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BRIEF COMMUNICATION

Effects of salinity, external K^+/Na^+ ratio and soil moisture on growth and ion content of *Sesbania rostrata*

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Abstract

Growth of *Sesbania rostrata* was decreased gradually with increase in root medium salinity (mixed salts or NaCl alone). Soil moisture or anoxia did not affect plant growth significantly. Higher K^+/Na^+ ratios in plant tissues compared to those in the root medium were found under different salinities. This indicated a high K^+-Na^+ selectivity, a characteristic generally considered unique to halophytes. *S. rostrata* is moderately salt tolerant and may be utilized as forage crop and green manure on saline land.

Additional key words: ion uptake, K^+ selectivity, stress tolerance.

Selection and use of salt tolerant plants has gathered a great attention for increasing productivity and improvement of saline lands. Green manure species like *Sesbania aculeata* and *S. rostrata* have pivotal role in improving the saline sodic soils (Sandhu and Malik 1975). However, precise information on their tolerance to salinity and water-logging is lacking in the literature. Therefore, the present paper describes the effects of different levels of salinity (mixed salts or NaCl), external K^+/Na^+ ratio, and soil water content on seed germination, growth and ion uptake of *S. rostrata*.

Salinity of different level (electrical conductivity, EC, 5, 10, 15, and 20 dS m^{-1}) was prepared by the addition of Na_2SO_4, $CaCl_2$, $MgCl_2$ and NaCl in the ratio of 10:5:1:4 on equivalent basis (Qureshi *et al.* 1977) to the Hoagland nutrient solution with EC of 2.5 dS m^{-1} used as control. Twenty seeds of *Sesbania rostrata* Brem. were placed on Petri dishes on filter paper soaked with 5 cm^3 of respective solution, four Petri dishes per treatment. Fresh solution was added daily and emergence of plumule was recorded over a period of 10 d.

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Glazed pots were filled with gravel saturated with Hoagland solution and four seedlings were planted in each pot. After 10 d, the plants were subjected to the salinity (EC from 5 to 20 dS m^{-1}), four pots per treatment. The higher salinities were achieved gradually by increases of salinity every day reaching EC 20 dS m^{-1} in one week. The solutions were aerated and completely replaced every two weeks. The plants were grown for 6 weeks and harvested.

To study the combined effect of salinity and soil moisture, seeds were sown in pots containing 3 kg soil having EC 1.7, 4.4 and 8.1 dS m^{-1}, six pots per salinity level. Two weeks after seed germination soil moisture was made to 50 or 100 % of soil water holding capacity (WHC). These moistures were maintained by weighing the pots and adding water as required. The plants were harvested after 8 weeks.

In another experiment, seedlings were grown for 10 d in aerated and non-aerated Hoagland nutrient solution with 0, 75, and 150 mM NaCl (EC 2.5, 9.1, and 15.6 dS m^{-1}). For selective ion uptake determination, 7-d-old seedlings grown in nutrient solution were gradually subjected to 50 and 150 mM NaCl. After 1 week, solutions were completely replaced with nutrient solutions having two potasium concentrations 9.45 ± 0.1 and 2.80 ± 0.05 mM K^+ and two NaCl concentrations 50 and 150 mM to give four treatment combinations. The plants were grown for 3 weeks and harvested.

During all experiments mentioned above, the plants were grown in the open net house during appropriate growing season. At harvest, biomass of roots and shoots was determined separately. Plant shoots and roots were analyzed for Na^+, K^+, and Ca^{2+} on flame photometer *MGa* (*Karl Kolb*, Frankfurt, Germany) following wet diggestion. The significance of differences between treatments was determined by *ANOVA* using PC package *CoStat* (*CoHort Software*, Berkeley, USA).

Seed germination and biomass yield of roots and shoots of *S. rostrata* was gradually reduced by increased salinity (Table 1). Significant negative correlation was observed between medium salinity and dry mass of shoots (r = -0.979; y = 2.187 - 0.088 x) and roots (r = -0.941; y = 0.563 - 0.025 x). Reduction of growth (50 % relative to control) was caused by salinity 12.9 dS m^{-1} in shoots and 13.2 dS m^{-1} in roots.

Na^+ concentration in all plant parts (roots, stems and leaves) significantly increased with increased salinity. Ca^{2+} concentration in roots was not affected by salinity, but Ca^{2+} contents of stems and leaves of control plants were significantly lower than those of treated plants (Table 1). K^+ concentration in roots decreased at all salinities compared to control. On the contrary, K^+ concentrations in stems and leaves slightly increased with salinity up to a certain level. However, K^+ contents in leaves were significantly lower at salinity corresponding to EC 15 and 20 dS m^{-1}. All plant parts had higher K^+/Na^+ ratios compared to external solution and exhibited high K^+-Na^+ selectivity (Table 1).

In soil, root and shoot dry masses were significantly decreased by high salinity compared to control (Table 2). Na^+ concentrations in roots and shoots significantly increased with increasing salinity. K^+ content in roots was not affected, but it significantly decreased in shoots at high salinity. Watering treatment had little effect on cation uptake except that shoot Na^+ was less increased due to salinity at high water content (Table 2). K^+/Na^+ ratio in plant parts was invariably higher than in substrate indicating selectivity for K^+ uptake. K^+-Na^+ selectivity was always higher in shoots than in roots suggesting significant translocation of K^+ from roots to shoots.

Table 1. Effect of salinity ($NaCl + CaCl_2 + MgCl_2 + Na_2SO_4$) on seed germination [%], fresh and dry biomass [g plant^{-1}], and cation content [mg g^{-1}] in different parts of *Sesbania rostrata*. Means of 4 replicates, each is represented by an average of 4 plants for biomass and cation content, and 20 seeds for germination. Values followed by the same letters in a row are not significantly different at $P < 0.05$. K^+-Na^+ selectivity values are K^+/Na^+ ratio in tissue divided by K^+/Na^+ ratio in the external medium.

EC [dS m^{-1}] K^+/Na^+		2.5 17.05	5 0.39	10 0.18	15 0.135	20 0.10
Germination		55.00a	43.30b	38.30b	26.60c	25.00b
Biomass	shoot fresh	14.93a	12.20d	8.42b	5.33c	3.04c
	shoot dry	2.09a	1.64b	1.21bc	0.77cd	0.52d
	root dry	0.46d	0.34b	0.25b	0.13c	0.11c
Root	Na^+	3.91d	14.72c	24.38b	33.81d	-
	K^+	53.82d	35.88b	30.81bc	25.74c	-
	K^+/Na^+	13.76	2.44	1.26	0.76	-
	K^+-Na^+ select.	0.81	6.25	7.04	5.63	-
	Ca^+	6.20d	7.00a	8.20d	7.20d	-
Stem	Na^+	2.76d	11.04c	18.40b	22.08b	84.18a
	K^+	62.01a	68.25d	62.79d	66.69d	53.04d
	K^+/Na^+	22.46	6.18	3.41	3.02	0.63
	K^+-Na^+ select.	1.32	15.85	18.95	22.37	6.30
	Ca^+	3.20d	4.00c	5.00b	6.00d	4.80bc
Root	Na^+	2.30d	4.83c	9.66b	11.73b	16.79d
	K^+	54.99d	56.55d	58.89d	42.51b	45.63b
	K^+/Na^+	23.91	11.71	6.09	3.62	2.71
	K^+-Na^+ select.	1.40	30.02	33.83	26.81	27.10
	Ca^+	3.40c	4.40b	4.40b	5.40d	4.60b

Growth of *S. rostrata* and cation contents in roots and shoots were not significantly different in aerated and non-aerated solutions (Table 3).

Varying K^+/Na^+ ratio in the medium had little effect on plant growth (Table 4). Na^+ concentration in roots and shoots was significantly higher and K^+ concentration was lower at 150 than 50 mM NaCl. Shoot Na^+ and K^+ contents were not affected by external K^+/Na^+ ratio, however, root Na^+ content was significantly increased and K^+ content was decreased at lower K^+/Na^+ ratio (Table 4).

Differently reduced seed germination and growth due to salinity are well known for several plant species differing in salt tolerance. *S. rostrata* exhibited great efficiency for selective K^+ uptake over Na^+ uptake under varying salinity and NaCl concentration in root medium (Tables 1 and 2). This high K^+-Na^+ selectivity was confirmed when plants were grown under varying K^+/Na^+ ratios in root medium

Table 2. Effect of salinity ($NaCl + CaCl_2 + MgCl_2 + Na_2SO_4$; EC 1.7, 4.4 and 8.1 dS m^{-1} and K^+/Na^+ ratio 1.94, 0.85 and 0.44, respectively) and soil moisture (50 or 100 % of water holding capacity), on fresh and dry biomass [g $plant^{-1}$], and cation content [mg g^{-1}] in roots and shoots of *Sesbania rostrata*. Means ± SE of 3 replicates, each represented by an average of 6 plants.

Parameters		Soil moisture	Salinity 1.7	4.4	8.1
Root	dry mass	50	0.27 ± 0.05	0.30 ± 0.06	0.08 ± 0.00
		100	0.41 ± 0.01	0.26 ± 0.03	0.13 ± 0.05
	Na^+	50	6.21 ± 0.46	8.51 ± 1.15	16.56 ± 1.38
		100	6.21 ± 0.46	9.66 ± 0.69	13.57 ± 0.23
	K^+	50	29.25 ± 1.56	23.79 ± 1.56	33.15 ± 0.60
		100	28.86 ± 0.78	27.69 ± 1.17	31.20 ± 2.34
	K^+/Na^+	50	4.71	2.79	2.00
		100	4.65	2.86	2.30
	K^+-Na^+ select.	50	2.43	3.28	4.54
		100	2.39	3.36	5.23
Shoot	fresh mass	50	5.92 ± 0.14	6.42 ± 0.61	4.53 ± 0.87
		100	7.50 ± 0.40	6.00 ± 0.29	6.70 ± 0.89
	dry mass	50	0.84 ± 0.04	0.85 ± 0.04	0.26 ± 0.02
		100	1.10 ± 0.05	0.85 ± 0.03	0.73 ± 0.10
	Na^+	50	5.52 ± 0.92	5.98 ± 0.23	12.88 ± 1.61
		100	5.06 ± 2.53	5.75 ± 0.92	8.05 ± 4.60
	K^+	50	41.73 ± 0.78	41.34 ± 2.34	36.27 ± 1.95
		100	43.29 ± 1.95	37.05 ± 1.17	37.44 ± 0.78
	K^+/Na^+	50	7.56	6.91	2.81
		100	8.55	6.44	4.65
	K^+-Na^+ select.	50	3.89	8.13	6.40
		100	4.41	7.58	10.57

Table 3. Biomass yield [g $plant^{-1}$] of *Sesbania rostrata* grown under different NaCl concentrations in aerated or non-aerated nutrient solution. Means ± SE of 6 replicates, each represented by average of 4 plants. EC of 0, 75 and 150 mM NaCl solutions was 2.5, 9.1 and 15.6 dS m^{-1}, respectively. Cation contents in plant parts were not different in aerated and non-aerated treatments, hence the values are not presented.

NaCl [mM]		Shoot fresh mass	Shoot dry mass	Root dry mass
0	aerated	2.83 ± 0.21	0.317 ± 0.024	0.097 ± 0.005
	non-aerated	2.67 ± 0.33	0.289 ± 0.039	0.091 ± 0.011
75	aerated	2.72 ± 0.37	0.314 ± 0.027	0.118 ± 0.016
	non-aerated	2.45 ± 0.17	0.316 ± 0.048	0.089 ± 0.005
150	aerated	2.53 ± 0.22	0.316 ± 0.048	0.124 ± 0.015
	non-aerated	2.23 ± 0.13	0.264 ± 0.017	0.097 ± 0.008

(Table 4). Such selectivity for K^+ uptake is an important factor for salinity tolerance (Mahmood and Malik 1987, Mahmood *et al.* 1996). However, the K^+/Na^+ ratio does

Table 4. Effect of different NaCl concentrations and K^+/Na^+ ratio on biomass [g plant^{-1}] and cation content [mg g^{-1}] of *Sesbania rostrata* shoots and roots. Means ± SE of 6 replicates, each represented by an average of 6 plants.

	NaCl [mM]	Shoots		Roots	
K^+ [mM]		9.45	2.80	9.45	2.80
External K^+/Na^+	50	0.316	0.086	0.316	0.086
	150	0.103	0.030	0.103	0.030
Plant fresh mass	50	1.81 ± 0.16	1.64 ± 0.09	2.22 ± 0.12	1.73 ± 0.10
	150	1.07 ± 0.40	0.99 ± 0.70	1.30 ± 0.10	1.05 ± 0.80
Dry mass	50	0.25 ± 0.02	0.22 ± 0.02	0.11 ± 0.01	0.10 ± 0.01
	150	0.13 ± 0.06	0.13 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
Na^+	50	11.27 ± 0.92	12.88 ± 0.92	12.19 ± 1.15	18.17 ± 0.69
	150	33.12 ± 4.14	32.66 ± 3.22	37.26 ± 2.99	41.86 ± 3.68
K^+	50	28.47 ± 0.39	25.35 ± 0.78	29.64 ± 2.34	27.30 ± 1.17
	150	17.94 ± 0.39	15.21 ± 0.78	26.91 ± 1.95	19.11 ± 0.78
K^+/Na^+	50	2.52	1.97	2.43	1.50
	150	0.54	0.46	0.72	0.45
K^+-Na^+ select.	50	7.97	22.90	7.69	17.44
	150	5.24	15.33	6.99	15.00

not always correlate with salt tolerance and it is not sufficient for selection for salinity tolerance (He and Cramer 1993). A high K^+/Na^+ ratio in tissues of *Brassica* species was considered a contributing factor in their salt tolerance (Ashraf and McNeily 1990), whereas no K^+-Na^+ selectivity occurred in sugar beet (Hasegawa and Yoneyama 1995), a salt tolerant species. The high K^+-Na^+ selectivity in *S. rostrata* differs from general observation that K^+/Na^+ ratio decreases in non-halophytic species under salinity (Porcelli *et al.* 1995). *S. rostrata* is perhaps a unique non-halophyte capable of such highly preferential K^+ uptake under salinity and further detailed studies on this aspect are needed.

Nevertheless, the present studies have shown that *S. rostrata* is moderately tolerant to salinity and can be used as forage crop or green manure in salt-affected lands.

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