GERMINATION, GROWTH AND ION REGULATION IN *PROSOPIS JULIFLORA* (SWARTZ) DC. UNDER SALINE CONDITIONS

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Abstract

Germination and seedling growth of *Prosopis juliflora* was tested using various dilutions of amended sea water. The plant exhibited high salt tolerance at germination as well as at the growth phase. Fifty percent reduction in plant biomass corresponded to EC_{iw}: 21.3 dS.m^{-1}. It responded to salinity through K^+ selectivity during ion influx and exclusion of Na^+ from the leaves by retaining it in the roots. Ca^{++} content decreased in all plant parts under saline conditions likewise, concentration of Mg^{++} declined in roots and did not change in stem but increased in leaves. The mechanism of salt tolerance is discussed with respect to ionic balance suggesting a wide ecological amplitude for *P. juliflora.*

Introduction

Prosopis juliflora (Swartz.) DC. is an aggressive species of wide ecological amplitude. In phytosociological studies of Pakistan coast, it was observed to be associated with several ecologically diverse taxa from glycophytes to halophytes, abounding with various levels of soil salinity (Khan, 1980, 1987). Yadav & Singh (1970) have reported that *P. juliflora* can tolerate calcarious soils with pH up to 9.5 and soluble salt concentration of 0.54%. The field studies of man-made *Prosopis* plantations in coastal sand dune ecosystem of Makran have provided evidence that this plant can survive in compact non-porous soils which are saline up to 35 dS.m^{-1} (Khan *et al.*, 1986). In the present study salt tolerance of this plant at germination and early growth phases was evaluated. The mechanism of salt tolerance with emphasis on the ionic regulation has also been investigated.

Material and Methods

Sea water diluted to simulate various salinity regimes was amended with calcium ammonium nitrate, single super phosphate and sulphate of potash to provide N:P:K in ratio of 170:41:156, and micronutrients corresponding to half strength Hoagland's solution. The analysis of the amended dilutions of sea water used in the experiments is given in Table 1.

Table 1. Analysis of different dilutions of sea water after chemical
amendments. (Data are the mean of 5 replicates).

Irrigation medium	pH	EC $(dS.m^{-1})$	Na^+	K^+	$Ca^{++} +$ Mg^{++}	SAR
					———(meq/l)———	
Control	7.35	1.20	3.26	1.27	32.43	0.63
10% Sea Water + Amendments	7.55	4.50	27.17	1.27	54.89	2.10
20% Sea Water + Amendments	7.45	9.50	32.82	3.19	69.86	6.04
30% Sea Water + Amendments	7.45	14.00	131.52	3.83	109.78	11.11
Sea Water (Arabian Sea)	7.50	40.00	328.80	8.00	162.17	36.51

(i) *Germination:* Seeds of *P. juliflora* collected from its population at Sonmiani coast were surface sterilized in 2% sodium hypochlorite solution and slightly abraded with sand paper to break dormancy due to hard seed coat (Khan *et al.,* 1984). Twenty seeds were placed in 9 cm diameter Petri plates lined with Whatman filter paper No. 1, soaked with a series of amended sea water dilutions (10-30%). The Petri plates with three replicates of each treatment were incubated in a growth chamber at $30 \pm 1^{\circ}C$. Germination counts were made daily.

(ii) *Growth:* In another set seeds were planted in 20 cm diameter earthen pots filled with 2 Kg coastal sand. Seeds were watered with tap water until germination and later, seedlings were irrigated with half strength Hoagland's solution. Seedlings were preconditioned by irrigating them with gradually increasing concentration of sea water up to the level in which the plants were to be grown finally. Pre-conditioned seedlings were treated with 10, 20 and 30% amended sea water on alternate days. Three replicates were kept for each treatment. Each plant received 250 ml of irrigation medium at each irrigation. Non-saline water supplemented with fertilizers and other amendments was used as control. After 22 irrigations, when the plants were 65-day old, growth parameters such as height of the seedlings, numbers of leaves/plant, fresh and dry weights of shoot and root were determined.

(iii) *Analysis of mineral ions:* Dry plant materials of root, stem and leaf were digested in concentrated nitric acid followed by 72% perchloric acid (Toth *et al.,* 1948). The cations extracted were estimated by Jarrell Ash AA-782A atomic absorption spectrophotometer.

Results and Discussion

There was no significant difference (Fig. 1) among final germination percentages of control and the treatments up to 30% amended sea water (EC_{iw}: 14 dS.m^{-1}), though the rate of germination was retarded. Gradual decrease in germination and/or delay in the initiation process under salinity is a well documented fact both in glycophytes (Rozema, 1975; Khan *et al.*, 1984) as well as in halophytes (Ungar, 1978; Khan & Ungar, 1984). There was little difference in germination of *Prosopis farcta* in 0-9 bars (EC: 0-25.35 dS.m^{-1}) NaCl concentrations (Bazzaz, 1973).

No significant difference on seedling height and dry weight of root at all the salinity levels was observed. Mean number of leaves/plant, however, declined from a mean quantum of 30 ± 1 leaves in control to 24.33 ± 1.2 leaves when seedlings were irrigated with 30% sea water. Dry weight of shoot decreased at higher salinity level (EC: 14 dS.m^{-1}). Linear regression analysis between relative total biomass/plant (Y) and electrical conductivity of the irrigation medium (X) showed a relationship as $Y = 100.34 - 2.316X$; $r = -0.9707$, $P < 0.05$). This equation predicts 50% reduction in plant biomass at EC_{iw}: 21.3 dS.m^{-1} indicating a good degree of salt tolerance in plant. Mesquite (*Prosopis glandulosa* var. *torreyana* can survive and flourish in saline soils (> 20 dS.m^{-1}) and root apparently can extract water from soil with salinity greater than 28 dS.m^{-1} (Jarrell & Virginia, 1984). Reduction in growth was apparent under high salinity. Since, salinity increases the energy necessary to combat the osmotic and ionic stresses for normal cellular maintenance, there is relatively less energy available for growth processes (O'Leary, 1986).
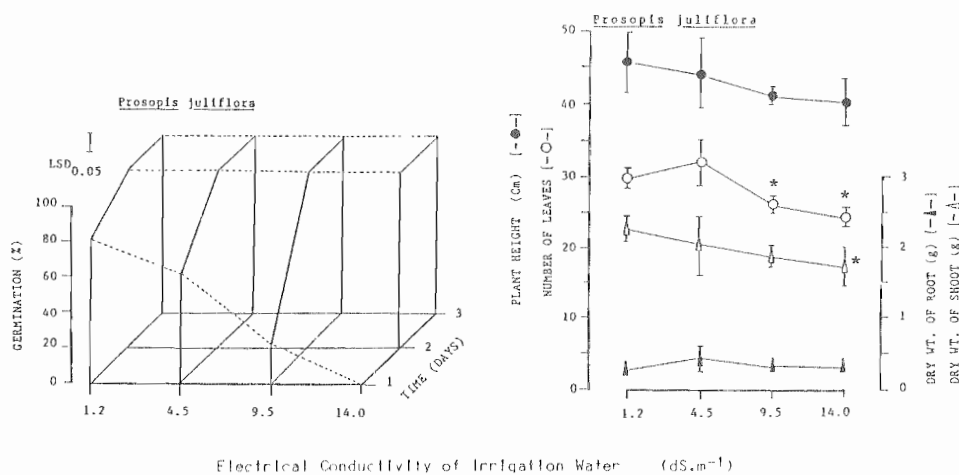

Fig. 1. Germination and early seedling growth of *Prosopis juliflora* under irrigation with amended sea water concentrations.

*Significantly different from the control [1.2 dS.m^{-1}] ($P < 0.05$) as given by t-test.

Table 2. Effect of chemically amended sea water irrigation on cationic
composition of *Prosopis juliflora* roots, stem and leaves.

Treatment	Na^+	K^+	Ca^{++}	Mg^{++}
			(meq/l)	
R O O T				
Control	3.100 a	3.088 a	9.904 a	4.667 a
	± 0.525	± 0.429	± 2.148	± 0.554
10% Sea Water	3.463 a	2.758 a	4.645 bc	3.391 a
+ Amendments	± 0.847	± 0.359	± 1.065	± 0.776
	(− 11.70)	(− 10.68)	(− 53.09)	(− 27.34)
20% Sea Water	3.861 a	1.919 b	6.027 b	2.898 bc
+ Amendments	± 0.507	± 0.401	± 0.802	± 1.223
	(+ 24.54)	(− 37.85)	(− 39.14)	(− 37.90)
30% Sea Water	6.211 b	2.244 b	3.475 c	1.556 c
+ Amendments	± 0.202	± 0.317	± 0.559	± 0.519
	(+ 100.35)	(− 27.33)	(− 64.91)	(− 66.66)
S T E M				
Control	3.093 a	3.156 a	2.133 a	1.309 a
	± 0.290	± 0.168	± 0.174	± 0.092
10% Sea Water	4.058 a	2.905 a	1.733 a	1.125 a
+ Amendments	± 0.523	± 0.308	± 0.166	± 0.129
	(+ 31.19)	(− 7.95)	(− 18.75)	(− 14.06)
20% Sea Water	4.333 a	2.563 a	1.300 b	1.649 a
+ Amendments	± 0.855	± 0.128	± 0.252	± 0.628
	(+ 40.09)	(− 18.79)	(− 39.06)	(+ 25.97)
30% Sea Water	4.058 a	2.905 a	1.783 ab	1.459 a
+ Amendments	± 0.523	± 0.308	± 0.188	± 0.152
	(+ 31.19)	(− 7.95)	(− 16.41)	(+ 11.46)
L E A V E S				
Control	2.609 a	4.305 a	1.680 a	1.938 a
	± 0.251	± 0.602	± 0.289	± 0.055
10% Sea Water	3.189 a	6.010 ab	1.100 ab	2.436 b
+ Admendments	± 0.316	± 2.218	± 0.231	± 0.224
	(+ 22.23)	(+ 39.61)	(− 34.64)	(+ 25.72)

20% Sea Water	2.554 a	4.965 a	1.233 ab	2.744 b
+ Amendments	± 0.257	± 1.514	± 0.233	± 0.437
	(− 2.11)	(+ 15.33)	(− 26.74)	(+ 41.57)
30% Sea Water	2.739 a	7.511 b	0.933 b	2.272 ab
+ Amendments	± 0.094	± 0.034	± 0.186	± 0.428
	(+ 4.98)	(+ 74.47)	(− 44.55)	(+ 17.21)

Mean values in vertical columns not followed by the same letter are significantly different at least at $P < 0.05$ as given by DMRT.

Figures in parenthesis indicates percent increase (+) or decrease (−) over control.

Prosopis juliflora showed a strong tendency for Na^+ exclusion from the leaves and its retention in the roots. Irrigation with 30% amended sea water concentration showed no significant difference on sodium concentration in leaves and stem of seedlings as compared to the controls. Na^+ showed an increase in roots of plants (Table 2). The magnitude of leaf/stem, leaf/root and shoot/root ratios for Na^+ were low in all the treatments (Table 3), whereas, the stem/root ratio was, however, slightly higher as compared to lower salinity level. K^+ content in roots decreased and its concentration did not change in stems and leaves at low salinity levels, whereas, it increased in leaves under high salinity (Table 2). Apparently there was a rapid transport of K^+ from root to stem and then to leaves which substantially increased with increase in salinity and sodicity in the root zone (Table 4). The plant exhibited a strong potassiophilic nature with a tendency of high K^+/Na^+ ratio in the leaves (Table 4), which showed an increase under salinity. The K^+/Na^+ ratio progressively declined in stem and root under increasing salinity levels. The sodium-potassium data would indicate that *P. juliflora* responds to salinity through; i) K^+ selectivity during ion influx; ii) rapid translocation of K^+ from root and stem to the leaves; and iii) Na^+ exclusion from leaves by its retention in the roots. During entry of salts into shoot, a selectivity may operate at the plasmalemma of xylem parenchyma cells in two ways: 1) K^+ or Na^+ could be favoured during xylem release; and b) Na^+ can be reabsorbed from xylem sap (Jeschke, 1984). In species which tend to have high K^+/Na^+ ratio in the shoot, a preference of K^+ during release to the xylem vessels could improve the overall selectivity. Most of the salt tolerant legumes respond to salinity by salt exclusion mechanism (Laüchli, 1984). Bean plants exclude sodium by its retention in its basal parts which gradually become saturated with the increasing salt concentrations in the medium (Jacoby, 1964). A salt-tolerant ecotype of *Prosopis farcta* was shown to restrict translocation of salts to the root and hypocotyl when grown in low salt concentration but under high salinity, it exuded salt through leaf apertures (Eshel & Waisel, 1965).

At increasing salt concentration in the irrigation medium, Ca^{++} content decreased in all the plant parts (Table 2). Ca^{++} uptake by roots was more as compared to Mg^{++} (Table 3). At higher salinities Mg^{++} and K^+ concentration declined in roots and

Table 3. Proportion of some cations with respect to various morphological parts of *Prosopis juliflora* grown under various dilutions of amended sea water.*

Ratio	Control	10% amended sea water	20% amended sea water	30% amended sea water
SODIUM				
Stem/Root	0.99	1.17	1.12	0.65
Leaf/Root	0.84	0.94	0.66	0.44
Leaf/Stem	0.84	0.79	0.59	0.67
Shoot/Root	0.92	0.96	0.89	0.55
POTASSIUM				
Stem/Root	1.02	1.05	1.34	1.30
Leaf/Root	1.39	2.18	2.59	3.35
Leaf/Stem	1.36	2.07	1.94	2.59
Shoot/Root	1.38	2.12	2.22	2.92
CALCIUM				
Stem/Root	0.21	0.37	0.22	0.51
Leaf/Root	0.17	0.24	0.21	0.27
Leaf/Stem	0.79	0.64	0.95	0.52
Shoot/Root	0.19	0.30	0.21	0.39
MAGNESIUM				
Stem/Root	0.28	0.33	0.57	0.94
Leaf/Root	0.42	0.72	0.95	1.46
Leaf/Stem	1.48	2.16	1.66	1.56
Shoot/Root	0.34	0.53	0.76	1.20

*Compiled from the data given in Table 2.

did not change in stem but increased in leaves. The magnitude of shoot/root, stem/root, leaf/stem and leaf/root ratios of Mg^{++} steadily increased with an increase in salinity indicating a relatively greater translocation of Mg^{++} to shoot (Table 4). Ca^{++}/Mg^{++} ratio in different plant parts showed greater translocation of Mg^{++} as compared to Ca^{++} in leaves (Table 4) related to an increase of salinity in the irrigation medium. Selective transport of Mg^{++} and accumulation of Ca^{++} by roots has been observed in *Hordeum vulgare* (Lazaroff & Pitman, 1966).

Table 4. K^+/Na^+ and Ca^{++}/Mg^{++} ratios in various morphological parts of
Prosopis juliflora grown under irrigation with amended sea water dilutions.*

Plant parts	Control	10% amended sea water	20% amended sea water	30% amended sea water
Potassium/Sodium				
Leaf	1.65	1.88	1.94	2.74
Stem	1.20	0.72	0.59	0.72
Root	0.99	0.80	0.50	0.36
Calcium/Magnesium				
Leaf	0.87	0.45	0.45	0.41
Stem	1.63	1.54	0.79	1.22
Root	2.12	1.37	2.10	2.23

*Compiled from the data given in Table 2.

Our results indicate that *P. juliflora* is highly salt tolerant during germination and growth. The plant is potassiophillic and resembles with *Ephedra pachyclada, Artemesia kuramensis, Peganum harmala, Calligonum caput-medusae* and certain varieties of *Zea mays* (Breckle, 1986). Inspite of very high sodium concentration in the root zone, it greatly reduced Na^+ uptake similar to mangroves (Scholander, 1968) and *Azadirachta indica* (Khan, 1987). *P. juliflora* favoured uptake of K^+ during ion influx and appeared as a perfect sodium regulator since concentration of Na^+ did not alter in leaves. Sodium was efficiently retained in roots, but may significantly increase in stem as observed in *P. juliflora* growing under very high soil salinity (> 35.0 $dS.m^{-1}$) in dunes at Makran coast (Khan *et al.*, 1986). The findings described here provide some clues to the salt tolerance mechanism of the plant and explains its occurrence in many salt marsh habitats of Pakistan coast. Mepham & Mepham (1985) have regarded *Prosopis juliflora* as a 'potential mangrove species' in the Indo-West Pacific where it is naturalizing in the tidal zone.

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