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BRIEF COMMUNICATION

Seed germination and salinity tolerance in plant species growing on saline wastelands

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Abstract

Seven plant species including three chenopods: *Suaeda fruticosa, Kochia indica, Atriplex crassifolia* and four grasses: *Sporobolus arabicus, Cynodon dactylon, Polypogon monspeliensis, Desmostachya bipinnata*, varied greatly in their seed germination and growth responses to soil moisture or salinity. The germination percentage of each species was significantly lower at soil moisture level of 25 % of water holding capacity than at the levels ranging from 50 to 125 %. Increase in salinity resulted in gradual decrease in seed germination of each species. Growth responses of species to salinity varied widely from significant decrease with slight salinity to stimulation up to salinity levels of 20 dS m^{-1}. Higher K^+/Na^+ ratios in plant shoots of all species compared to that in the root medium indicated selective K^+ uptake. Higher tolerance in chenopod species seems to be attendant on their ability for internal ion regulation.

Additional key words: ion uptake, plant growth, stress.

Pakistan has about 5.8 million hectares of salt-affected land which could be economically utilized and made productive by growing salt tolerant plants (Qureshi *et al.* 1993). In addition to introducing selected species, the natural flora is also important for enhancing productivity of such wastelands. Seven species: *Suaeda fruticosa, Kochia indica, Atriplex crassifolia, Sporobolus arabicus, Cynodon dactylon, Desmostachya bipinnata* and *Polypogon monspeliensis* were found commonly in saline areas (Mahmood *et al.* 1989, 1994). The purpose of present study was to evaluate the aforementioned species for salt tolerance.

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Oven dried soil [electrical conductivity (EC) = 1.0 dS m^{-1}, pH 7.8, water holding capacity (WHC) = 37.8 %] was taken and five levels of moisture: 25, 50, 75, 100 or 125 % of WHC were obtained by adding calculated amount of distilled water. To achieve the lowest moisture level (25 % WHC), appropriate amount of water was added to soil and kept at 5 °C for one week. The soil moisture was daily maintained and soil gently mixed to allow uniform distribution of water. Twenty seeds of a species were sown in each Petri dish. Each species had four replicate dishes for a moisture level. The percentage of seeds germinated (plumule emergence) was recorded over a period of 20 d.

For salinity effects, 20 seeds of each species were placed on filter paper in Petri dishes supplied with 5 cm^3 of solution of appropriate salinity. The treatments were: Hoagland nutrient solution (Arnon and Hoagland 1940) having EC = 3 dS m^{-1} (control), and salinity levels from 3 to 40 dS m^{-1}, four Petri dishes per salinity level. The salinity levels were made by the addition of NaCl, Na_2SO_4, $CaCl_2$ and $MgCl_2$ in the molar ratio 4:10:5:1 to Hoagland solution (Qureshi *et al.* 1977). Fresh solution was added daily and emergence of plumule was recorded over a period of 2 weeks.

Glazed pots (26 cm diameter, 28 cm deep) having drainage holes were filled with acid- and water-washed gravel (2 - 5 mm diameter) and saturated with Hoagland solution. Four seedlings of similar size and appearance were planted in each pot. After 2 weeks, the pots were subjected to the saline treatments having EC from 3 to 50 dS m^{-1}, four pots per treatment. The higher salinity levels were achieved after seedling transplanting gradually by stepwise increases of salinity every alternate day. The salinity of the root medium was maintained and the solution was aerated daily. The solution was leached and completely replaced every 2 weeks after attaining the aforementioned salinity levels. The plants were grown in the open in a net house during appropriate growing season for each species. The plants were harvested after 8 to 10 weeks and biomass of roots and shoots of each species was determined separately. Plant shoots or leaves of different species were analysed for Na^+, K^+ and Ca^{2+} on a flame-photometer following wet digestion.

Seed germination of the species tested was affected differently by soil moisture levels. Germination percentage of each species was significantly lower at WHC 25 % level compared to that in the remaining soil moisture levels which ranged from 50 to 125 % WHC (Table 1). Soil water content greatly affects the germination of seeds as net gain in water is prerequisite.

Seed germination percentage in four species was not very different over a soil moisture range of WHC 50 - 125 %. *Kochia indica* gave optimum germination percentage at WHC 50 and 75 % indicating relatively greater efficiency of water absorption than other seeds. The seeds of *K. indica* are the largest and flat. Consequently, a relatively large part of seed coat is in contact with the soil water. Further, the seeds of *K. indica* have high (10.86 %) moisture content (Zahran and Wahid 1982) which may also contribute to higher germination of seeds at low soil moisture.

On the other hand, the seeds of grass species studied, being very small in size, showed a marked response to increases in soil moisture and optimum germination percentage was obtained at WHC 100 % (Table 1). Similarly, seeds of *Polypogon* *monspeliensis* are extremely small and their germination percentage increased gradually with increasing soil moisture content. However, percentage germination of almost all species decreased at WHC 125 % probably because of slow gas exchange rates due to excess of water in soil.

Table 1. Seed germination [%] of different plant species at different levels of soil moisture [% of water holding capacity]. Values are means of 4 replicates, each with 20 seeds.

Species	Soil moisture [% WHC]				
	25	50	75	100	125
Suaeda fruticosa	6.25b	40.0a	36.2a	32.5a	27.0a
Kochia indica	1.25c	87.5a	93.7a	63.7a	47.5b
Sporobolus arabicus	6.25b	17.5b	16.2b	32.5a	11.2b
Cynodon dactylon	6.50b	30.0a	33.2a	36.5a	33.2a
Polypogon monspeliensis	1.25d	25.0c	46.5bc	75.0a	57.5ab
Desmostachya bipinnata	27.50b	61.2a	62.2a	61.2a	71.2a

Values followed by different letters in a row differ significantly at $P \leq 0.05$.

Germination percentage of *Cynodon, Polypogon, Sporobolus* and *Kochia indica* was optimum in Hoagland solution (control) and gradually decreased at increased salinity (Table 2). Such responses to salinity are well known. Germination of seeds of *Desmostachya* was stimulated by low salinity (5 dS m^{-1}).

Ranking of species for salt tolerance based merely on germination responses may be misleading because salinity tolerance of a species may vary at different growth stages.

The different species tested exhibited great variations in their responses to different levels of salinity as regard their dry matter yields. Growth responses ranged from significant reduction to stimulation in dry matter production by low salinity compared to control (Table 2). At higher salinity levels, dry masses of roots and shoots of each species were significantly lower than those in control.

Suaeda fruticosa was tolerant to salinity; its growth was stimulated by a salinity level of 20 dS m^{-1}. *Cynodon* and *Polypogon* also gave higher yields at 5 dS m^{-1} treatment compared to control but these species had lower tolerance. The growth of *Kochia, Atriplex* and *Sporobolus* decreased consistently with increase in salinity. Growth stimulation at low salinity is not necessarily associated with greater tolerance (Waisel 1972). On the other hand, reduction in growth of highly tolerant species by low salinity has been reported (*e.g.* Sandhu *et al.* 1981, Mahmood and Malik 1986).

The growth of shoots and roots of different species was not affected to the same extent. Root/shoot mass ratios increased with increasing salinity levels and this response was very pronounced in grass species (Table 2). Higher root/shoot ratio may be favourable but root growth in saline media may be at the expense of shoot growth resulting in a larger relative-to-control reduction in shoot growth.

Na^+ concentrations in plant shoots significantly increased with increase in salinity (Table 3). *Suaeda, Kochia* and *Atriplex* had significantly higher Na^+ contents compared to the grass species. Uptake of Ca^{2+} was inconsistent under saline conditions and the pattern differed widely between the species (Table 3).

Table 2. Seed germination and biomass yield of different plant species at varying levels of salinity (characterized by electrical conductivity) in the medium. Values are means of 4 replicates.

Salinity [dS m-1]	Seed germination [%]	Shoot mass [g plant-1] fresh	dry	dry/fresh	Root dry mass [g plant-1]	Root/shoot
S. fruticosa						
3(Control)	45.0a	34.6ab	6.82ab	0.196	0.87a	0.127
5	47.5a	-	-	-	-	-
10	48.7a	39.8a	7.57ab	0.190	0.87a	0.115
15	21.2b	-	-	-	-	-
20	0c	39.8a	8.08a	0.203	0.98a	0.121
30	-	35.1ab	6.74ab	0.192	0.89a	0.132
40	-	24.4bc	4.98bc	0.204	0.49b	0.098
50	-	15.9c	3.24c	0.203	0.40b	0.123
60	-	14.6c	3.33c	0.228	0.46b	0.138
K. indica						
3	73.7a	25.2a	5.29a	0.210	0.82a	0.155
10	71.2a	23.2a	4.93a	0.212	0.64b	0.130
20	61.2a	21.8a	3.77b	0.172	0.49c	0.130
30	40.2b	23.7a	3.85b	0.162	0.51c	0.132
40	7.5c	14.4b	2.41c	0.167	0.31d	0.129
A. crassifolia						
3	-	25.2b	7.05a	0.279	1.06a	0.150
10	-	28.5d	6.73a	0.236	0.99a	0.147
20	-	17.4c	3.79b	0.217	0.54b	0.142
30	-	12.8d	2.75c	0.215	0.47b	0.171
40	-	10.5d	2.07d	0.196	0.29c	0.140
50	-	7.3e	1.54d	0.211	0.27c	0.175
S. arabicus						
3	36.2a	30.9a	10.17a	0.280	1.36a	0.134
5	23.7b	31.2a	8.37ab	0.268	1.34a	0.160
10	23.7b	27.6ab	7.67b	0.277	1.35a	0.176
15	20.0bc	23.4b	6.72bc	0.287	1.04a	0.155
20	11.2c	17.6c	5.66cd	0.321	1.27a	0.224
25	-	11.8d	4.25de	0.361	0.94a	0.221
30	-	8.4d	3.00e	0.357	0.84a	0.280
C. dactylon						
3	36.6a	20.7b	6.57b	0.317	1.51b	0.229
5	30.0ab	24.8a	8.45a	0.339	2.21a	0.261
10	21.6b	12.6c	4.29c	0.340	1.27bc	0.296
15	6.6c	7.7d	2.75d	0.355	0.86cd	0.313
20	0d	3.7e	1.38e	0.366	0.68cd	0.493
25		2.3ef	0.87e	0.373	0.39d	0.448
30		1.0f	0.44e	0.440	0.31d	0.704

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Table 2 (continued)

P. monspeliensis						
3	71.6a	36.4a	3.75b	0.103	0.64b	0.171
5	48.3b	38.5d	4.05a	0.105	0.75a	0.185
10	8.3c	29.5b	3.30b	0.112	0.49c	0.148
15	0d	11.2c	1.27c	0.113	0.33d	0.259
20	-	4.7d	0.60d	0.126	0.12e	0.200
25	-	2.9de	0.42d	0.142	0.08e	0.190
30	-	1.0e	0.20d	0.194	0.09e	0.450
D. bipinnata						
3	50.0b	4:47a	1.33a	0.297	0.77a	0.579
5	73.7a	2.77b	0.79b	0.285	0.48b	0.607
10	51.2b	2.09bc	0.63bc	0.301	0.39b	0.619
15	42.5b	1.33cd	0.47bcd	0.353	0.45b	0.957
20	40.0b	1.09cd	0.34cd	0.312	0.27bc	0.794
25	-	0.31d	0.13d	0.419	0.05c	0.384

Values followed by different letters in a column differ significantly at $P \leq 0.05$.

Table 3. Cation contents [meq g^{-1}] in leaves of or shoots of different plant species as affected by salinity. Values are means of 4 replicates.

Salinity [dS m^{-1}]	Na^+	K^+	Ca^{2+}	K^+/Na^+
S. fruticosa (leaves)				
3 (10.09)	1.19d	3.38a	0.57a	2.840
10 (0.11)	5.58c	1.07b	0.33b	0.192
20 (0.06)	6.15bc	0.86c	0.25c	0.139
30 (0.04)	7.78a	0.76cd	0.26bc	0.098
40 (0.03)	7.26ab	0.67d	0.26bc	0.092
50 (0.02)	7.85a	0.71d	0.26bc	0.091
60 (0.015)	8.00a	0.71d	0.27bc	0.089
K. indica (leaves)				
3	0.68d	2.46a	0.40a	3.625
10	2.40c	1.28b	0.28b	0.535
20	3.43b	1.16b	0.27b	0.339
30	4.26a	1.20b	0.29b	0.281
40	4.12a	1.20b	0.24b	0.291
A. crassifolia (leaves)				
3	0.62e	1.40a	0.37a	2.263
10	2.56d	0.82b	0.29bcd	0.322
20	3.65c	0.71c	0.25d	0.194
30	4.66b	0.66c	0.28cd	0.143
40	5.79a	0.73bc	0.34ab	0.126
50	6.08a	0.72bc	0.32abc	0.118

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Table 3 (continued)

S. arabicus (shoot)				
3	0.31f	0.81a	0.13a	2.648
5	0.54e	0.69b	0.12a	1.283
10	0.81d	0.64bc	0.13a	0.794
15	1.02c	0.61cd	0.12a	0.596
20	1.04c	0.57d	0.10b	0.547
25	1.16b	0.56d	0.088c	0.478
30	1.31a	0.58d	0.098bc	0.441
C. dactylon (shoot)				
3	0.12e	0.88a	0.12a	7.333
5	0.21d	0.84a	0.12a	3.971
10	0.28c	0.70b	0.13a	2.447
15	0.49b	0.57c	0.12a	1.148
20	0.47b	0.56cd	0.13a	1.183
25	0.85a	0.50d	0.14a	0.584
P. monspeliensis (shoot)				
3	0.11c	1.37a	0.20ab	12.150
5	0.76b	1.08bc	0.16bc	1.419
10	0.86b	0.96c	0.15c	1.116
15	0.88b	1.03bc	0.18abc	1.173
20	0.82b	1.06bc	0.15c	1.300
25	0.85b	1.18b	0.19abc	1.390
30	1.09a	1.17b	0.21a	1.073

Values in parentheses are K^+/Na^+ ratios in solution. Values followed by different letters in a column differ significantly at $P \leq 0.05$. Cation concentrations in stems of *Suaeda, Kochia* and *Atriplex* followed the pattern similar to that in the leaves but the values were significantly smaller.

K^+ concentrations in shoots of all species grown in control were significantly higher than those in plants of saline treatments: 5 and 10 dS m^{-1} (Table 3). Further increase in salinity reduced K^+ uptake by plants up to a level depending on the species. K^+/Na^+ ratios in shoots of all species decreased with increase in salinity but K^+/Na^+ ratios in plants were higher than those in the respective root medium solution (Table 3). Such selectivity for K^+ absorption is an important factor conferring salinity tolerance in plant species (Mahmood and Malik 1987). However, grass species, having lower tolerance, had higher K^+/Na^+ ratios compared to highly tolerant chenopod species. This was due to very high accumulation of Na^+ in the leaves of chenopod species as their K^+ contents were higher or similar to those of grass species. Salt tolerance is achieved in different ways in different species and selective K^+ uptake is one of the many factors involved.

The tolerance levels of different species, determined in the present study, did not always have definite relationship with the salinity of soils dominated by them (Mahmood *et al.* 1989, 1994). Under field conditions, seeds germinate after rain when salts have been leached resulting in lower salinity in the top soil. Thus, the species sensitive to salinity have a chance to establish before salinity again develops in the top soil. Therefore, the inferred level of salt tolerance of a species may under-estimate the range of environmental conditions under which it could potentially grow. The tested species exhibited wide range of tolerance to salinity; most of these may be utilized for enhancing productivity of salt-affected land.

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