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Saline Irrigation Effects on Growth and Mineral Composition of *Prosopis juliflora* and *Acacia arabica* in Saudi Arabia

Saad F. Alshammary

National Center for Agricultural Technology (NCAT), King Abdulaziz City for Science and Technology (KACST), P. O. Box 6086, Riyadh - 11442, Saudi Arabia.

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A field study was carried to determine the effect of saline irrigation on growth and mineral composition of *Prosopis juliflora* and *Acacia arabica* in an arid environment of Saudi Arabia. Four irrigation waters with salinity levels of 2000, 8000, 12000 and 16000 total dissolved solids (TDS, mg L^{-1}) were used in the study. Mean biomass yield of shoots and roots of both trees increased significantly with increasing irrigation water salinity. Mean concentration of protein, Ca and Na increased while that of P, K and Mg decreased with increasing irrigation water salinity. Irrigation with high salinity water also caused significant increase in soil salinity.The study proved the sequence for salt tolerance as *Acacia arabica* > *Prosopis juliflora*. Overall, the study showed the potential of developing range lands by growing these two trees using saline irrigation water.

Key words: Irrigation water salinity, *Prosopis juliflora*.

Soil salinity is a global problem of many arid and semi-arid regions of the world due to saline water irrigation supplementing inadequate fresh irrigation supplies and high crop evapo-transpiration rates (Lauchli and Epstein, 1990; Ashraf *et al*., 2008; Kamal Uddin *et al*., 2009). Worldwide about 20% of cultivated land is adversely affected by high salt concentration, which inhibits plant growth and yield (Tanji, 1990). In warm and dry areas salt concentration increases in the upper soil layer due to high water losses which exceed precipitation (Ebert *et al*., 2002). Salinity is a menace for agriculture, forestry, pasture development and other similar practices. It is well known that high concentrations of salts have detrimental effects on plant growth (Mer *et al*., 2000; Lopez *et al*., 2002; Ashraf, 2002; Ashraf *et al*.,2004; Alshammary,2008; Hussain, and Alshammary, 2008) and excessive concentrations kill growing plants (Munns, 2002).

Many countries in arid and semi-arid Africa are suffering from decline in fresh water resources available for agriculture and looking for alternative methods to balance between supply and demand. Many investigators have reported retardation of germination and seedling growth at high salinity (Ashraf, 2002; Ramoliya and Pandey, 2003; Ashraf *et al*., 2004; Ashraf *et al*.,2008). However, plant species differ in their sensitivity or tolerance to salts. The negative impact of salinity on growth of plants in irrigated and non-irrigated areas of the world especially in the arid regions continues to be a major problem. Urban expansion and increasing population have developed competition for freshwater among the municipal, industrial and agricultural sectors in several regions. The consequence has been a decreased allocation of

* To whom all correspondence should be addressed.
Tel.: + 966503188293; Fax: +96611481361;
E-mail: sshammary@kacst.edu.sa.

freshwater to agriculture (Tilman *et al*., 2002). This phenomenon is expected to continue and to intensify in less developed, arid region countries that already have high population growth rates and suffer from serious environmental problems. In Argentina, Velarde *et al*. (2003) observed that the survival of P. pallid families was significantly greater (61.1% vs. 41.7%) and percentage of seedlings that grew (37.4% vs. 23%) at seawater salinities of 45 dS $m^{-}1$ than P. alba.

Qadir and Oster (2004) emphasized that production systems based on salt tolerant plant species using drainage waters may be sustainable with the potential of transforming such waters from an environmental burden into an economic asset. Meloni *et al*. (2004) stated that *Prosopis alba* (algarrobo) is one of the most important salt-tolerant legumes used in the food and furniture industries. They observed that only the highest NaCl concentration affected all of the considered parameters. Thus, 600 mmol.L^{-1} NaCl caused a significant reduction in root and shoot growth, but an increase in the root/shoot ratio. Tomar and Yadav (1980) observed that the percentage of germination, shoot growth and root length of plant species such as Acacia nilotica, Pongamiapinnata and *Prosopis juliflora* and mortality increased by increasing EC, SAR and RSC than the control (fresh water irrigation). However, the plant species mentioned above proved sensitive to saline water with an EC > 2 dS m^{-1} and an SAR > 5 at the early stages of germination. However, in the presence of fresh water supplies, waters of EC 8-10 dS m^{-1} and SAR up to 30 can be used for *Acacia nilotica*, *Pongamia pinnata* and *Prosopis juliflora*, and waters of EC 4-6 dS m^{-1} and SAR up to 15 can be used for A. tortilis, *Albizia lebbeck* [lebbek], *Azadirachta indica*, *Lawsonia glauca* and *Parkinsonia aculeata*. Ewens *et al*. (2012) established *Prosopisalba, P. vinalillo* and Peruvian *Prosopis* in a seed orchard/ long term evaluation trial on soils with low salinity (EC 5.1–7.5 dS m^{-1}) but high pH (8.9 to 10.2). They observed salt tolerance of the putative *P. vinalillo*clones may prove useful as rootstocks for recently described high pod producing *P. alba*clones.

Miyamoto *et al*. (1996) carried out lysimeter investigation in the coastal deserts of Sonora, Maxico on salt tolerance, salt uptake and water use of four halophytes (*Atriplex nummularia*, Distichlispalmeri, Batis maritime and Suadaesteroa) using saline irrigation water. They stated that frequent irrigation at higher leaching fractions may be required at higher salinities. Congming *et al*. (2002) stated that increasing salt concentration of irrigation waters resulted in a significant accumulation of sodium and chloride in leaves of halophyte Suaeda salsa. Ramoliya and Pandey (2002) found that *Salvadora oleoides* (Salvadoraceae) at seed germination stage exhibited a negative relationship with increasing concentration of salts and showed its salt tolerance at this stage. Seedlings survived and grew upto 16.5 dS m^{-1}. Khasa *et al*. (2002) found a significant interaction between salt treatments and seed lots within species as well as between salt treatments and plant species for weight and necrosis indicating that the plant genotype responded differently to salt treatment. However, Ungar (1998) observed that the influence of physiochemical and biotic factors is important to the distribution and establishment of halophytes.

Viegas *et al*. (2004) stated that plants grown in 25 and 50 mmol L^{-1}NaCl accumulated a total dry mass (DM) and shoot N content greater than the control. However, at 75 and 100 mmol L^{-1} NaCl such parameters were diminished. Increasing external NaCl concentration increased K/Na ratio of both plant parts (shoot and root). Salt tolerance has been partially linked to the regulation of shoot Cl and Na concentration (Teleisnik and Grunberg, 1994). Plant adaptation to salinity during germination and early stages of growth is crucial for the establishment of species especially under saline environments (Unger, 1995, 1996). Abo-Kassem (2007) stated that high salinity delayed radical emergence and decreased germination percentage in all plants including Atriplexhortensis specie.

Although much research has been conducted on many salt tolerance and drought resistant range plants such as Acacia nilotica, Pongamiapinnata and Prosopisjuliflora elsewhere, but very little is accomplished on these plants in Saudi Arabia. Therefore, the main objective of this study was to study the performance some of these trees such as Prosopisjuliflora and Acacia arabica under saline irrigation in an arid environment of Saudi Arabia for the development of sustainable rangelands as viable source of fodder for range animals.

MATERIALS AND METHODS

The experiment was carried out at King Abdulaziz City for Science and Technology (KACST), Research Station, Al-Muzahmiyah around 70 km west of Riyadh. The experiment was carried for 2-years from 2010 -2011 season.

Experimental treatments

The experimental treatments include one soil(sandy), four Irrigation Water Salinity levels (2, 8, 12 and 16 Thousand total dissolved solids, TDS mg L^{-1}), two tree species (Prosopisjuliflora and Acacia arabica) and one irrigation level (irrigation at 50 % moisture depletion at field capacity). The treatments were replicated 3 times.

Experimental procedure

The selected local tree species were planted in the field at Al-Muzahmyia Research Station. The total area of each experimental block was 2 x 2 m^2 and was walled with concrete block around it. The experiment was setup by following A Complete Randomized Block Design. The trees were planted by following "Completely Randomized Design".

Composition of irrigation waters

Irrigation waters of different salinities were prepared by mixing freshwater (well water) and highly saline water from an evaporation pond in an appropriate combination. Water samples were collected after each preparation for analysis. Mean chemical composition of irrigation waters is presented in Table 1.

Establishment of irrigation system

The irrigation system was established by placing one water tank of 3 m^3capacity for each water salinity treatment. A small water pump of 1-Horse Power was installed at the base of each water tank for irrigation. However, the control treatment plots received fresh irrigation water directly through the main water supply line. Trees were irrigated with the desired salinity waters with an irrigation interval of 2-3 days during the growth period. The soil moisture contents were measured by gravimetric method (USDA, 1954). The soil moisture contents of soil (sandy) came to 18-19 % by weight at saturation and 8-9 % by weight at field capacity. The soil moisture contents of irrigation basin of each tree (size = 40 cm diameter x 50 cm depth) were calculated to determine the amount of irrigation water needed to fulfill the field capacity of soil. The bulk density of soil was determine and came to 1.60 g cm^{-3}. The irrigation criterion was to maintain the soil moisture level to field capacity. A pre-sowing irrigation was applied by putting about 8.3 liters of water to bring the soil in the basin to field capacity. The experimental soil was sandy (94 % sand, 3 % silt and 2 % clay) with a field capacity of 8 % by weight, EC of 2.25 dS m^{-1}, SAR of 1.75 and 3.75 % $CaCO_3$. The irrigation was applied at 50 % moisture depletion at field capacity. The soil moisture deficit was monitored by tesiometers installed in the experimental plots at 20 cm and 40 cm depth. A calibration curve was developed for the tensiometer readings against the soil moisture contents to determine the soil moisture deficit for irrigation. Total amount of irrigation water came to 3-4 liters per irrigation per tree as deficit to bring back the soil moisture to field capacity level.

Soil samples

Three composite soil samples were taken for the experimental soil from 0-15 and 15-30 cm depth for physical and chemical properties. These soil textures, soil pH, EC, cations and anions and $CaCO_3$ contents. Post-harvest soil salinity measurements were taken every year. The soil pH and EC were determined by following Method No. 3a (pp. 84) and 4a (pp. 89) of USDA (1954).

Plant analysis

Plant samples were collected at the time of harvest, air-dried, ground in a Willy Mill and stored for analysis. Plant samples were analyzed for P, Na, K, Ca, Mg and protein contents to evaluate the nutritional value of plants for forage purposes. The plant samples were analyzed by following by different analytical methods as described by Chapman and Pratt (1978).

Analytical procedures

The standard analytical procedures described in the AOAC (2003) were followed for soil, water and plant analysis. The following laboratory equipment / instruments were used for analytical work.

Plant growth measurements

Plant growth measurements included fresh biomass and fresh root weight. Also, root to shoot ratios were calculated.

Data analysis

Data were analyzed by ANOVA and

S. No.	Description	Analysis
1	ICP OPTIMA 2000DV (Perken Elmer)	Trace Elements
2	Ion-Chromatography	Anions (HCO_3, Cl, SO_4, NO_3).
3	Ion-Chromatography	Cations (Na, K, Mg, Ca)
4.	Mars-5 Digestion/Extraction	Sample Preparation.
5.	pH/ Conductivity meter/DO Star-5	Field Analysis (EC, DO, Temperature, pH, turbidity).

regression techniques for treatment evaluation at 5 % level of significance according to SAS Institute (2001).

RESULTS

Fresh biomass yield

Mean fresh biomass yield (kg/plant) ranged from 1.13-2.02 (*Prospis juliflora*) and 1.14-6.74 (Acacia arabica) in different water salinity treatments (Table 2a). Mean biomass yield of both the trees increased significantly with increasing irrigation water salinity than the control treatment. This suggests that highly saline irrigation water proved a source of nutrition to these trees. Overall, *Acacia arabica* proved more salt tolerant than *P. juliflora* under the existing plant growing conditions.

Fresh weight of plants roots

Mean fresh weight of plants roots (kg/plant) ranged from 0.65-0.72 (*Prosopis juliflora*) and 0.72-1.96 (*Acacia arabica*) in different water salinity treatments (Table 2b). Mean fresh weight of plant root increased significantly for both the trees than the control treatment with increasing salinity of irrigation waters. The results indicated that high irrigation water salinity proved a source of nutrition to these trees for its growth. In conclusion, *A. arabica* proved more salt tolerant than *P. juliflora* under the existing experimental conditions.

Plant root/shoot ratio

Mean root to shoot ratios of different plants were 0.36-0.58 (*Prosopis juliflora*) and 0.29-0.63 (*Acacia arabica*) in different water salinity treatments (Table 2c). It was noticed that root/shoot ratios of trees decreased with increasing water salinity for both the trees. This decrease in root to shoot ratio might be due to adverse effect of increasing irrigation water salinity on plant root development thus causing appreciable reduction in plant roots as compared to the above ground plant biomass production.

Mineral composition of plant shoots:

Prosopis juliflora

Mean concentration (%) of different minerals ranged from 7.76 – 8.75 (Protein), 0.110-0.165 (P), 0.73-0.96 (K), 1.03-1.45 (Ca), 0.25-0.32 (Mg) and 0.85-1.79 (Na) in different water salinity treatments (Table 3). Mean protein contents of P. juliflora increased with increasing water salinity. The concentration of Ca and Na ions increased while that of P, K, Mg decreased significantly with increasing irrigation water salinity.

Table 1. Mean Chemical Composition of Well, Evaporation Pond and Treatments Waters

Parameter	Pond Water	Treatment1(Well Water)	Treatment 2	Treatment 3	Treatment 4
PH	7.8	7.6	8.7	7.7	7.64
TDS (mg L^{-1})	17,760	2,021	8,000	12,000	16,000
Calcium (mg L^{-1})	1512	208	731	947	1239
Magnesium(mg L^{-1})	798	58	370	492	680
Sodium (mg L^{-1})	4398	222	1930	2786	3800
Potassium (mg L^{-1})	251	15	109	160	166
Chloride (mg L^{-1})	8394	640	4319	5464	7740
Carbonate (mg L^{-1})	18	0	16	6.9	30
Bicarbonate(mg L^{-1})	172	149	130	110	147
SAR	24	3.4	16.6	20.2	21.45

Acacia arabica

Mean contents (%) of different minerals ranged from 8.15-11.20 (Protein), 0.089-0.132

(P), 1.76-1.98 (K), 1.30-2.60 (Ca), 0.72-1.15 (Mg) and 0.17-0.49 (Na) in different water salinity treatments (Table 3). Mean protein concentration of *A.arabica* increased significantly with increasing water salinity. However, the concentration of P, K, and Mg decreased and that of Na and Ca increased significantly with increasing irrigation water salinity.

Mineral Composition of Plant Roots:

Prosopis juliflora

Mean contents (%) of different minerals were 0.37-0.50 (K), 1.55-2.18(Ca), 0.15-0.22(Mg) and 1.28-2.69 (Na) in different water salinity treatments (Table 4). Mean K and Mg contents decreased, whereas Na and Ca contents increased significantly with increasing irrigation water salinity.

Acacia arabica

Mean contents (%) of different minerals were 0.77-1.02 (K), 1.93-3.96 (Ca), 0.47-0.75 (Mg) and 0.26-0.74 (Na) in different water salinity treatments (Table 4). The Ca and Na contents increased while that of K and Mg contents decreased significantly with increasing irrigation water salinity in different treatments.

Soil salinity

Mean soil salinity (EC as dS m^{-1}) of 0-15 cm surface soil depth was 3.85 (T-1, control), 9.55 (T-2), 13.85 (T-3) and 18.54(T-4) and for 15-30 cm soil depth 4.86(T-1), 8.28 (T-2), 14.57 (T-3) and 20.45 (T-4) in different water salinity treatments during the growing season (Table 5). Overall, weighted mean soil salinity (EC as dS m^{-1}) of 0-30 cm soil depth was 4.35, 8.92, 14.21 and 19.50 in T-1, T-2, T-3 and T-4 treatments, respectively (Table 5). Mean soil salinity increased significantly with increasing irrigation water salinity. The significant increase in soil salinity might be due to the addition of salts by high irrigation water salinities.

Table 2. Effect of Irrigation Water Salinity on Fresh Biomass and Fresh Root Weight of Plants (Kg/Plant)

Fresh Biomass Yield Tree/Plant	2000 kg /plant	8000	12000	16000
P. juliflora	1.13 a	1.37 b	1.87 b	2.02 b
A. arabica	1.14 a	5.37 a	6.53 a	6.74 a
Plant Root Fresh Weight				
P. juliflora	0.65 b	0.59 b	0.68 b	0.72 b
A. arabica	0.72 a	1.75 a	1.92 a	1.96 a
Plant Root/Shoot Ratio				
P. juliflora	0.58 b	0.43 a	0.36 a	0.36 a
A. arabica	0.63 a	0.33 b	0.29 b	0.29 b

Mean values in a row followed by the same letter are not significantly different by $LSD_{0.05}$.

Table 3. Mean Mineral Composition (%) of Different Plants

Protein Tree/Plant	2000 kg /plant	8000	12000	16000
P. juliflora	7.76	7.98	8.38	8.75
A.arabica	8.15	9.75	10.25	11.20
Phosphorus (P)				
P. juliflora	0.165	0.145	0.125	0.110
A.arabica	0.132	0.112	0.096	0.089
Potassium (K)				
P. juliflora	0.96	0.91	0.85	0.73
A.arabica	1.98	1.88	1.79	1.76
Calcium (Ca)				
P. juliflora	1.03	1.12	1.28	1.45
A.arabica	1.30	1.82	2.26	2.60
Magnesium (Mg)				
P. juliflora	0.32	0.31	0.25	0.26
A.arabica	1.15	0.95	0.79	0.72
Sodium (Na)				
P. juliflora	0.85	1.35	1.57	1.79
A.arabica	0.17	0.28	0.35	0.49

Table 4. Mean Mineral Composition (%) of Plant Roots

Potassium (K) Tree/Plant	2000 kg /plant	8000	12000	16000
P. juliflora	0.50	0.48	0.43	0.37
A.arabica	1.02	0.98	0.87	0.77
Calcium (Ca)				
P. juliflora	1.55	1.71	1.89	2.18
A.arabica	1.93	2.80	3.36	3.96
Magnesium (Mg)				
P. juliflora	0.22	0.21	0.15	0.16
A.arabica	0.75	0.65	0.53	0.47
Sodium (Na)				
P. juliflora	1.28	2.05	2.35	2.69
A.arabica	0.26	0.48	0.55	0.74

Table 5. Effect of Irrigation Water Salinity on Soil Salinity (ECe = dS m^{-1})

Soil Depth	Water Salinity (TDS, mg L^{-1})			
(cm)	2000	8000	12000	16000
0-15	3.85	9.55	13.85	18.54
15-30	4.86	8.28	14.57	20.45
0-30	4.35	8.92	14.21	19.50

DISCUSSION

The results of the present study showed that boimass yield and the plant root biomass of both trees (ProsopsiJuliflora and Acacia Arabica) increased significantly with an increase in irrigation water salinity. The results agree with those of Gerhart *et al*. (2006) who used high total dissolved solid (TDS) blow down water from cooling towers for irrigation of some landscape trees. All plants grew well and irrigation salinity did not have a significant effect on growth or water use. The growth and survival of 27 Prosopis families in Argentina was compared as a function of salinity from 10 to 45 dS m^{-1}. The mean of the P. pallid families had a significantly greater survival (61.1% vs. 41.7%) and percentage of seedlings that grew (37.4% vs. 23%) at seawater salinities of 45 dS m^{-1} than P. alba. In another study, Tomar and Gupta (1985) reported that due to genetic differences, species of trees differed in their ability to withstand salinity and aeration stresses individually and simultaneously. Tree species like *Casuarina equisetifolia, Tamarix articulata* and *Prosopis juliflora* can be planted where high salinity or high water table conditions exist separately or simultaneously.

Mean mineral composition of both P. juliflora and *A. arabica* showed that concentration of Ca and Na ions increased while that of P, K, Mg decreased significantly with increasing irrigation water salinity in the plant tissue and roots. Similar findings were reported by many investigators such as Soliman *et al*. (2012) who investigated the alleviation of salt stress (0, 6.25, 12.50 and 25 dS/m) on growth and development of *Acacia saligna.* The salt stress increases the percentage of sodium (Na) and calcium (Ca) contents as well as proline; but it reduced the nitrogen, phosphorus, potassium contents. In another study, a negative relationship between seed germination and salt concentration was obtained in *Acacia catechu* (Mimosaceae). Plants accumulated Na in roots and K rapidly decreased in root tissues with increased salinisation. Nitrogen content decreased in all tissues (leaf, stem and root) in response to low water treatment and salinisation of soil. Phosphorus content significantly decreased, while Ca increased in leaves as soil salinity increased (Ramoliya *et al*., 2004). Some studies determined the effects of soil salinization on emergence, growth, water status, proline content, and mineral accumulation of seedlings of Acacia auriculiformis A. (Fabaceae). It was observed that potassium and sodium content significantly increased in tissues as salinity increased. Nitrogen content significantly increased in tissues with soil salinization. Phosphorus, calcium and magnesium content significantly decreased as salinity increased (Patel *et al*., 2010).

Soil salinity also increased significantly with increasing irrigation water salinity in this study. These findings are similar to those of El-Hendawy (2004) who stated that irrigation with low quality water (up to salinity of 4.5 dS/m) is one of many reasons that cause secondary salinization in Egypt (El-Hendawy, 2004). Therefore, planting salt tolerant species is the most useful approach in rehabilitating salt-affected degraded lands (Rasmussen *et al*., 2009).

CONCLUSIONS

Mean biomass yield of both the trees (*Prosopis juliflora* and *Acacia arabica*) increased significantly with corresponding increase in irrigation water salinity. Also, high irrigation water salinity proved as source of nutrition to these trees which are semi ot high salt tolerant species. The concentration of Ca and Na increased while that of Mg, K and P decreased with increasing irrigation water salinity. Soil salinity also increased with irrigation waters of high salinity. The study proved the sequence for salt tolerance as Acacia Arabica >Prosopisjuliflora. Overall, the study showed the potential of developing range lands by growing these two trees using saline irrigation water.

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