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SALT TOLERANCE OF *KOCHIA SCOPARIA*: A NEW FODDER CROP FOR HIGHLY SALINE ARID REGIONS

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Abstract

Effects of salinity on germination, growth, ion accumulation and water relations were studied in a highly palatable and nutritious forage grass species- *Kochia scoparia,* under greenhouse conditions. It was highly tolerant to salinity (600-800 mM NaCl) at germination; the seedling growth remained unaffected up to 600 mM NaCl and the plants survived with reduced growth upto a high salinity of 1800 mM NaCl. Maintenance of leaf succulence seemed dominant factor in offsetting harmful effects of salinity.

Introduction

Salinity of soil and water has been major impediment for plant growth and a solution is not forthcoming at least in the near future. Our best bet lies in identifying plant species that could tolerate the adverse conditions prevailing in such situations. This approach is equally applicable to plants of human and animal consumption. However, whereas changing culinary preferences of mankind may be problematic, it may comparatively be easier to accomplish in case of animals. This would not only ease pressure on arable lands, thus making them available for our conventional agricultural crops, but also help in increased production of meat, milk and other dairy products.

Use of halophytes as animal fodder attracted attention of scientists toward the later half of last century and papers on effect of brackish drinking water and salty feed on animal health and meat quality/quantity started appearing (Wilson, 1966, Walker *et al*., 1971, Hopkins & Nicholson, 1999, Thomas *et al*., 2007) and the problems encountered in such studies were identified (Weston *et al*., 1970, Weston, 1996, Wilson & Kennedy, 1996). Subsequently, scattered reports appeared in the literature where scientists from Australia, Indo-Pakistan, Middle East, Africa and North/South America working in the relevant fields have attempted replacing the regular fodder with one or another halophyte.

In almost all of these studies halophytes from family Amaranthaceae have been used, many of which have toxic organic compounds and a high salt load in their foliage e.g. *Atriplex* spp., *Suaeda* spp., *Salicornia bigelovii* (Graetz & Wilson, 1980, Nawaz & Hanjra, 1993, Glenn *et al*., 1992, Swingle *et al*., 1996, Kraidees *et al*., 1998,). This not only reduces palatability and causes disturbance in the digestion process (Hemsley *et al*., 1975) but also increases the thirst of the animals (Marai *et al*., 1995). In a water deficit environment of an arid area, this may be a major limitation.

Kochia scoparia, a dicotyledonous erect annual herb of the family Amaranthaceae with high genetic diversity and great potential as fodder, is found scattered in salt and/or drought affected areas (Mullinex, 1998, Al-Ahmadi & Kafi, 2008, Kafi *et al*., 2010). The plant height may range between 15 cm and 2 m depending upon density stand; high density stands (more than 600 plants.m^2) result in reducing height (Galitzer & Oehme, 1979). Kafi *et al*., (2010) have recently published a detailed account of the salt tolerance of Iranian variety of *K. scoparia* and are of the view that it is a potential fodder species in cold temperate regions of the world. Riasi *et al*., (2008) conducted feeding trial of leaf succulent halophytes and reported that *K. scoparia* had better nutritional and digestive values as forage for ruminants compared to the other species under test. In addition, rapid vegetative growth under high salinity, drought and temperature stress makes it a very valuable candidate as a non-conventional fodder crop for arid temperate regions (Jami Al Ahmadi & Kafi, 2008a).

The present study investigates the salt tolerance of *K. scoparia* collected from Great Basin Desert, USA during germination and growth under salinity regimes up to twice the concentration of seawater.

Material and Methods

The seeds of *K. scoparia* were collected from a salt marsh located 30 miles south of Great Salt Lake, Faust, Utah, USA, separated from the inflorescence and stored at 4^{o}C after surface sterilization using the fungicide Phygon (Hopkins Agricultural Chemical Co., Madison, Wis.). Germination was carried out in 50 mm x 9 mm tight-fitting plastic Petri dishes with 5 ml of 0, 300, 600, 900, 1200 and 1800 mM NaCl solution. Each dish was placed in a 10 cm diameter plastic Petri dish as an added precaution against loss of water by evaporation. Four replicates of 25 seeds each were used for each treatment. Seeds were germinated in a growth chamber at an alternating temperature regime of 25-35^{o}C where the higher temperature coincided with the 12-h light period (Sylvania cool white fluorescent lamps 25 μmol-m-^{2}.s-^{1}, 400-750 nm) and the lower temperature coincided with the 12-h dark period. Germination was recorded for 20 days on every alternate day and seeds were considered germinated at the emergence of radicle.

For seedling growth under salinity, cores along with soil of young seedlings about 3cm size were planted in sand filled plastic pots of 12.7 cm diameter x 12.7 cm height and thinned after one week to leave five equal sized seedlings in each pot. Six salinities (300, 600, 900, 1200, 1500, 1800 mM NaCl) and a control without salts with four replicates were used and these pots were sub-irrigated after placing them in plastic trays containing half strength Hoagland solution. Water level in the trays was adjusted daily and the solutions were completely replaced every seven days. The salinity was increased gradually by 300 mM at alternate days till the required concentration was achieved. The temperature and light/dark regimes during growth were same as described above for seed germination study. The plants were harvested 60 days after attaining desired salinity and dried at 80^{o}C for 48 h in a forced draft oven after recording their fresh weight.

For determination of ions concentration, 0.5 g dried plant material was boiled in 25 ml distilled water for two hr at 100^{o}C in a dry heat bath, cooled and filtered. Cl, NO_3 and SO_4 were measured with a DX-100 ion chromatograph while Na, K, Ca and Mg were analyzed using a Perkin Elmer model 360 atomic absorption spectrophotometer. Water potential was determined with a plant moisture stress instrument (PMS Instruments). The results were subjected to one-way ANOVA to determine significant differences among means and Bonferroni test was carried out for significance between individual treatments (Anon., 1996).

Results

Germination remained unaffected by salinity at 200 mM NaCl but reduced to around 50% at 600 mM and to 20% at 1000 while no seed germinated beyond 1400 mM (Fig. 1). Fresh and dry weights of shoot (Figs. 2, 3) remained unchanged from control up to 600 mM but higher salinity reduced both. This reduction was more in fresh than in dry weight. Root weights (both fresh and dry, Figs. 2, 3) remained almost unaffected by salts. Compared to control, shoot water content was higher in plants growing at 300 mM while higher salinities reduced it back to the values observed in control. Roots under salinity generally contained more water than under control (Fig. 4). The ion contents were generally more in shoot (Table 1) than in roots (Table 2) with the exception of calcium and nitrate which had an opposite trend.

Discussion

Soil salinity exists naturally or develops as a consequence of improper irrigation practices without taking into consideration the leaching fraction. This increases the level of underground water table which eventually results in buildup of high salinities in the upper soil layers due to capillary rise of water and its subsequent evaporation leaving the salts behind. The phenomenon attains significance in dry regions which occupy more than one-third of the earth's land area and are inhabited by approximately 16% of human population where climatic change has disturbed the ecological balance. Irregular rainfall creates further problems here.

Finding suitable forage/fodder which does not encroach upon the land under conventional crops may be useful for cattle raising and meeting the requirement of meat and dairy products; Kochia may be one such option. The seeds of the present study were collected from the salt playa of Great Basin, Utah where high salinity and extremes of temperatures (both low and high) exist; these were not as salt tolerant at germination as during early seedling growth. Like a typical halophyte, the seeds under natural condition, lie dormant and start germination with the onset of summer which brings favourable temperatures while early season rains dilute substrate salinity and does not much hinder the growth.

Steppuhn & Wall (1993) claimed that Kochia offers great potential as a crop that can be grown on saline soils, yielding fodder in quantities approaching that produced by alfalfa (*Medicago sativa* L.). Shamsutdinov *et al*., (1996) also reported more than 15 Mg ha^{-1} dry matter production for Kochia under saline conditions and concluded that it is a good candidate for forage hay. Coxworth & Salmon (1972) proposed the use of Kochia seed as a component of the diet of turkey poultry. The possibility of converting Kochia from a wild pioneer plant to a cultivated annual forage crop has been considered by many workers (Coxworth *et al*., 1988, Steppuhn and Wall, 1993, Jami Al Ahmadi & Kafi, 2008b). Farmers in some arid areas of the world have already begun to cultivate Kochia as a salt-tolerant forage crop on lands where other crops are difficult to grow; accordingly, it has been called ''the poor man's alfalfa'' (Kafi & Jami Al Ahmadi, 2008). The fast vegetative growth and drought/high temperature tolerance of Kochia indicate that this plant has a high potential to be adopted as an important forage and fodder crop, especially in desert areas (Jami Al Ahmadi & Kafi, 2008a).

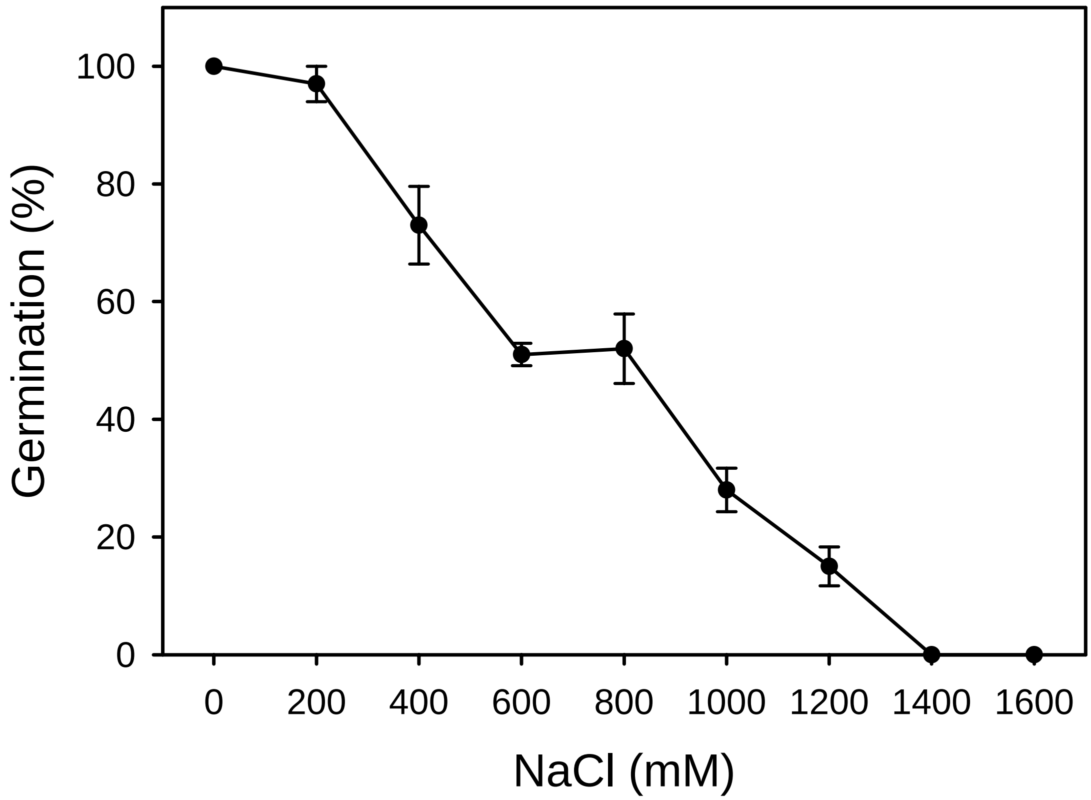

Fig. 1. Seed germination (Mean± S.E.) of *Kochia scoparia* under various concentrations of NaCl at 25-35^{o}C.

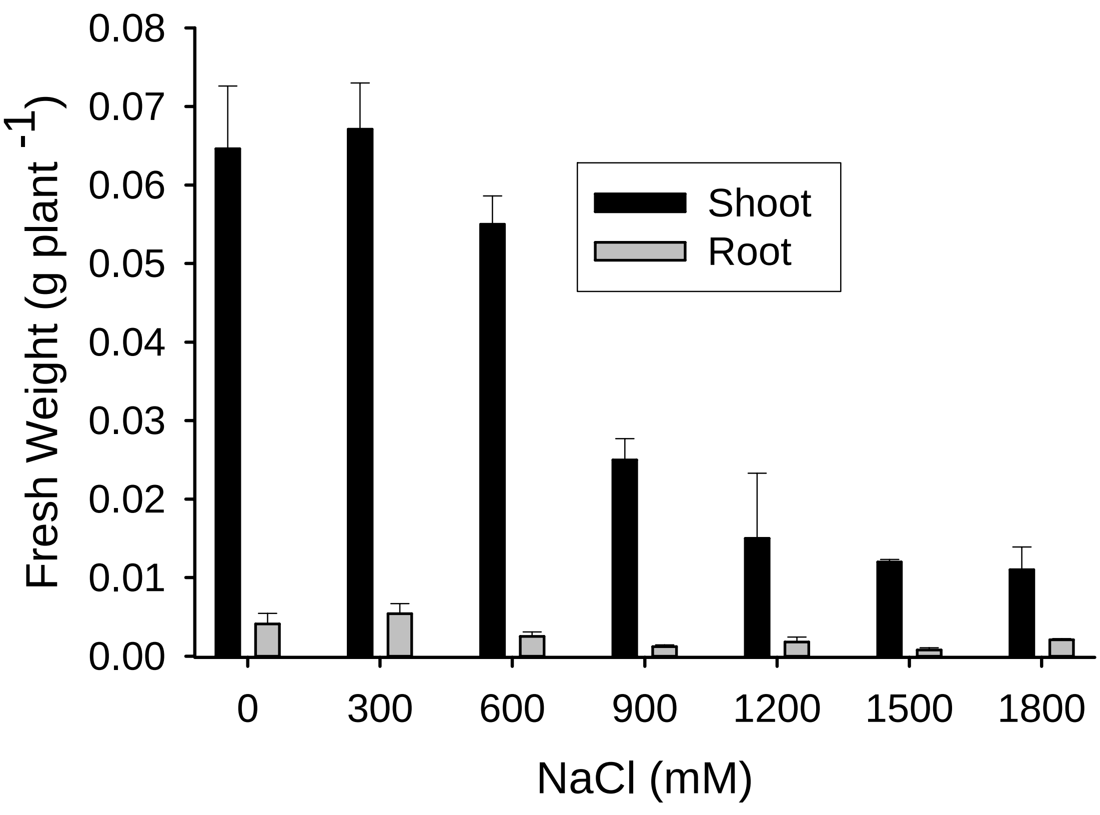

Fig. 2. Effect of NaCl on fresh weight of Kochia scoparia shoots and roots. Bar represents means with standard errors. Different letters above bars represents a significant difference ($p<0.05$) between salinity treatments.

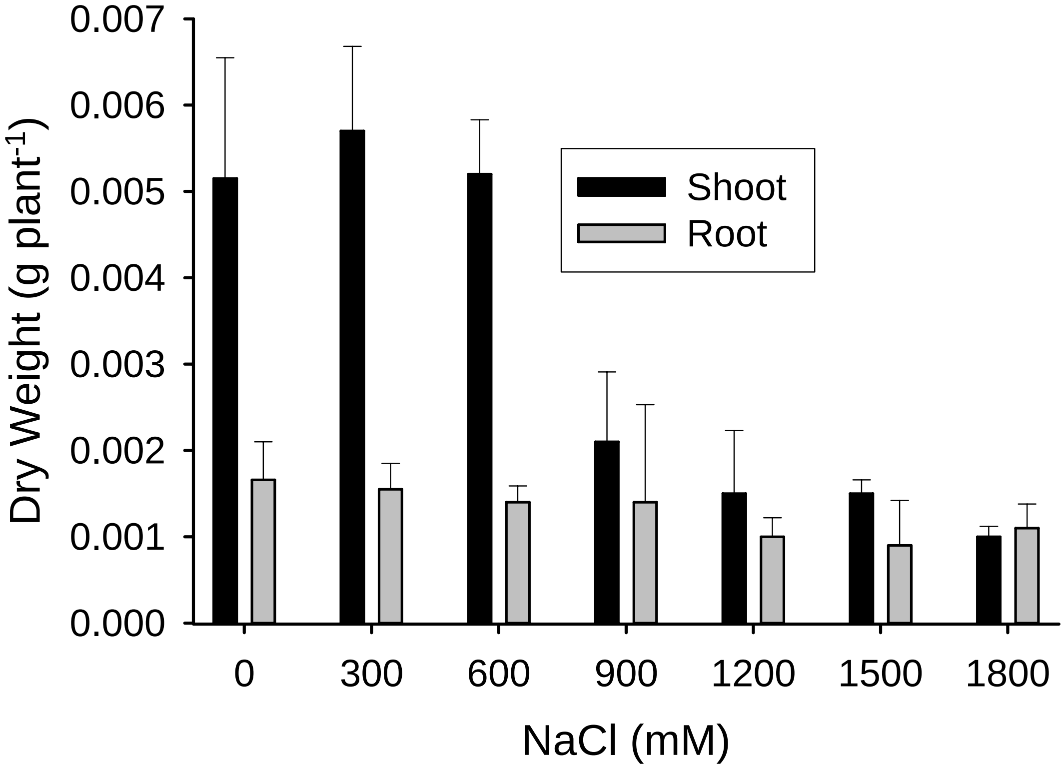

Fig. 3. Effect of NaCl on dry weight of *Kochia scoparia* shoots and roots. Bar represents means with standard errors. Different letters above bars represents a significant difference ($p<0.05$) between salinity treatments.

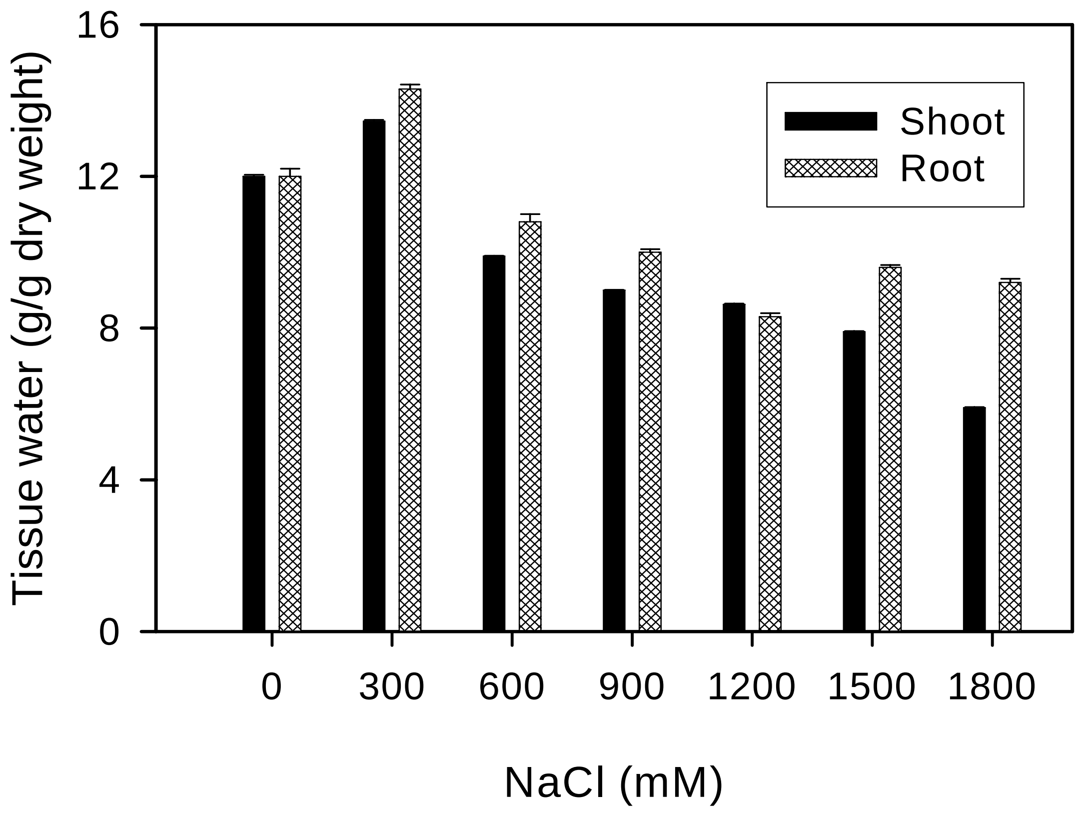

Fig. 4. Effect of NaCl on tissue water content of *Kochia scoparia* shoots and roots. Bar represents standard error. Difference letters above bars represents a significant difference ($p<0.05$) between salinity treatments.

Table 1. Change in cations and anions concentrations in the shoots of *Kochia scoparia* under various NaCl concentrations. Values represent Means ± standard error.

NaCl (mM)	Na^+ (mM)	K^+ (mM)	Ca^{++} (mM)	Mg^{++} (mM)	Cl^- (mM)	SO_4 (mM)	NO_3 (mM)
0	960	17.0	0.7	66.6	973	30.09	0.04
	±15.2	±0.8	±0.1	±0.8	±22.2	±11.5	±0.01
300	1102	15.0	1.0	70.4	1162	68.7	0.19
	±24.7	±0.7	±0.2	±3.0	±54.3	±5.0	±0.1
600	1433	12.4	0.9	74.4	1503	43.6	0.17
	±14.6	±0.9	±0.21	±3.7	±53.3	±8.3	±0.03
900	1635	10.0	1.1	60.7	1702	37.2	0.39
	±31.3	±1.2	±0.3	±4.9	±84.3	±8.5	±0.17
1200	1788	11.8	0.6	57.9	1760	36.9	0.18
	±22.4	±0.8	±0.2	±0.8	±74.2	±3.7	±0.006
1500	1830	10.4	0.7	58.4	1835	27.7	0.56
	±53.5	±0.9	±0.1	±3.4	±40.6	±4.7	±0.09
1800	1890	10.5	0.7	60.4	1913	31.7	0.46
	±36.5	±0.8	±0.1	±1.4	±61.2	±9.4	±0.07

Table 2. Change in cations and anions concentrations in the roots of *Kochia scoparia* under various NaCl concentrations. Values represent Means ± standard error.

NaCl (mM)	Na^+ (mM)	K^+ (mM)	Ca^{++} (mM)	Mg^{++} (mM)	Cl^- (mM)	SO_4 (mM)	NO_3 (mM)
0	839	9.9	3.6	62.1	776	24.1	9.8
	±41.0	±1.3	±0.5	±0.5	±70	±3.7	±4.5
300	1067	8.7	4.8	54.7	987	17.1	8.6
	±32.4	±1.6	±0.8	±1.6	±19	±2.6	±1.2
600	1248	10.9	9.6	46.1	1187	13.7	8.4
	±15.8	±0.9	±2.3	±0.9	±30	±2.4	±5.4
900	1395	8.0	6.4	45.5	1283	14.3	11.3
	±28.7	±0.7	±2.4	±1.8	±28	±2.0	±6.2
1200	1517	9.9	3.6	43.6	1464	16.6	9.6
	±16.7	±1.2	±0.4	±2.7	±38	±4.8	±2.0
1500	1815	9.3	5.6	51.8	1687	37.1	4.3
	±27.3	±0.7	±0.5	±4.2	±32	±19.0	±0.4
1800	1936	8.5	5.9	41.8	1787	27.7	3.6
	±40.8	±0.9	±0.3	±3.8	±54	±8.0	±0.9

Germination tests of Kochia seeds evaluated under different levels of salinity (0–20, 5 dS m_1 intervals) and temperatures (10–40 8C) showed adaptability under a wide range of temperatures, from 3.4°C (Tbase) to 49.7°C (Tmax), with the optimum of 24°C (Jami Al Ahmadi & Kafi, 2006, 2007). Steppuhn & Wall (1993) tested the germination of Kochia seeds in saline solutions, with salinities reaching up to 30 dS m^{-1}, and reported that germination of this plant reduced 3.3% per 1 dS m^{-1} increment of salinity between 12 and 30 dS m^{-1}. Khan *et al*., (2001) reported that a few seeds of this plant germinated even at 1000 mmol/L NaCl.

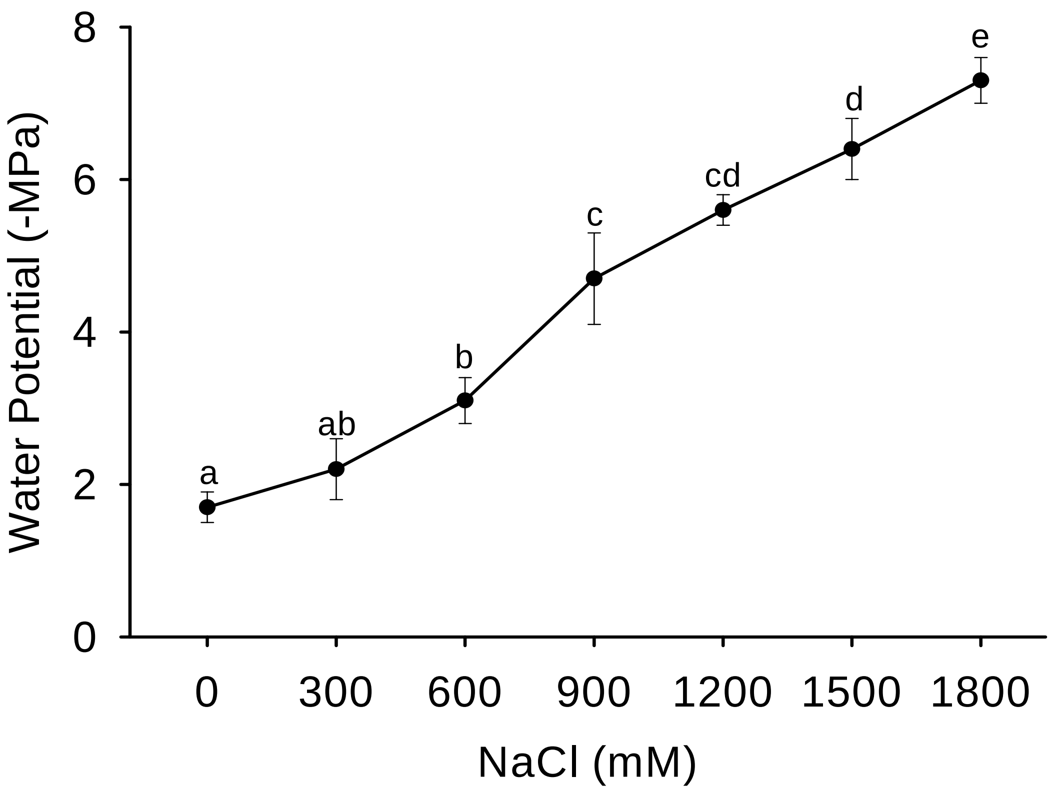

Fig. 5. Effect of NaCl on tissue water potential of *Salicornia utahensis*. Lines represent mean with standard error. Different letters above lines represent a significant difference ($p<0.05$) between treatments (Bonferroni test).

In other studies (Jami Al Ahmadi & Kafi, 2008a,b), growth and development of Kochia were tested in the field at three levels of irrigation-water salinity (1.5, 8.6, and 28.2 dS m^{-1}). Salinity negatively influenced most of the morphological and physiological indices of the plant; yet, the dry-matter accumulation under the highest salinity (28.2 dS m^{-1}) level reached 60% of that in plants grown at lower saline levels, while the moderate salinity (8.6 dS m^{-1}) caused a small amount of stimulus in the plant's growth and yield. Although Kochia is not grown for seed production, its seeds contain considerable amounts of protein (20–25%) and oil (8–10%). Moreover, in some countries such as Iran, in addition to fodder production, the dried branches of this plant are harvested at the ripening stage for use as a broom for open-space cleaning. We have reported here an initial assessment of the salt tolerance potential of Kochia at germination and early seedling stages however, taking into consideration the diverse usages of this species, it would be worthwhile to evaluate in more details the effects of different levels of irrigation water salinity and regulated irrigation regimes on growth, green area index (GAI), photosynthesis, transpiration, fodder and seed production, and protein content of three genotypes of *K.scoparia*- two Iranian (also found in Pakistan) and one Indian populations. The findings will be reported elsewhere at a later stage.

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