USE OF HIGH-SALINITY WATERS TO GROW *Kochia scoparia* L. Schrad. AS ALTERNATIVE FODDER IN SALINE ENVIRONMENTS IN NORTHWESTERN MEXICO

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SUMMARY

This study examines the effects of different tap water: seawater ratios in the halophytic plant Kochia scoparia*, for potential use as fodder in saline agroecosystems of Northwestern Mexico. Salinity postpones initiation of the germination process and after 6 days the decrease in germination with respect to the control in tap water was 9, 44, 77, and 85% in treatments 75:25, 50:50, 25:75, and 00:100 (tap water: seawater ratios), respectively. In treated plants for 20 and 42 days, growth decreased with the increase of sea water in the treatments in both periods. In the initial growth stage of* K. scoparia*, K^+ concentrations in leaves and stem are high, whereas Na^+ concentrations are low, indicating selective uptake of K^+ and the preferential exclusion of Na^+ from the shoot. Consequently, the ability of* K. scoparia *to counteract salinity partially depends on the levels of K^+ available to maintain a high cytosolic K^+/Na^+ ratio. In more advanced growth stages this species employs a rapid growth strategy in order to dilute salt concentrations, which minimizes salt stress.* K. scoparia *has high forage quality. The protein and carbohydrate contents were high, whereas the fiber level was low, particularly when seawater proportion was increased. The plants accumulated oxalates and NO_3 preferentially in the leaves and stems, which are the edible organs for livestock, but the recorded levels are below those considered toxic for livestock.*

The two major environmental factors that currently reduce plant productivity are drought and salinity. In Mexico, 10% of irrigated land is affected by salinity and nearly two thirds of this area lies in the northern part of the country (Umali, 1993).

In arid zones, groundwater is generally too salty to irrigate conventional crops; however, it could be used to grow salt tolerant plants with agricultural or industrial potential. These plants could include fodder for cattle. In these zones, the natural vegetation is insufficient to feed grazing cattle, which is one of the main problems in meat production. Certain salt tolerant plants could provide alternative animal fodder in many developing countries located in arid and semi-arid zones. A promising solution could be to grow certain species of edible xerophytes and/or halophytes, which would be cultivated under marginal conditions, such as salinity, by using water and land classified as inadequate for traditional fodder crops.

The halophyte *Kochia scoparia* has attracted attention in a wide range of research in diverse regions (López-Aguilar *et al*., 2003a; Kafi *et al*., 2010). *K. scoparia* has been a problem weed in croplands; however, it could be used as a cover crop for degraded soils, as well as a valuable fodder for livestock in coastal areas with salinity problems.

As very few studies have been published regarding the effects of seawater on *K. scoparia* cultivation, this study reports the effects of different dilutions of seawater on seed germination, plant growth, ion uptake and indicators of fodder quality.

Materials and Methods

Experiment on seed germination

Germination was measured in glass Petri dishes using filter pa-

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per (Advantec #2) moistened with the desired sea water dilution on which 20 *Kochia scoparia* L. Schrad. seeds were placed. The Petri dishes were kept at 25ºC in an incubator for germination. The germination rate was evaluated at ratios of 100:00 ($0.96dS \cdot m^{-1}$), 75:25($12.4dS \cdot m^{-1}$), 50:50 ($23.6dS \cdot m^{-1}$), 25:75 ($35.7dS \cdot m^{-1}$), and 00:100 ($42.9dS \cdot m^{-1}$) tap water:seawater over 6 days. Sea water obtained from Guerrero Negro Lagoon, Baja California, Mexico, contained 3.58% NaCl, the major components being 491mM Na^+, 11.1mM K^+, 11.8mM Ca^{2+}, 54.2mM $Mg^{2+}$and 598mM Cl^-. Treatments were replicated four times, and the germinated seeds (emergence of radicle) were recorded daily.

Experiment on plant growth, treatments and growth conditions

K. scoparia seeds were planted in (54×28×6.0cm) trays with 128 cells filled with inert material (Canadian sphagnum peat moss; Sunshine, Sun Gro Horticulture Inc., Washington, USA) and placed in a plastic-covered greenhouse under natural light conditions. The trays were watered daily with tap water until the first true leaf emerged. From then on, the plants were watered daily with a nutrient solution containing macronutrients (in mmol l^{-1}): 3.5 $Ca(NO_3)_2$, 0.5 KH_2PO_4, 3.0 KNO_3 and 1.5 $MgSO_4$ and micronutrients (in µmol l^{-1}): 15 Fe^{3+}-EDTA, 5 H_3BO_3, 5 $MnSO_4$, 10 $ZnSO_4$, 0.5 $CuSO_4$, and 0.2 H_2MoO_4 added to the tap water. The plants were maintained for 28 days under these conditions and were later removed from the trays and transplanted into plastic pots (16cm top diameter,14cm bottom diameter × 26cm deep) filled with the same inert material, with one plant in each pot. The plants were watered daily with 200ml of the nutrient solution.

Seven days after transplantation, when the plants reached a height of 18cm, saline treatments were initiated. The treatments were prepared by mixing tap water and seawater in different proportions as described in the seed germination experiment. The nutrients supplied to treatments were the same as in the previously described nutrient solution. Plants were watered daily with sufficient amounts of solution in each treatment to prevent the accumulation of salts in the substrate.

Average temperature inside greenhouse was 16ºC/28ºC (night/day); the average relative humidity was 32% during the day and 65% at night. Plants were grown in an average of 12h photoperiod of 285 ±25µµmol$\cdot m^{-2} \cdot s^{-1}$ photosynthetically active radiation.

TABLE I
GERMINATION OF *K. scoparia* SEEDS AT DIFFERENT TAP WATER: SEAWATER RATIOS *

Days	Tap water : sea water ratios				
	100:00	75:25	50:50	25:75	00:100
1	26.2 ±2.7 (100)	8.7 ±1.5 (33)	2.5 ±0.7 (10)	0.0 ±0.0 (0)	2.5 ±0.5 (9)
2	52.5 ±5.2 (100)	17.5 ±2.7 (33)	7.5 ±2.2 (14)	3.7 ±1.2 (7)	6.2 ±1.7 (12)
3	87.5 ±7.5 (100)	73.7 ±9.2 (84)	43.7 ±6.7 (50)	7.5 ±1.7 (9)	8.7 ±2.2 (10)
4	91.5 ±8.1 (100)	78.7 ±7.5 (86)	50.0 ±8.7 (55)	18.7 ±3.5 (20)	11.2 ±3.5 (12)
5	96.2 ±7.5 (100)	87.5 ±9.5 (91)	52.5 ±5.2 (54)	21.2 ±5.2 (22)	13.7 ±3.7 (14)
6	98.5 ±7.2 (100)	89.7 ±9.2 (91)	54.7 ±6.2 (56)	22.7 ±4.7 (23)	14.5 ±3.5 (15)

* Germination percentages were measured over the 6 days period after the treatments were initiated. The values are means ±standard error of 4 replicates of 20 seeds. The numbers in parenthesis indicate percentages for the controls (100:00)

Growth analysis

After 20 and 42 days, eight pots of each treatment were sampled. At the time of harvest, the leaf area was measured using a leaf area meter (Model ACC-400, Hayashi-Denko, Japan). The dry matter was determined after the plant parts were dried in an air-forced oven at 65ºC for 72h. To compare the effects of salt stress on plant growth, the relative growth rate (RGR) and the net assimilation rate (NAR) were calculated according to Hunt (1982). RGR and NAR were calculated as

$$RGR= (\log_e W_2 - \log_e W_1) / (T_2-T_1)$$

$$NAR= (W_2 - W_1)/(T_2 - T_1) \times (\log_e La_2-\log_e La_1)(La_2- La_1)$$

where W_1 and W_2: dry weight of plants at harvest times T_1 and T_2, and La: leaf area. Specific leaf area (SLA) was calculated by dividing leaf area by leaf biomass per plant.

Tissue analysis

After plants were harvested, the roots were rinsed with tap water until all particles of potting mixture were removed and then rinsed with distilled water for 3min. The plants were divided into root, stem + petioles, and leaves in the first sampling period. During the second sampling period, the plants were separated into roots and shoots. Each plant part was measured separately and placed in paper bags to dry in a 65ºC oven for 3 days for chemical analysis. Total nitrogen in the plant parts was determined by micro-Kjeldahl digestion, followed by ammonia estimation using the Nessler method. Ca, Mg, Na, and K were extracted in an acid mixture of H_2SO_4:HNO_3:$HClO_4$ (1:10:4), respectively proportioned and estimated by atomic absorption spectrophotometry (Shimadzu AA-660, Shimadzu, Japan).

The shoots of the plants were analyzed to determine fodder quality. Nitrate (NO_3) contents were extracted in boiling water and determined by ion chromatography (Shimadzu HIC-6A, Shimadzu, Japan). The oxalate content of the plant parts were determined by titrating an aliquot of extracts from the homogenized samples with 0.01M $KMnO_4$ solution (AOAC, 1990). Crude protein (CP) was determined by the micro-Kjeldahl method with a 6.25 factor to obtain CP from total nitrogen. Cellulose and lignin content were determined by the detergent method developed by Van Soest and Wine (1967) and using some modifications according to the technique of Osaki *et al.* (1991). Acid detergent fiber values (Goering and Van Soest, 1970) were used to calculate *K. scoparia* dry matter digestibility (DMD) according to the equation proposed to estimate DMD of alfalfa by Linn and Martin (1989), in which %DMD= 88.9-(0.779×%ADF). Each measurement was repeated in duplicate with eight replicates.

Experimental design and statistical analyses

The experimental design was completely randomized with 16 pots in each treatment. One pot with one plant was considered an experimental unit. The data were analyzed using analysis of variance (ANOVA) procedures and means separated by Tukey's multiple range tests when the F test was significant at $P<0.05$ (SAS, 2002).

Results and Discussion

Effect of seawater concentration on seed germination

Germination is one of the most critical periods for the majority of plants subjected to salinity. The present study indicates that *K. scoparia* is very sensitive to salinity during germination and becomes progressively salt tolerant from the young seedling stage onward. In this species salinity reduces the total number of seeds germinating and postpones initiation of germination processes (Table I). The germination percentage gradually declined in relation to the increase in salt concentration. After treatment for 6 days, seed germination declined 9, 44, 77 and 85% with respect to the control in treatments 75:25, 50:50, 25:75 and 00:100 tap water:seawater ratios, respectively. Stepphun and Wall (1993) tested the germination of *K. scoparia* seeds in salinities reaching up to 30dS·m^{-1} and reported that germination was reduced 3.3% per 1dS·m^{-1} increment of salinity between 12 and 30dS·m^{-1}. Similar results were obtained in the present experiment, as an increase of irrigation water salinity from 12.4dS·m^{-1}(75:25) to 23.6dS·m^{-1}(50:50) reduced seed germination 3% per 1dS·m^{-1}.

Different responses to salinity have been reported between germination and seedlings growth of a number of halophytes (Khan *et al*., 2002). Seeds of halophytes germinate best under non-saline conditions, while others have demonstrated that seeds of many halophytes not only retain viability for a long time when exposed to strong salt solutions, but also germinate readily after the salt stress is relieved (Xiao-Xia *et al*., 2008).

In this study, we did not identify whether salinity did not identify clearly whether salinity influences seed germination primarily by lowering the osmotic potential of the culture solution sufficiently to retard water absorption by seeds or by toxicity to the embryo, or by a combination of both (Munns and Tester, 2008). On the other hand, some studies have shown that *K. scoparia* seeds are not vigorous and only germinate appropriately 6 to 8 months after harvest (Kitchen and Monsen, 2001), which could be a factor influencing the reduction in germination when the seeds are subjected to salt stress.

Effect of seawater concentration on plant growth

Salt tolerance is usually assessed as the percent biomass production in saline *versus* control conditions over a prolonged time period (Munns and Tester, 2008). Many dicotyledonous halophytes show optimal growth in concentrations of 50-250mM NaCl, while monocotyledonous halophytes generally grow optimally in the absence of salt or, if growth is stimulated, it is by a low (≤50mM) NaCl concentration (Flowers and Colmer, 2008). Our results indicated that above 100mM NaCl (treatment 75:25; EC= 12.4dS·m^{-1}) the growth of *K. scoparia*, a dicotyledonous halophyte, was reduced. When the plants were subjected to salinity in the initial stages of development, lineal reductions in the total plant biomass were caused by the increase in salinity (Figure 1). For both sampling dates, the aerial

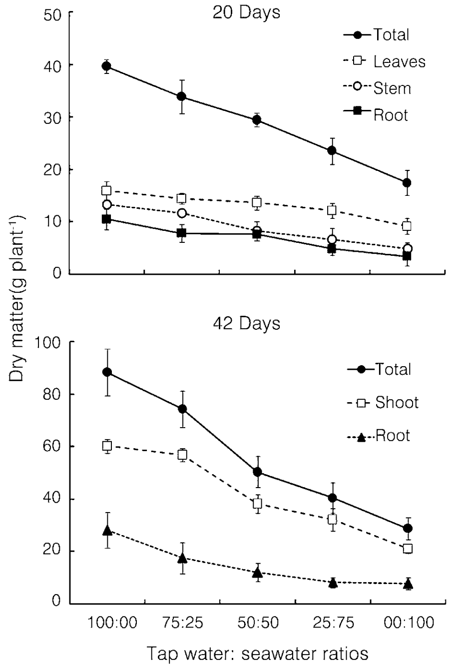

Figure 1. Effect of different tap water:seawater ratios on dry matter of whole plant, leaves, stem and root of *K. scoparia* subjected to treatments for 20 days and dry matter of whole plant, shoot and root of *K. scoparia* subjected to treatments for 42 days. Data points are means ±standard error of 8 replicates.

part was more affected by salinity than the roots, particularly when seawater proportions exceeded 50%. At 42 days after treatment initiation, the whole plant dry weight in the 75:25, 50:50, 25:75, and 00:100 treatments was reduced 16, 43, 54, and 67% respectively, compared to controls (100:00). Salehi *et al.* (2009) reported that plant dry weight of *K. scoparia* diminished 48% at 35dS·m^{-1} compared with that in controls. In our study, plants receiving treatment 25:75 (35.7dS·m^{-1}) reduced 54% plant dry weight in comparison with the control. In other studies it has been reported that lowering till 50% the water requirement of *K. scoparia* and increasing salinity up to 20dS·m^{-1} will reduce the yield less than 25% (Kafi and Salehi, 2012). Like the dry matter of the plant parts, RGR gradually declined with the increase in salinity. Plants irrigated with 100% seawater showed a 25% decline in RGR with respect to plants irrigated with 100% tap water. These results are in agreement with those of Salehi *et al.* (2009), who underlined that growth parameters of *K. scoparia* decreased with increasing salinity above 7dS·m^{-1}.

NAR also decreased with the increase in salinity, but the reduction was less pronounced and there were no significant differences in plants irrigated with 100% tap water and plants irrigated with 100% seawater. On the contrary, Salehi *et al.* (2009) reported that increasing salinity decreased NAR of *K. scoparia*; the authors concluded, based on their data, that salinity firstly affected leaf area index and consequently NAR was also reduced. The SLA was significantly reduced with increase in seawater concentrations. The SLA was 2 times less in plants irrigated with 100% seawater than those irrigated with 100% tap water (Table II). Others researchers (Karimi *et al*., 2005; Salehi *et al*., 2009) also mentioned that SLA of *Kochia* sp. decreased with higher levels of salinity. Reduction in SLA due to smaller and thicker leaves is largely attributed to the osmotic effect of the salt (Munns and Tester, 2008).

K. scoparia grown in open fields produces 125-150t·ha^{-1} of fresh matter or 25-30t·ha^{-1} of dry matter (Anaya, 1999). The results of the present study indicate that if the crop is grown with poor quality irrigation water (EC= 24dS·m^{-1}), fodder production per harvest could be 60-65t·ha^{-1} of fresh matter or 12-13t·ha^{-1} of dry matter. Salehi *et al.* (2012) found that during non-stress conditions *K. scoparia* showed a remarkable yield of dry matter (37t·ha^{-1}) and still produced up to 8t·ha^{-1} during severe drought and saline conditions. Other authors have reported that dry matter yields of some forage crops grown under non-saline conditions was 16-18t·ha^{-1} for alfalfa (Rimi *et al*., 2010), 4-7t·ha^{-1} for wheat, 6t·ha^{-1} for barley, 6-8t·ha^{-1} for oats (Quintana and Prieto, 1982), and 18-20t·ha^{-1} for maize (Lorenz *et al*., 2010). These crops do not tolerate high sa-

TABLE II
RELATIVE GROWTH RATE (RGR), NET ASSIMILATION RATE (NAR) AND SPECIFIC LEAF AREA (SLA) OF *K. scoparia* SUBJECTED FOR 42 DAYS AT DIFFERENT TAP: SEAWATER (Tw:Sw) RATIOS

Tw:Sw ratio	RGR (g g^{-1} d^{-1})	RGR decrease relative to control (100:00) (%)	NAR (mg cm^{2} d^{-1})	NAR decrease relative to control (100:00) (%)	SLA (cm^{2} g^{-1})
100:00	0.108 a		1.54 a		33.16 a
75:25	0.104 a	3.71	1.52 a	1.30	27.86 b
50:50	0.102 a	5.56	1.50 a	2.59	26.62 b
25:75	0.090 b	16.67	1.49 a	3.25	23.32 c
00:100	0.081 c	25.00	1.50 a	2.59	17.15 d

Values are means of 8 replicates. Means with the same letter in a column are not significantly different at P=0.05, according to Tukey's multiple range tests.

line levels. Legumes used for fodder are also considered salt sensitive crops (Francois and Maas, 1994). For example, clovers and alfalfa, the predominant legumes of pastures, tend to die out on salt affected soils where *K. scoparia* can be grown satisfactorily. Studies carried out in arid zones of northeastern Mexico indicate that it is unlikely to find irrigation waters with EC >20dS·m^{-1}, such as present in the 50:50, 25:75 and 00:100 treatments. Yet, cropland has been abandoned as a result of the use of irrigation water with high salt content, which increased soil salinity up to levels of EC= 7-9dS·m^{-1} (data not published). At least, expected reductions of fodder yield of *K. scoparia* under saline conditions would be minimal. In studies cited by Kafi *et al.* (2010), *K. scoparia* produced a large amount of dry matter (7.5t·ha^{-1}) even when irrigated with 20dS·m^{-1} saline water and it was only 12% less than the biomass production at 5dS·m^{-1}.

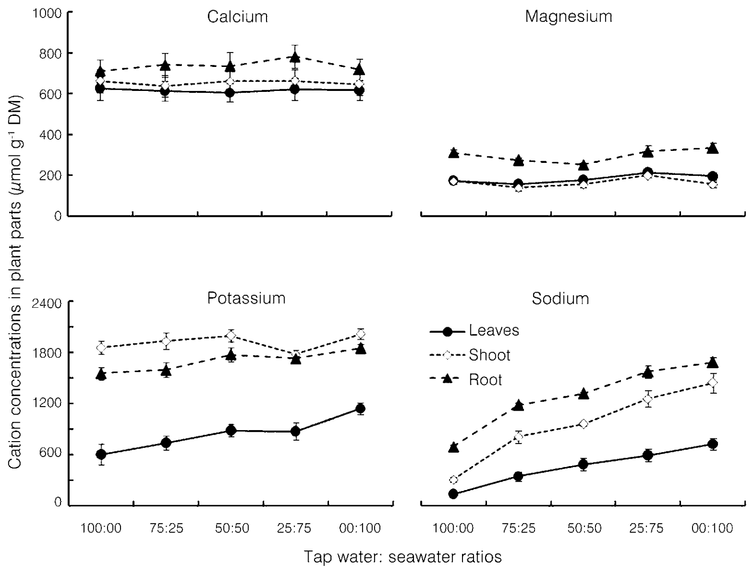

Figure 2. Cation concentrations in plant parts of *K. scoparia* subjected to different tap water: seawater ratios for 20 days. Data points are means ±standard error of 8 replicates.

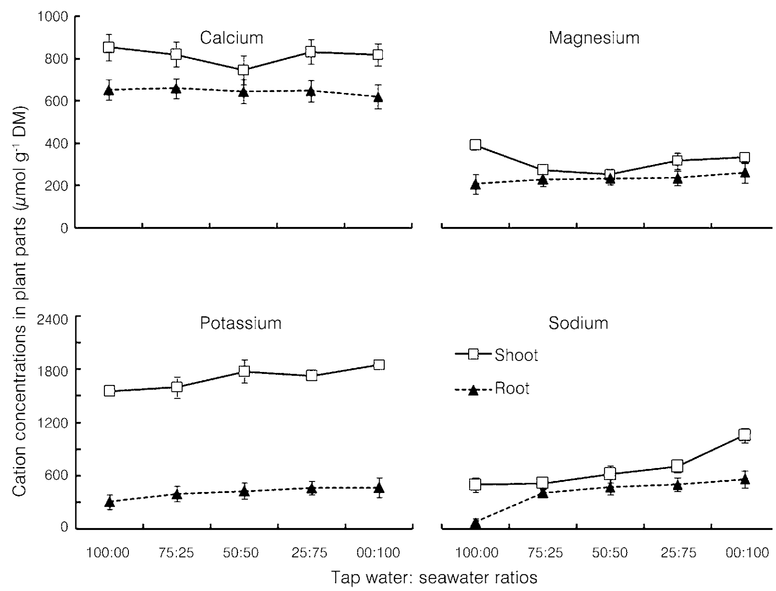

Figure 3. Cation concentrations in shoots and roots of *K. scoparia* subjected to different tap water: seawater ratios for 42 days. Data points are means ±standard error of 8 replicates.

Ion uptake

Figure 2 presents the cation concentration in plant parts at 20 days after treatments were initiated. The Na^+ and K^+ concentrations in the plant parts increased according to the increase in seawater content, but K^+ concentrations were significantly higher than those of Na^+, indicating selective uptake of K^+ and preferential exclusion of Na^+ from shoots. As demonstrated in other plants (Shabala and Cuin, 2008), the ability of *K. scoparia* to counteract salt stress depends partly on the levels of K^+ available to the plant, functioning as a balancing charge. The plant must maintain a high K^+ level to counterbalance the excess NaCl. Some studies have shown that the plant capacity to maintain a high level of K^+ is associated with salt tolerance (Wakeel *et al*., 2011). *K. scoparia* responds to elevated Na^+ concentrations by maintaining a low Na^+ concentration and a high K^+/Na^+ ratio in the cytosol. The K^+/Na^+ ratios in the leaves at 20 days of treatment were 4.24, 2.12, 1.80, 1.47 and 1.57 in treatments with 100:00, 75:25, 50:50, 25:75 and 00:100 tap water: sea water ratios, respectively..

At 42 days after treatment, Na^+ and K^+ concentrations were significantly higher in the shoots than in the roots and the increase was greater for higher seawater concentration (Figure 3). *K. scoparia* continued to maintain a high cytosolic K^+/Na^+ ratio in the shoots, thus lessening salt damage. Salehi and Kafi (2011) found that increasing salinity did not have an adverse effect on K uptake and transportation in *K. scoparia*, and Kernan *et al.* (1986) reported that a K^+/Na^+ ratio of 1.96 in this plant did not change greatly by increasing salinity. At 42 days, the K^+/Na^+ ratios in the shoots were 3.14, 2.24, 2.06, 1.90, and 1.54, in the respective treatments 100:00, 75:25, 50:50, 25:75, and 00:100. The K^+/Na^+ ratio was significantly reduced with increasing salinity, as also observed in many chenopodiaceous species (Jeschke and Stelter, 1983; Ramos *et al*., 2004; Eisa *et al*., 2012). The differences in K^+ uptake relative to that of Na^+ at increasing salinity levels can be appropriately expressed as selectivity ratios (Pitman, 1976). This ratio is calculated as the K^+/Na^+ ratio in the plant tissue divided by the K^+/Na^+ ratio in the nutrient solution. In the present study, the K^+/Na^+ selectivity ratios in shoots of *K. scoparia* decreased with the increase in seawater content. At 42 days, the K^+/Na^+ selectivity ratios in shoots were 95, 89, 83 and 68 in the respective treatments 75:25, 50:50, 25:75 and 00:100. However, salt-induced reduction in K^+ contents does not necessarily mean that there was a potassium deficiency, as in many dicotyledonous halophytes (Shennan *et al*., 1987) the osmotic function of K, Mg or Ca in the vacuoles can be substituted by Na without any reduction in growth. Curtin *et al.* (1993) demonstrated that *K. scoparia* tended to have higher selectivity for nutrient cations (Ca^{2+}, Mg^{2+} and K^+) over Na^+ when the plants were grown at higher NaCl salinities. This may be an indication of a beneficial effect of the high Ca supply on membrane selectivity and the plant ability to maintain high cytosolic K^+/Na^+ ratios to tolerate salt stress (Shabala and Cuin, 2008).

In the present study, Ca^{2+} and Mg^{2+} concentrations were less affected by seawater concentrations and no significant differences were detected between treatments in both sampling dates. At 20 days, Ca^{2+} and Mg^{2+} concentrations were higher in the root than in leaves and stem, whereas 42 days after treatments they were higher in the shoot than in the root. This indicates that higher cation uptake and transport under saline conditions are necessary to neutralize the excess Cl^- ion (Xu et al., 1999; López-Aguilar et al., 2003b; Arndt et al., 2004).

Generally, highly salt-tolerant halophytes withstand high tissue salt concentrations, largely through osmotic adjustment (Flowers et al., 2010). However, there are exceptions (such as *Suaeda maritima*) that grow faster as salinity increases, which serves to dilute the salt concentration in the leaves (Clipson et al., 1985). In *K. scoparia*, the strategies used to tolerate salinity are: 1) selectivity in the ion absorption by the root cells, 2) low transport rates of Na^+ to shoots with high selectivity for K^+ over Na^+, and 3) rapid growth that maintains a roughly constant salt concentration in the shoots by dilution to prevent an increase in salt concentration. Strategies 1 and 2 operate initially, but break down over time, while strategy 3 is used in the more advanced stages of development. At later growth stages *K. scoparia* had more biomass and more Na^+ was translocated to the shoot through the transpiration stream. However, the Na content rarefied in different parts of the plants due to the increased biomass, thus reducing the negative effect of Na (Salehi and Kafi, 2011).

Forage quality

Halophytes typically have poorer forage quality, including higher ash contents, lower metabolizable energy, and unfavorable morphological characteristics such as a tendency towards steminess, slower digestibility and correlated reduced intake (El Shaer, 2010). However, *K. scoparia* showed a higher forage quality. Crude protein and carbohydrate content were high, while fiber level was relatively low, particularly when seawater concentration was increased. Also, dry matter digestibility of shoots was high in all treatments and seawater concentration positively influenced this variable (Table III). CP was not significantly affected by the treatments at either sample date, with the exception of stems in the 100:00 treatment. The CP in leaves was ~twice that of stems. ADF content significantly declined in stems and leaves at 20 days after treatment, as was also observed in the shoot at 42 days after treatment. At 20 days, lignin in the stem was 2 to 3 times greater than in leaves, and at 42 days after treatments, lignin in shoots declined significantly in proportion to the increase in seawater concentration. Hagège et al. (1988) quantified lignin content in the third and fourth internodes of *Suaeda maritima* cultured in the absence and presence of NaCl and reported that the lignin content decreased from 5.99mg·g^{-1} to 1.64mg·g^{-1} as the salinity was increased to 130mM.

TABLE III
EFFECT OF SEAWATER CONCENTRATION ON SEVERAL FORAGE QUALITY VARIABLES DETERMINED IN THE STEM AND LEAF (% DRY MATTER BASIS) AT 20 DAYS AND IN THE SHOOT AT 42 DAYS AFTER TREATMENTS (DAT)

DAT			Tap water: seawater ratio 100:00	75:25	50:50	25:75	00:100
20	Sugars	Stem	6.7 b	6.9 b	7.3 b	8.1 a	8.5 a
		Leaves	5.6 a	5.2 a	5.2 a	5.0 a	5.2 a
	Starch	Stem	11.4 ab	10.3 ab	10.7 ab	11.6 a	10.6 ab
		Leaves	11.2 a	10.6 ab	9.6 bc	9.1 c	8.9 c
	CP	Stem	13.2 b	14.1 a	14.7 a	13.9 a	14.1 a
		Leaves	24.8 a	25.7 a	26.5 a	25.4 a	25.1 a
	ADF	Stem	32.5 a	28.7 b	26.4 c	23.7 d	21.2 e
		Leaves	19.6 a	18.5 ab	18.2 b	14.3 c	14.1 c
	Lignin	Stem	11.7 c	13.3 b	15.4 a	13.1 b	6.7 d
		Leaves	5.8 a	5.3 a	5.7 a	4.1 b	3.9 b
	Cellulose	Stem	20.8 a	15.4 b	11.0 c	10.6 c	14.5 b
		Leaves	13.8 a	13.2 ab	12.5 b	10.2 c	10.2 c
	DMD	Stem	63.6 e	66.6 d	68.3 c	70.4 b	72.4 a
		Leaves	73.7 c	74.5 c	74.7 b	77.8 ab	77.9 a
	Nitrate	Stem	0.8 c	0.9 c	1.3 b	1.0 c	1.6 a
		Leaves	0.7 a	0.9 a	0.9 a	0.8 a	0.8 a
	Oxalate	Stem	0.9 a	1.1 a	0.9 a	1.0 a	1.1 a
		Leaves	1.8 b	2.2 a	1.6 a	1.8 a	2.1 a
42	Sugars	Shoot	7.9 c	8.5 c	9.8 b	16.5 a	16.5 a
	Starch	Shoot	10.9 a	10.6 a	10.9 a	19.3 b	18.7 b
	CP	Shoot	18.2 a	17.5 a	18.9 a	18.6 a	18.1 a
	ADF	Shoot	28.2 a	27.1 b	24.7 c	20.5 d	16.1 e
	Lignin	Shoot	7.6 a	2.8 b	2.2 c	1.9 c	1.1d
	Cellulose	Shoot	20.6 c	24.3 a	22.5 b	18.6 d	15.0 e
	DMD	Shoot	66.9 e	67.8 d	69.7 c	72.9 b	76.3 a
	Nitrate	Shoot	0.3 a	0.3 a	0.4 a	0.4 a	0.4 a
	Oxalate	Shoot	1.4 a	1.6 a	1.7 a	1.9 a	2.1 a

Values are means ±standard error of 8 replicates. Means with the same letter in a row are not significantly different at P=0.05 according to Tukey's multiple range tests. CP: crude protein, AD: acid detergent fiber, DMD: dry matter digestibility.

Cellulose content was greater in stem than in leaves. In leaves and shoots it was reduced significantly when seawater concentration was >50%. Dry matter digestibility increased significantly in proportion to the increase in seawater concentration; the lowest values being found in stems (64-72%) and the highest ones in leaves (74-78%). In shoots, dry matter digestibility varied from 67 to 76%. Increasing salinity improved forage digestibility of *K. scoparia* to some extent by restricting stem growth and increasing partitioning to leaves (Al-Ahmadi and Kafi, 2008).

Twenty days after treatments, the concentration of sugars increased significantly in stems of plants (25:75 and 00:100 treatments), whereas the sugar content in leaves did not differ significantly between treatments. At 42 days, the sugar concentration in shoots significantly increased in plants treated at the 25:75 and 00:100 ratios. Joshi et al. (2005) evaluated salt stress in two forage grasses and reported accumulation of glucose and galactose in *Aeluropus lagopoides* and, additionally, that of arabinose and rhamnose in *Sporobolus madraspatanus* was greater in seedlings raised in seawater concentrations. At 20 days, the concentration of starch in the leaves was significantly reduced with increased seawater treatments, while there were no clear differences in starch content found in the stem that could be attributed to the effects of seawater concentrations.

Nitrates are known to accumulate in some members of Chenopodiaceae under certain conditions and can accumulate to levels that are toxic to livestock. At 20 days, nitrate concentration in leaves varied from 0.7 to 0.9% whereas the nitrate concentration in the stem varied from 0.8 to 1.6%. At 42 days after treatments, nitrate concentration in shoots varied from 0.3 to 0.4% and did not differ significantly between treatments. Nitrate accumulation in plants, such as sorghums, corn, oats, or ryes (Aiello and Mays, 1998) occurs when absorption exceeds reduction and subsequent assimilation. However, nitrates tend to decrease with maturity in a few species used as fodder, such as Russian thistle (Fowler *et al*., 1992). After 42 days, nitrate levels were lower than those at 20 days. The highest nitrate content was found in plants under the 50:50 treatments, but not exceeding $5g\cdot kg^{-1}$ DW (Table III), considered the threshold level of toxicity for livestock (NRC, 1974). This suggests that although *K. scoparia* accumulates nitrates preferentially in the parts that are eaten by livestock, the recorded levels are below toxic levels and are probably at their lowest level at the time of harvest. *K. scoparia* has been reported to be an oxalate accumulator (Cheeke and Shull, 1985). Oxalate content of *K. scoparia* should be further appraised since acute hypocalcemia in non-adapted ruminants would be expected at high concentrations. Blaney *et al*. (1982) have shown that Ca absorption is reduced by 20% when cattle are fed forages with moderate oxalate concentrations (1.3-1.8%). At 42 days, oxalate levels in the shoots were low with a mean of 1.76% and the oxalate:calcium ratio was 0.54 suggesting that ~50% of Ca could be bound to oxalate. These results suggest that *K. scoparia* hay can be fed at levels up to 50-60% of total dry matter intake to maintain ruminants without overt signs of toxicosis. Further studies, especially long term ones, are needed to validate and improve the recommended safe levels of oxalate in animals.

Conclusions

Kochia scoparia is very sensitive to salinity during germination and becomes progressively salt tolerant from young seedling stage onward.

When increasing electrical conductivity of the irrigation water from 0.96 to $24dS\cdot m^{-1}$ (50:50 tap water: seawater ratio), *K. scoparia* reduced its yield by only 30%.

K. scoparia responds to elevated Na^+ concentrations in the growth medium by maintaining relatively low Na^+ concentrations and a high K^+/Na^+ ratio in the shoots, which indicates selective uptake of K^+ and preferential exclusion of Na^+ from the shoots.

This work demonstrates the potentiality of *K. scoparia* as forage for livestock. In general, the plant contained sufficient levels of minerals in comparison with those recommended for ruminants. The proximate analysis and fiber constituents (starch, CP, ADF, lignin and cellulose) were within the normal ranges of nutritious fodder. Although *K. scoparia* accumulates nitrates in the parts eaten by livestock, the recorded levels are below toxic levels. The shoots had moderate oxalate concentrations (1.4-2.1%), which is an appropriate level to avoid oxalate poisoning in ruminants.

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USO DE AGUAS ALTAMENTE SALINAS PARA CULTIVAR *Kochia scoparia* L. Schrad. COMO FORRAJE ALTERNATIVO EN AMBIENTES SALINOS DEL NOROESTE DE MÉXICO

Raúl López-Aguilar, Guadalupe Rodríguez-Quezada, Armando Lucero-Arce y Arturo Naranjo-Murillo

RESUMEN

Este estudio examina los efectos de diferentes proporciones de agua potable y agua de mar en la planta halófila Kochia scoparia*, para su uso potencial como planta forrajera en agroecosistemas salinos del Noroeste de México. La salinidad retarda la germinación y después de 6 días la reducción con respecto al control en agua potable fue de 9, 44, 77 y 85% en los tratamientos 75:25, 50:50, 25:75 y 00:100 (proporción agua potable: agua de mar), respectivamente. En plantas tratadas por 20 y 42 días, el crecimiento disminuyó con el incremento de agua de mar en los tratamientos en ambos periodos. En el crecimiento inicial de* K. scoparia*, las concentraciones de K^+ en hojas y tallo son altas mientras que las concentraciones de Na^+ son bajas, indicando una absorción selectiva de K^+ y la exclusión preferencial de Na^+ del follaje. Por tanto, la habilidad de* K. scoparia *para contrarrestar la salinidad depende parcialmente de los niveles de K^+ disponible para mantener una proporción elevada de K^+/Na^+ en el citosol. En etapas de crecimiento más avanzadas esta especie emplea la estrategia de rápido crecimiento para diluir las concentraciones de sales, lo cual minimiza el estrés salino.* K. scoparia *tiene una alta calidad forrajera. Los contenidos de proteínas y carbohidratos fueron altos, mientras el nivel de fibra fue bajo, particularmente cuando se incrementó la proporción de agua de mar. Las plantas acumularon oxalatos y NO_3 preferentemente en las hojas y tallos, los cuales son los órganos comestibles por el ganado, pero los niveles registrados están por debajo de aquellos considerados tóxicos para el ganado.*

USO DE ÁGUAS ALTAMENTE SALINAS PARA CULTIVAR *Kochia scoparia* L. SCHRAD. COMO FORRAGEM ALTERNATIVA EM AMBIENTES SALINOS DO NOROESTE DO MEXICO

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RESUMO

Este estudo examina os efeitos de diferentes proporções de água potável e água de mar na planta halófila Kochia scoparia*, para seu uso potencial como planta forrageira em agro ecossistemas salinos no Noroeste do México. A salinidade retarda a germinação e depois de 6 dias a redução em relação ao controle em água potável foi de 9, 44, 77 e 85% nos tratamentos 75:25, 50:50, 25:75 e 00:100 (proporção água potável: agua de mar), respectivamente. Em plantas tratadas por 20 e 42 dias, o crescimento diminuiu com o incremento de água de mar nos tratamentos em ambos os períodos. No crescimento inicial de* K. scoparia*, as concentrações de K^+ em folhas e caule são altas enquanto que as concentrações de Na^+ são baixas, indicando uma absorção seletiva de K^+ e a exclusão preferencial de Na^+ da folhagem. Portanto, a habilidade de* K. scoparia *para neutralizar a salinidade depende parcialmente dos níveis de K^+ disponível para manter uma proporção elevada de K^+/Na^+ no citosol. Em etapas de crescimento mais avançadas esta espécie emprega a estratégia de rápido crescimento para diluir as concentrações de sais, o qual minimiza o estresse salino.* K. scoparia *tem uma alta qualidade forrageira. Os conteúdos de proteínas e carboidratos foram altos, enquanto o nível de fibra foi baixo, particularmente quando se incrementou a proporção de agua de mar. As plantas acumularam oxalatos e NO_3 preferentemente nas folhas e caules, os quais são os órgãos comestíveis pelo gado, mas os níveis registrados estão abaixo daqueles considerados tóxicos para o gado.*