noted that plants survived in all sodicity levels ranging from 20 to 50 mmol/L$^{1/2}$. However, plants could not survive in SAR of 60 and 70 mmol/l$^{1/2}$. The collected and statistically processed data of two years also indicated that sodium concentration in plant leaves highly increased while K^+, Ca^{2+} and Mg^{2+} decreased with increasing levels of stresses. The plant successfully tolerated sodicity stress through ion selectivity (keeping K^+: Na^+ ratio comparatively wider) and compartmentation. *Acacia ampliceps* improved the soil health through decreasing SAR of soil underneath the plants.

KEYWORDS: Saline sodic soils; *Acacia ampliceps*; reclamation; sodium absorption ratio; agronomic characters; Pakistan.

INTRODUCTION

Salt-affected lands in Pakistan are estimated at about 6.8 million hectares (4). It was also estimated that there was a net yearly addition of 0.98 to 2.47 tons salts per hectare, through various sources. Each year 0.2 to 0.4 percent of total arable land was going out of cultivation because of salinity and water logging (15). The annual losses because of salinity under rice-wheat rotation are Rs. 10 billion (12).

The saline agriculture approach is based on growing salt tolerant plant species and use of saline waters to utilize salt-affected soils which has been explored to a lesser extent (13). However, an understanding of the plant

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responses to various stresses and mechanisms that make some species/genotypes more tolerant than others, is essential. Naturally there are two groups of plants with respect to their adaptability under saline conditions. The plants may be sensitive to saline environment; the glycophytes, or can tolerate the salinity; the halophytes (6). Halophytes represent an interesting group of plants because of very low water potential and high salt concentration (3). True halophytes accumulate large amount of Na^+ and Cl^- in higher concentration for osmotic adjustment within their tissues to keep the water potential at desired level. Maintenance of plant growth in the presence of such high concentrations of toxic ions depends on the localization of ions in tissues and efficient partitioning of solutes between vacuole and cytoplasm (2). Crops/varieties are available with high salt tolerance (5, 15) but there is a severe reduction in the yield of different agricultural crops when grown on ultra saline soils. Therefore, these are not economical to grow on these lands (1). Instead, the development and maintenance of sustainable agro-ecosystems in highly salt-affected lands will be easier and more economical with perennial salt tolerant plant species such as forage shrubs and trees.

Acacia ampliceps very highly salt tolerant plant from Australian origin is fast growing. Its leaves, flowers and pods can be fed to sheep and goats. It can be mixed with other fodders to feed the cattle. This fast growing dense shrub can be used as wind breaks, soil conservation and stabilization of dunes. It enhances reclamation of salt-affected soils through root action and decomposition of organic matter. Its wood is a good fuel that burns well. The wood is hard and tough, hence can be used as posts and small poles (14).

The present study was conducted to assess the tolerance of *Acacia ampliceps* against various salinity levels. The information generated through this study would prove helpful not only in understanding the tolerance and adaptability of *Acacia ampliceps* to saline environment but may also lead to the productive use of saline lands.

MATERIALS AND METHODS

This study was conducted in pots at Soil Salinity Research Institute, Pindi Bhattian, Pakistan during 2005 and 2006. A normal soil (Texture = Sandy loam, Saturation percentage = 35.70, EC_e = 1.70 dS/m, pH_s = 8.19 and SAR = 10.95 mmol/l$^{1/2}$ was selected and brought to the wire-house in bulk. Soil sodicity levels of 20, 30, 40, 50, 60 and 70 mmol/l$^{1/2}$ were developed artificially, in addition to original soil status. Sodium bicarbonate ($NaHCO_3$) in calculated amounts was added to develop the desired sodicity levels. Salt was dissolved in distilled water and sprayed on the soil that was spread in thin layers. Soil was stirred and mixed after each application of salt. Samples were obtained separately from each soil to ascertain the development of desired levels. After development of desired levels, the soil was filled in pots. The pots were arranged in CRD. There were three repeats of each experiment. Three seedlings of *Acacia ampliceps* of same age and approximately same height (25-30 cm) were transplanted in each pot and irrigated subsequently with canal water having EC = 0.28 dS/m, SAR 0.16 $mmol/l^{1/2}$ and RSC zero. However, one seedling was maintained in each pot after 30 days. Fertilizer was applied in solution form. One liter of 1 percent urea, TSP (triple super phosphate) and potassium sulphate were applied in each pot one week after transplantation and after every six months. Various growth parameters like plant height, stem diameter (girth), number of leaves and branches per plant, canopy volume of each plant and weight of shoot and root per plant were measured after every six months during the period of two years. Stem diameter of smaller plants was taken by Vernier Calliper. However, the diameter of bigger plants was indirectly calculated from the circumference (C) that was measured by a measuring tape. The formula for calculation of diameter (D) is as under:

$$D = C / 3.14$$

The canopy volume (CV) in cubic meter was determined by the following formula:

$$D_1 + D_2 / 2 = r$$
$$CV = 3.14\, r^2 \times h / 4$$

where D_1 = Diameter of one side of the plant, D_2 = Diameter of the other side of the plant and h = Height of the plant.

Plants were harvested after completion of two years period. Roots were separated from the soil, washing the soil with distilled water. The oven dry root and shoot weights were recorded separately. The data collected were subjected to analysis of variance (ANOVA) (17).

RESULTS AND DISCUSSION

The plants could not survive in SAR 60 and 70 while growth was suppressed to various degrees under other levels. Effects on different parameters are presented as under:-

Plant height

Increase in plant height was checked due to sodicity levels but statistical difference only occurred with SAR 50 in six months plants (Table 1). After

Table 1. Effect of sodicity on plant height (cm) of *Acacia ampliceps.*

Sodicity levels SAR $(mmol/l)^{1/2}$	At transplant-ation time	After six months	After one year	After one and a half year	After two years	Increase in two years	Difference over control	Decrease over control (%)
Control	30	60 a	135 a	193 a	296 a	266	-	-
20	30	59 a	128 ab	168 b	247 b	217	49	18
30	32	56 a	122 ab	151 c	214 c	182	84	32
40	32	50 a	112 b	131 d	163 d	131	135	51
50	32	39 b	48 c	56 e	68 e	36	230	86

next six months (one year old plants) the last two levels became prominent. The effects were more pronounced in second year and each level differentiated significantly. Thus, sodicity penetrated with time. The overall decrease in two years were found to be 18, 32, 51 and 86 percent over control for SAR 20, 30, 40 and 50, respectively. Hence, there was nominal increase in plant height during two years growth period under higher sodicity level of SAR 50.

Stem diameter (girth)

The thinner plants at the time of transplantation became gradually thicker and stem diameter grew by 2.30 cm during two years (Table 2) in absence of any stress (control). However, sodicity hindered the increase in stem diameter that became significant within six months due to SAR 50, after one year with SAR 40 and 50 and in all SAR levels during second year. The stem diameter of 2.60 cm attained after two years in control plants was restricted to only 0.76 cm by the level of SAR 50. The value of this parameter was 0.25 cm initially at the time of transplantation. The decrease in stem diameter was recorded as 13, 25, 43 and 78 percent with respective SAR levels of 20, 30, 40 and 50.

Number of leaves

The number of leaves is a sign of healthy plant that steadily increased from 29 (initial) to 578 in non-stressed plants during two years but these were restricted to only 112 with SAR 50 (Table 3). Penetration of sodicity effect was found to be significant for SAR 40 and 50 in first year and all levels during the second year. The decrease in total leaves was noted as 8, 20, 48 and 85 percent under sodic conditions of SAR 20, 30, 40 and 50, respectively. Thus, SAR 40 caused about 48 percent reduction, which is very closer to 50 percent that is considered least economical in salt tolerant studies.

Table 2. Effect of sodicity on stem diameter (cm) of *Acacia ampliceps.*

Sodicity levelsSAR $(mmoll)^{1/2}$	At trans plant-ation time	After six months	After one year	After one and a half year	After two years	Increase in two years	Difference over control	Decrease over control (%)
Control	0.30	0.89 a	1.55 a	2.06 a	2.60 a	2.30	-	-
20	0.30	0.86 a	1.51 a	1.78 b	2.31 b	2.01	0.29	13
30	0.27	0.80 a	1.46 a	1.67 c	1.99 c	1.72	0.58	25
40	0.26	0.74 a	1.28 b	1.38 d	1.58 d	1.32	0.98	43
50	0.25	0.32 b	0.56 c	0.64 e	0.76 e	0.51	1.79	78

Table 3. Effect of sodicity on number of leaves per plant of *Acacia ampliceps.*

Sodicity levels SAR $(mmol/l)^{1/2}$	At trans plant-ation time	After six months	After one year	After one and a half year	After two years	Increase in two years	Difference over control	Decrease over control (%)
Control	29	133 a	270 a	343 a	578 a	549	-	-
20	31	130 a	267 a	305 b	535 b	504	45	8
30	29	103 ab	265 a	289 c	466 c	437	112	20
40	27	89 b	175 b	224 d	315 d	288	261	48
50	28	36 c	48 c	70 e	112 e	84	465	85

Number of branches

The single stem branched into 47 during two years without any stress. The effects of sodicity proved highly negative and higher level of SAR 50 retarded to only 7 branches (Table 4). Such effects were significant just after six months even with SAR 20 but SAR 50 was highly pronounced. The effects of different levels were overcome in one-year plant but SAR 50 still remained significant. All SAR levels were statistically differentiated in the last year. The reduction in number of branches was evaluated as 30, 48, 63 and 87 percent with corresponding levels of SAR 20, 30, 40 and 50.

Canopy volume

The spread of plant, as measured through canopy volume, was significantly checked by each sodicity level (Table 5). The negative effect increased with enhancing SAR. It started from beginning of experiment and persisted like

Table 4. Effect of sodicity on number of branches per plant of *Acacia ampliceps.*

Sodicity levels SAR $(mmol/l)^{1/2}$	At trans plant-ation time	After six months	After one year	After one and a half year	After two years	Increase in two years	Difference over control	Decrease over control (%)
Control	**1**	**12 a**	**18 a**	**27 a**	**47 a**	**46**	**-**	**-**
20	**1**	**8 b**	**16 a**	**20 b**	**33 b**	**32**	**14**	**30**
30	**1**	**9 b**	**13 a**	**17 c**	**24 c**	**24**	**22**	**48**
40	**1**	**8 b**	**13 a**	**16 c**	**18 d**	**17**	**29**	**63**
50	**1**	**2 c**	**5 b**	**6 d**	**7 e**	**6**	**40**	**87**

Table 5. Effect of sodicity on canopy volume (m^3) of *Acacia ampliceps.*

Sodicity levels SAR $(mmol/l)^{1/2}$	At trans-plant-ation Time	After six months	After one year	After one and a half year	After two years	Increase in two years	Difference over control	Decrease over control (%)
Control	0.005	0.031 A	0.077 A	1.38 A	5.22 A	5.21	-	-
20	0.005	0.022 B	0.054 B	1.21 B	4.45 B	4.44	0.77	15
30	0.005	0.014 C	0.030 C	1.04 C	3.25 C	3.24	1.97	38
40	0.005	0.010 C	0.025 D	0.79 D	1.23 D	1.22	3.99	77
50	0.005	0.007 D	0.10 E	0.32 E	0.50 E	0.49	4.72	90

this to the end because same trend was observed during all four six monthly observations. The nominal canopy volume (0.005 m^3) at transplantation time, increase to 5.22 m^3 in the absence of any stress that was restricted just to 0.49 m^3 in higher SAR 50. The over all decrements were found to be 15, 38, 77 and 90 percent for respective SAR levels of 20, 30, 40 and 50.

Plants shoot weight

The total fresh biomass of 2460 g per plant was harvested in control, which was just 549 g in higher sodicity level of SAR 50. There was corresponding decrease as SAR was elevated. Higher dry weight (1009 g/plant) was noted in control pots that was reduced to 976, 824, 473 and 303 g per plant with progressive sodicity levels of SAR 20,30,40 and 50 (Table 6). These decreases differed significantly in each level. The loss in fresh mass was also maximum in control plants indicating less water uptake under sodic environment. The detrimental effect of SAR levels was calculated as 3, 18, 53 and 70 percent on the basis of loss in dry mass during two years.

Table 6. Effect of sodicity on shoot weight (g/plant) of *Acacia ampliceps.*

Sodicity levels SAR $(mmol/l)^{1/2}$	Total biomass	Fresh weight	Dry weight	Loss in weight	Moisture %	Decrease in dry shoot weight over control	Decrease in dry shoot weight over control (%)
Control	**2460 a**	**2101 a**	**1009 a**	**1092**	**52**	**-**	**-**
20	**2042 b**	**1773 b**	**976 b**	**797**	**45**	**33**	**3**
30	**1583 c**	**1375 c**	**824 c**	**551**	**40**	**185**	**18**
40	**879 d**	**732 d**	**473 d**	**259**	**35**	**536**	**53**
50	**549 e**	**448 e**	**303 e**	**145**	**32**	**706**	**70**

Plants root weight

Not only shoot was affected negatively under sodic conditions but also root development was restricted significantly. Each SAR level suppressed it appreciably. The record dry mass of 243 g per plant under normal conditions was restricted to only 83 g per plant in the highest sodicity (Table 7). The reduction was recorded as 20, 34, 52 and 66 percent with respective levels of SAR 20, 30, 40 and 50. The reduction in root mass was more than shoot magnitude with first two levels (20 and 30 SAR). Moisture percentage was more in unstressed or less stressed plants compared with plant growing in highly sodic environment.

Table 7. Effect of sodicity on root weight (g/plant) of *Acacia ampliceps.*

Sodicity levels SAR $(mmol/l)^{1/2}$	Total biomass	Fresh weight	Dry weight	Loss in weight	Moisture %	Decrease in dry root weight over control	Decrease in dry root weight over control (%)
Control	2460 a	359 a	243 a	116	32	-	-
20	2042 b	269 b	194 b	75	28	49	20
30	1583 c	207 c	160 c	47	23	83	34
40	879 d	147 d	116 d	31	21	127	52
50	549 e	101 e	83 e	18	18	160	66

Note: Plants could not survive in SAR 60 and 70.

Soil characteristics (soil sodicity parameters)

Soil analysis after harvesting and uprooting of plants indicated that end SAR values remained very closer to those created before transplantation of plants. Thus, plants remained growing and faced the stressed conditions. Hence, the sodicity tolerance evaluation was almost correct, as no significant changes occurred afterwards. For example, created soil SAR level of 50 was having 47.73 mmol/l$^{1/2}$ even after two years.

Sodicity is characterized by excessive amount of sodium in soil solution and clay particle complex. Sodicity affects the plants in three ways; specific ion effect, nutritional imbalance (especially Ca, K and S) in plants and clay dispersion. Excessive Na in the soil disperses the soil granules, pores are closed/reduced in size or number, water infiltration and hydraulic conductivity is decreased, soil becomes very hard, root penetration is highly checked, root development retarded, roots suffer from air deficit and resultantly water as well as nutrients uptake is severely cut down. Thus, sodicity imposes more threat to plant growth than salinity. Functions of K, Ca and S are very vital in plants but excessive amount of Na is a big constraint for normal metabolic functions. On one way, Na reduces chances of uptake of essential elements while on the other way the lesser amount of nutrients absorbed can not perform exact and balanced role due to overwhelming quantities of Na every where within tissues. Thus, plant growth is either checked fully or partially, depending on the level of Na being faced by the plants. However, it also depends upon the nature of plant itself because certain plants have developed mechanism either to avoid sodicity or tolerate it.

The data of investigations on sodicity (Table 1-5) indicated that plant growth parameters were more negatively affected to various degrees as compared to sodicity quantum upto SAR 50 while plants could not survive and grow in levels of SAR 60 and 70. The reductions in plant height were 18, 32, 51 and 86 percent at respective levels of SAR 20, 30, 40 and 50. Stem diameter reduced from 13 to 78 percent. The number of leaves decreased from 8 to 85 percent and branches 30 to 87 percent. Canopy volume was cut short by 15 to 90 percent. These results indicate that recorded reductions were lesser when compared with many other plants. Reduction of almost 50 percent occurred at SAR 40. Hence, this plant offered very good tolerance against sodicity as well.

Another fact observed during this study was that sodicity effect was more pronounced. It did not only affect the plants directly but also deteriorated physical properties of the soil that were urgent requirements of normal growth. Research work of Maas (5) and Muhammad (9) indicated that physical conditions of soil also affected salt tolerance and root growth. The poor soil aeration in sodic soil after irrigations caused less shoot growth (10, 11).

It is clearly understandable that suppression of growth will ultimately be translated into reduction of root and shoot weight. There was decrease of 3, 18, 53 and 70 percent over control (non-sodic) in shoot weight with SAR levels of 20, 30, 40 and 50 while respective cut short was 20, 34, 52 and 66 percent in case of root dry weight.

Mass formation in plant is the product of several metabolic processes. The plant nitrogen is hydrogenised, synthesized into amino acids, proteins, cellulose and chain compounds of unbreakable nature like lignin. But if the synthesis process is slowed down or stopped totally the mass of plant measured as dry matter will ultimately be lessened corresponding with the quantum of sodicity stress. That is why, total stoppage of such reactions resulted in death of plant, as was observed in SAR 60 and 70 where plants could not survive beyond a few days. However, plants indicated almost 50 percent reduction at SAR 40 that was fairly good tolerance against more destructive stress. *Acacia ampliceps* has been reported to be tolerant of highly saline sodic and alkaline soil but intolerant to acid soils and water logging (8). Findings of Mahmood (7) were also in the same direction.

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