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EFFECTS OF IRRIGATION WITH AMENDED DILUTIONS OF SEAWATER ON GERMINATION, GROWTH AND CATIONS DISTRIBUTION IN *PANICUM TURGIDUM* FORSK. - A DESERT FODDER GRAMINOID

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ABSTRACT

Germination, growth and mineral distribution in *Panicum turgidum* Forsk. were investigated using 10-30% amended seawater (ECiw: 4.5-14.0 $dS.m^{-1}$) for irrigation . Fifty percent reduction in germination (in Petri-plates) corresponded with ECiw: 6.72 $dS.m^{-1}$ and threshold ECiw corresponding with 50% reduction in growth (in drum pot culture) was around 13.46 ± 0.51 $dS.m^{-1}$.The plant showed good regeneration after bi-monthly clipping around the year except that growth was extremely reduced during winter season. The cumulative forage biomass harvested per annum with 30 % amended seawater (ECiw: 14.0 $dS.m^{-1}$) was 1279.79 ±16.59 $g.drum^{-1}$ (FW). It was 2851.85 ± 57.83 $g.drum^{-1}$ (FW) in control (1.2 $dS.m^{-1}$); reduction being c. 55%. The reduction in forage production in 10 and 20% seawater was c.23 and c.34% of the control, respectively. The plant showed flowering throughout the year.

The plant irrigated with saline water showed decrease in chlorophyll and sugar contents and increase in proline level whereas moisture and protein concentration remained quite unaffected. The uptake of cations was selective. Sodium increased in the roots and shoots with almost equal magnitude and potassium declined in concentration with the salinity. There was, however, rapid translocation of potassium from roots to the shoots. The divalent cations like calcium and magnesium accumulated in greater concentration in the shoot.

Key Words: *Panicum turgidum*, Amended Seawater irrigation, Germination, Growth, Biomass productivity, Chlorophyll, Total sugars, proline, Protein and cationic Distribution.

INTRODUCTION

Panicum turgidum Forsk. is a psammophytic graminoid grazed intensely by a number of desert animals. Chaudhri and Chattar (1966) reported it to form the pioneer vegetation of sand dunes of Thar Desert. It associated with salt free to slightly saline sandy soils of the Pakistan coast with a salinity of ECe:7.8 $dS.m^{-1}$ and maximum sodicity in terms of ESP as high as 15.24 (Khan, 1987). This grass is rated amongst the best grazing plants. Growing salt-tolerant under-exploited plants by utilizing saline water can provide an economic use of abandoned semi-arid and arid lands (Dagar *et al.*, 2006). Experimental investigations related to salt tolerance of *P. turgidum* are, therefore, worthy to be undertaken in order to determine its possible utilization in developing pasture under saline irrigation in sandy soils. The effects of saline water irrigation on germination, growth, productivity and regeneration of *P. turgidum* have been investigated in this paper. The studies in relation to variation of biochemical compounds such as chlorophyll, total sugars, proline and protein contents and cationic distribution under salinity have also been undertaken.

MATERIALS AND METHODS

(i) Preparation of Irrigation Media

Different dilutions of sea water (10-30%), in order to reduce Na toxicity, were amended with fertilizer-mixture using Calcium Ammonium Nitrate (CAN), Single Super Phosphate (SSP) and Sulphate of Potash (SOP) in amounts appropriate to provide N:P:K ratio of 170:41:156. Magnesium was provided as Magnesium Sulphate. Micronutrients and Fe-EDTA each corresponding to half strength Hoagland's solution were added at the rate of 1ml per liter of culture solution to complete its composition. Control culture solution was prepared in tap water. The chemical analysis of the irrigation media appears in Table 1.

(ii) Germination

The caryopses of *P. turgidum* were collected from its population at Bhawani (off Balochistan coast). These caryopses exhibited no dormancy. Twenty surface-sterilized caryopses were placed on Whatman filter paper No. 1 in a 9 cm. diameter Petri-plates to germinate in a series of amended seawater dilution at 30 ± 1 ^{o}C with light

intensity of 4000 Lux for 14h day-length. The control and treatments were replicated thrice. Germination counts were made daily.

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(iii) Growth

The plants of *P. turgidum* were raised by vegetative propagation in poylethylene bags containing 1 kg sandy soil and provided with a basal perforation. The plants for this purpose were collected from Bhawani, off Balochistan Coast. The rooting medium was initially half strength Hoagland's solution and later tap water at the alternate days till such a time those plants were subject to pre-conditioning.

(a) Preconditioning

In order to avoid the shock effects of saline irrigation, the plants after one month of growth in polyethylene bags were pre-conditioned by irrigating them initially with 5% amended sea water and gradually increasing the concentration up to a level in which the plants were to be finally grown.

(b) Drum Pot Culture

Plastic drums were sunken in slightly slanting position in a cemented platform so as to ensure rapid drainage of saline water from the basal outlet. Each drum was filled with 300 kg of coastal sand collected from Sonmiani Beach (Balochistan). Each drum was capable of retaining 44 liter of irrigation water at field capacity. Over irrigation was practiced to avoid accumulation of salts in the root zone. Each drum was irrigated with 16 liter of irrigation medium at weekly interval, irrespective of any rains.

Plants, being pre-conditioned when reached up to a level of 10, 20 and 30% amended sea water, were transplanted in drum pots and irrigated with their respective concentration of seawater till the end of the experiment. Three replicates were kept for each treatment and the control. The experiment was continued for one year period.

The foliage biomass in terms of fresh weight was taken as criterion of growth. Foliage was clipped after every two months interval at 30 cm. height from the soil. At the final harvest, residual shoot and root biomass were also recorded.

Germination test of the caryopses produced by the plants grown under drum pot culture was also conducted in order to determine their viability and germinability.

(iv) Moisture Content and Biochemical Estimation

Moisture content of the foliage was determined by the relative difference in fresh and dry weights of the sample and expressed as percentage of fresh weight. Chlorophyll (Maclachlam and Zalik (1963), total sugars (Yemm and Willis, 1956), proteins (Lowry *et. al.*, 1951), proline contents (Bates *et. al*., 1973) of leaf were determined.

(v) Analysis of Mineral Ions

Cations were extracted by acid digestion of 1g dry plant material following the method of Toth *et. al*., (1948). The digestion was carried out in conc. Nitric acid followed by 72% Perchloric acid. The digested material was dissolved in 100ml deionized water. Na, K, Ca, and Mg were estimated using JARREL ASH-782-A Atomic Absorption Spectrophotometer. Three replicates were used for each treatment and control.

OBSERVATION AND RESULTS

The germination as well as the rate of the germination declined substantially under increasing salinities so that germination was completely inhibited in 30% amended sea water (Fig. 1). The final germination (Y) and the electrical conductivity of the irrigation medium (X, $dS.m^{-1}$) related as $Y = 56.54 - 4.21X$ ($r = -0.9939$; $p < 0.001$). The 50% reduction in final germination thus corresponded with ECiw: $6.72 dS.m^{-1}$.

The increase of concentration of salts in irrigation medium caused decrease in shoot biomass throughout the year (Table 2). The biomass production in plants irrigated with 30% sea water was $476.66 \pm 32.83 g.drum^{-1}$ during monsoon season (July-August – 65.1 mm rains *in toto*) when reduction compared to control was only around 10%. The maximum biomass during monsoon was recorded in 20 % amended sea water (646.66 ± 8.82 $g.drum^{-1}$ – 21% more than the respective control). The minimum biomass production was recorded in winter

(January-February) with a reduction of 88% as compared with the control. The variation in biomass of seasonal clippings was the maximum in plants irrigated with 30% sea water and minimum in the control. The plants exhibited flowering throughout the year, however, salinity appeared to induce flowering little earlier in plants irrigated with 30% sea water. Salinity also declined vegetative growth more substantially in winter. The winter harvest was indeed mostly composed of inflorescences with little amount of stems and leaves.

Table 1. Analysis of different dilutions of seawater after chemical amendments (data is a mean of 5 replicates).

Irrigation Medium	pH	EC_{iw}: $dS.m^{-1}$	Na (meq/l)	K (meq/L)	Ca + Mg (meq/L)	SAR
Control	7.35	1.2	3.26	1.27	32.43	0.63
10% SW + amendments	7.55	4.5	27.17	1.27	54.89	2.10
20% SW + amendments	7.45	9.5	32.82	3.19	69.86	6.04
30% Sw + amendments	7.45	14.0	131.52	3.83	109.78	11.11
Seawater (Arabian sea)	7.50	40.0	328.00	8.00	162.17	36.51

Table 2. Fresh weight of shoot biomass (g) clipped from *P. turgidum* as affected with seasonal variation and irrigation with amended dilutions of seawater.

TREATMENT	SEP-OCT 255.0 mm*	NOV-DEC Zero	JAN-FEB Zero	MAR-APR Zero	MAY-JUN Zero	JUL-AUG 65.1mm
CONTROL	456.73± 7.92 Aab	552.77± 22.08 Aab	564.69± 24.58 Ab	337.00± 2.30 Ac	409.33 ± 6.35 Acd	531.33± 33.15 Aab
10% SEAWATER + AMENDMENTS	304.73 ± 22.36 Ba (-33.26)	371.91± 19.68 Bb (-32.71)	292.85 ± 18.79 Ba (-48.14)	314.66 ± 32.33 ACab (-6.63)	332.00 ± 27.16 ACab (-18.89)	553.70 ±23.55Ad (+4.21)
20% SEAWATER + AMENDMENTS	223.88 ± 9.04 BCa (-50.98)	226.59± 16.58 Cb (-59.01)	195.51 ± 11.57 BCa (-65.37)	265.23 ± 21.06 BCa (-21.29)	308.00 ± 1.03 BCd (-24.76)	646.66 ± 8.82 Be (+21.70)
30% SEAWATER + AMENDMENTS	196.90 ± 14.78 Ca (-56.88)	71.94 ± 16.58 Db (-86.99)	69.47 ± 19.98 Ba (-87.69)	204.47 ± 17.32 Ba (-36.40)	260.33 ± 17.32 Ba (-36.40)	476.66 ± 32.83 Ac (-10.29)

*, rainfall in mm; Figures in parenthesis indicate percent increase (+) or decrease (-) over control. Mean data not followed by the same letter are significantly different at least at $p < 0.05$ as given by DMRT. Capital letters compares the columns and small letters the rows.

Table 3. ANOVA for seasonal harvests of *Panicum turgidum* grown under various salinity levels (amended seawater irrigation).

SOURCE	SS	df	MS	F	p
Block/ Subject	846.578	2			
Harvests	668798.461	5	133759.692	56.534	0.001
Error (a)	23660.182	10	2366.018		
Treatment	648059.127	3	216019.709	174.869	0.001
Error (b)	7410.7348	6	1235.123		
Harvest x Treatments	373505.772	15	24900.385	13.283	0.001
Error (C)	56240.039	30	1874.668		
Total	1778520.900	71			
Residual	87310.959	46			

CV (a) = 14.43; CV (b) = 10.43; CV (c) = 12.85 %. Grand mean = 337.04g

It was clear from ANOVA for the harvested biomass (Table 3) that both harvest and treatment had significant effect on plant growth ($p < 0.001$) and there was also a significant interaction between treatment (salinity) and harvest ($p < 0.001$). The coefficients of variation for harvest effect (CV(a)), treatment effect (CV(b)) and interaction effect (CV(c)) were of low order indicating that the measurement of harvest, salinity and their interaction effects were of high and more and less equal precision.

Table 4 presents data on annual total biomass production. The total shoot biomass clipped from the plants irrigated with 30% sea water reduced to around 55% of the control. The shoot biomass clipped from plants treated with 20 % seawater was around 66% of the control. The residual shoot biomass gave more or less similar pattern. The root biomass, however, increased up to 20% sea water but declined thereafter by a magnitude of 28% in 30% sea water. The total plant biomass which was 3725.85 ± 49.59 g /plant in control reduced to 1831.10 ± 23.98 g/plant in 30% sea water; reduction being almost 50%.

Table 4. Shoot biomass production (cumulative) per annum of *P. turgidum* irrigated with various dilutions of amended seawater.

TREATMENT	BIOMASS HARVESTED ($g.drum^{-1}. yr^{-1}FW$)	RESIDUAL BIOMASS		TOTAL BIOMASS ($g.drum^{-1}. yr^{-1}FW$)
		Shoot (g)	Root (g)	
Control	2851.85 ± 57.83	390.00 ± 11.55	484.00 ± 13.38	3725.85 ± 49.59
10% Seawater + Amendments	2169.85 ± 35.34 (-23.91)	316.33 ± 17.13 (-18.89)	763.33 ± 84.13 (+57.71)	3249.51 ± 31.11 (-12.79)
20% Seawater + Amendments	1865.88 ± 18.93 (-34.57)	280.66 ± 29.03 (-28.03)	526.66 ± 51.92 (+8.81)	2673.21 ± 48.29 (-28.25)
30% Seawater + amendments	1279.77 ± 16.59 (-55.13)	206.67 ± 6.67 (-47.01)	344.66 ± 48.48 (-28.79)	1831.10 ± 23.98 (-50.85)

Figures in parenthesis indicate per cent promotion (+) or reduction (-) over control.

Table5. Linear correlation and regression between electrical conductivity (ECiw: $dS.m^{-1}$) of irrigation water and various growth parameters of *Panicum turgidum*.

ECiw: $dS.m^{-1}$ (X) / Parameter Studies (Y)	r	Regression a	Regression b	ECiw: $dS.m^{-1}$ Corresponding to 50% reduction	Average ECiw: $dS.m^{-1}$
ECiw / biomass Clipped	- 0.978 ***	2873.1	- 113.87	12.62	
ECiw / Residual Shoot Biomass (g) FW	- 0.914 ***	395.7	-13.32	14.85	
ECiw / Total Shoot Biomass (g) FW	- 0.972 ***	3269.2	-127.68	12.80	13.46 ± 0.51 CV= 7.54 %
ECiw / Total Biomass (g) FW – including Root Biomass	- 0.995 ***	3923.3	-144.30	13.59	

CV, Coefficient of variation; ***, $p < 0.001$, N = 12.

Linear correlation and regression analysis between salinity and various growth parameters of *P. turgidum* suggested that the threshold values of ECiw corresponding to 50% reduction in terms of various parameters, are fairly consistent (12.62 - 14.85 $dS.m^{-1}$) averaging to 13.46 ± 0.51 $dS.m^{-1}$ (Table 5). This threshold value is exactly double to that corresponding with 50% reduction in final germination.

Germination studies conducted in order to evaluate the germinability of the caryopses produced under various salinity regimes indicated that so far as the final germination is concerned, no significant difference occurred in germinability amongst the caryopses obtained from the control and the treated plants (Fig. 2).

The irrigation with different seawater dilutions reduced the chlorophyll content but no significant change in ratio of chlorophyll a/b was noticed. The moisture content remained more or less unaffected. Total sugar content decreased at all salinity levels and protein level was not much affected. Proline concentration increased in 20% and 30% seawater treatment (Table. 6).

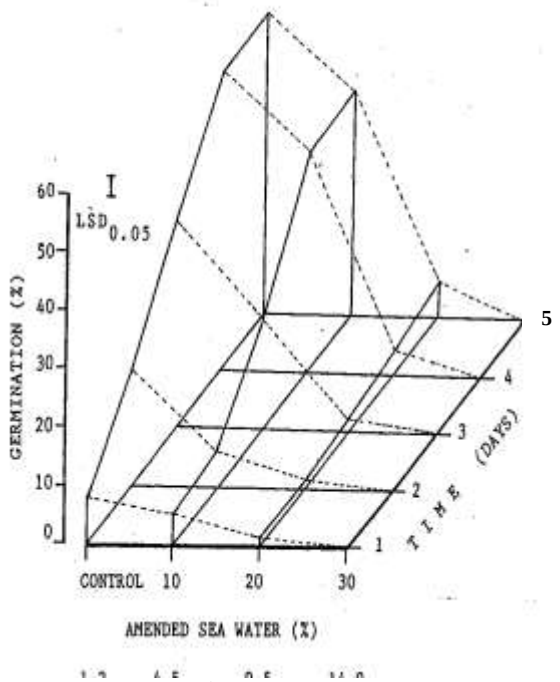

Fig.1. Germination response of *Penicum turgidum* to various salinity regimes.

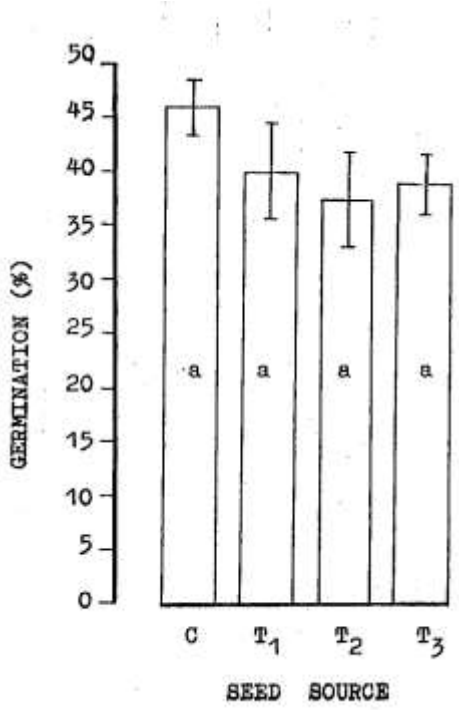

Fig.2. Germination of seeds collected from plant grown under various salinity regimes. C= Control, T1= 10% Sea Water (SW), T2= 20%, SW T3= 30% SW.

Table 6. Effect of amended seawater irrigation on chlorophyll, moisture and biochemical constituents of *P. turgidum* leaves.

Treatment	Chl. a mg.g^{-1}FW	Chl. b mg.g^{-1}FW	Total Chl. mg.g^{-1}FW	Chl. a / b ratio	Moisture (%)	Total Sugars mg.g^{-1}DW	Protein mg.g^{-1}DW	Proline mg.g^{-1}DW
Control	0.429 ± 0.017 a	0.646 ± 0.059 a	1.076 ± 0.065 a	0.673 ± 0.053	71.52 ± 2.05 a	32.99 ± 2.864 a	33.201 ± 0.462 a	1.481± 0.462 a
10% SW +A	0.344 ± 0.017 b (-19.82)	0.493 ± 0.018 ab (-23.68)	0.836 ± 0.035 b (-22.31)	0.698 ± 0.010 (+3.714)	73.31± 1.260 a (+2.50)	25.304 ± 1.010 b (-23.311)	29.982 ± 2.645 a (-9.695)	1.130 ± 0.019 a (-23.701)
20 % SW+ A	0.347 ± 0.0.016 b (-19.16)	0.489± 0.012 b (-24.30)	0.837 ± 0.027 b (-22.21)	0.709 ± 0.017 (+5.349)	70.05 ± 0.29 a (-2.05)	28.25 ± 1.170 ab (-14.368)	30.796 ± 3.333 a (-7.243)	1.547 ± 0.130 a (+4.456)
30 % SW+ A	0.306 ± 0.032 c (-28.67)	0.464 ± 0.014 b (-30.96)	0.752 ± 0.079 b (-30.11)	0.686 ± 0.012 (+1.931)	70.61 ± 1.24 a (-1.27)	24.844 ± 2.787 b (-24.692)	31.307± 2.205 a (-5.705)	2.087 ± 0.112 b (+40.918)

Mean data in column not followed by the same letter are significantly different at least at $p < 0.05$ as given by DMRT. Figures in parenthesis indicate percent increase (+) or decrease (-) over control. SW +A, Amended seawater

Table 7. Effect of amended seawater irrigation on cationic composition of *P. turgidum* roots and leaves.

Treatment	Sodium (meq /l)		Potassium (meq / l)		Calcium (meq/l)		Magnesium (meq / l)	
	Root	Leaves	Root	Leaves	Root	Leaves	Root	Leaves
Control	1.877± 0.598 a	4.492 ± 0.076 a	2.018 ± 0.218 a	8.354 ± 0.558 a	0.797 ± 0.129 a	3.240 ± 0.213 a	0.853 ± 0.173 a	3.160 ± 0.173 a
10% SWA	3.962 ± 0.895 b (+111.08)	4.818 ± 0.226 a (+7.257)	1.087 ± 0.133 b (-46.135))	4.732± 0.128 b (-43.36)	0.673 ± 0.278 a (-15.508)	3.990± 0.315 a (+23.15)	0.574 ± 0.080 b (-32.669)	2.792 ± 0.063 b (-11.65)
20 % SWA	4.435 ± 1.283 bc (+136.28)	5.268 ± 0.130 ab (+17.275)	0.818 ± 0.179 b (-59.465))	3.564 ± 0.322 c (-53.34)	0.528 ± 0.109 a (-33.752))	3.093 ± 0.411 a (-4.537)	0.443 ± 0.084 b (-48.023)	2.613 ± 0.084 b (-17.31)
30 % SWA	5.044± 1.337 c (+168.72)	6.098 ± 0.160 b (+35.75)	0.882 ± 0.148 b (-56.293)	2.950 ± 0.062 c (-64.69)	0.537 ± 0.089 a (-32.610))	3.011 ± 0.196 a (--7.067)	0.545 ± 0.034 b (-36.023)	2.224± 0.092 c (-28.98)

Mean data in column not followed by the same letter are significantly different at least at $p < 0.05$ as given by DMRT. Figures in parenthesis indicate percent increase (+) or decrease (-) over control. SW + A, Amended seawater.

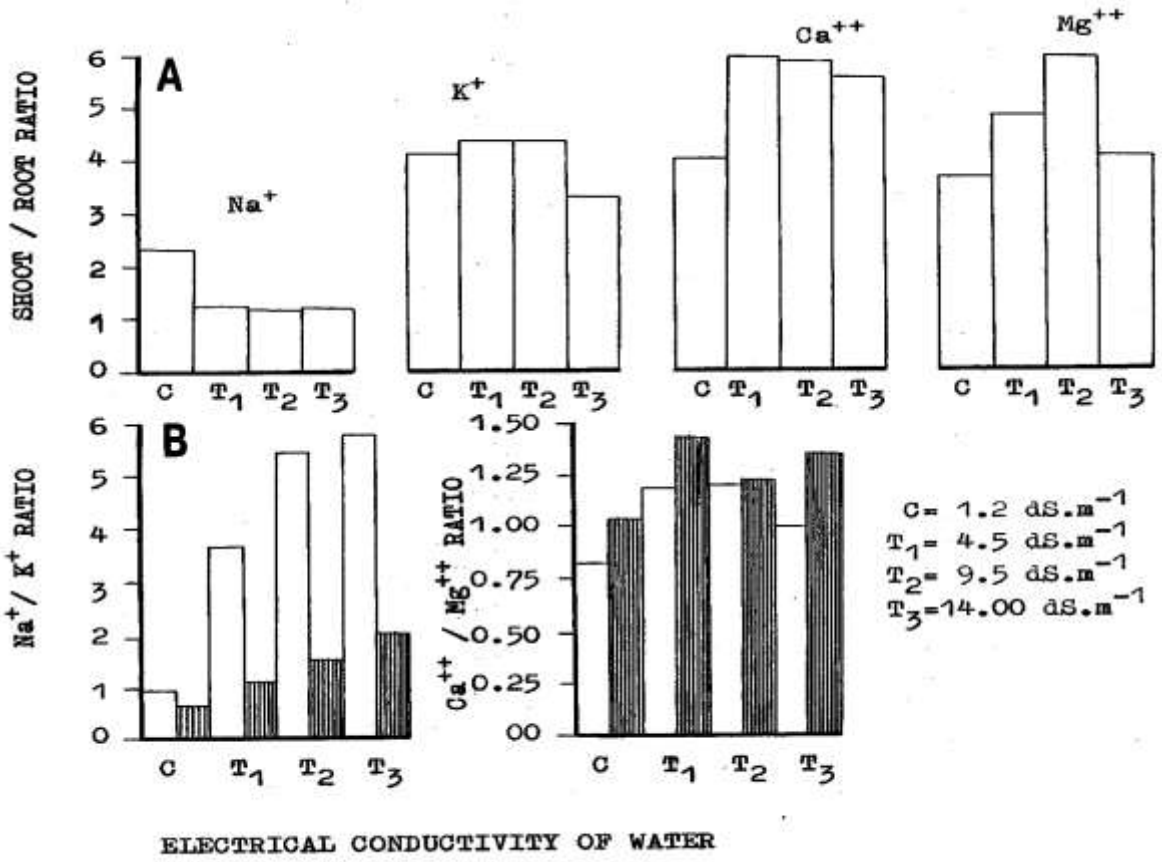

Fig.3. Comparative account of ions in root and shoot (A) and Na+ / K+ and Ca++ / Mg++ rations in root (thatched) and shoot (open) (B) of *P. turgidum* grown under various salinity regimes.

The data on cationic composition (Table 7) shows that with the increase in salt concentration of seawater there occurred an increase in Na and decrease in K in leaves as well as roots. No significant difference was observed in concentration of Ca in leaves and roots though Mg content declined. The concentration of Ca and Mg was, however, comparatively higher in leaves than in the roots.

It is apparent from the relative intracellular cationic accumulations that shoot/root ratio of Na were low and around one particularly in the treated plants (Fig. 3). There was rapid translocation of K, ca and Mg from the roots to the shoots as is evident by the values of shoot/root ratios of these ions. The plant exhibited the tendency of having comparatively lower Na/K ratio in shoot as compared to that in the root, but due to gradual increase of Na in leaves with salinity and concomitant decrease in K , the Na/K ratio of 0.5 in control plants increased to 2.0 in leaves of plants treated with 30% sea water i.e., at higher salinity foliar Na concentration was double to that of K. Ca/Mg ratio in root as well as the shoot remained almost unaffected with salinity.

DISCUSSION

Our studies indicate that *P. turgidum* is more sensitive to salinity at germination than at the subsequent growth stage. It is in agreement with the contention of Ayers (1952) that salt tolerance at germination and other phases of life cycle are not necessarily correlated. Azizov (1974) has reported that seeds of sea lavender (*Limonium meyeri*) can not germinate in salts solution above 1.5%, yet the mature plant can grow even in the presence of 10% salt solution in soil. Fifty per cent reduction in germination and biomass production in *Indigofera oblongifolia* is reported to correspond with ECiw: 10.0 and 12.05 $dS.m^{-1}$, respectively (Khan and Ahmad, 1998) and in case of *Sporobolus arabicus*, such a reduction corresponded with ECiw: 32.4 and 28.6 $dS.m^{-1}$, respectively (Khan and

Ahmad, 2002). Seeds of halophytic Andean Qu*inoa* (*Chenopodium quinoa*), exhibited only around 14% germination in 0.4 M NaCl compared to that in controls (87%) (Prado *et al.,* 2000). Halophytes, from marshy habitats, such as *Aeluropus lagopoide*s and *Sporobolus madraspatanum* are reported not to germinate in 8 $dS.m^{-1}$ seawater or 5 ppt NaCl (Joshi *et al.,* 2005). According to Gulzar *et al.* (2001) halophytic *Urochondra setulosa* seeds best germinate in non-saline environment and only less than 10% seeds could germinate in 500 mM NaCl salinity. Ungar (1974) has, on the other hand, reported that seed germination in *Hordeum jubatum* is more resistant process to salinity than the later growth of the seedling. This indicates that a substantial degree of variation in salt tolerance may exist within a species depending upon different developmental stages of its life. Salt tolerance at germination and growth phases is not, therefore, necessarily correlated.

Our studies suggest *P. turgidum* to be a fairly salt tolerant plant, at growth stage, with good regeneration after repeated bimonthly clipping. It retains the physiological balance in the caryopses even when irrigated with highly saline water. Many species of genus *Panicum* e.g., *P. porphyrrhizos*, *P. repens* (Verboom and Brunt, 1970), *P. antidotale* (Riyan *et al.,* 1975), *P. schinzii* (Kumar and Abrol, 1983) and P. *virgatum* (White, 1980) have been reported to be salt tolerant.

Although, *P. turgidum* exhibited 55% reduction in growth in 30% seawater, its yield was within permissible limits up to 20% seawater; reduction being around 34% (cf. Naqvi (1983) - according to which a reduction up to 50% may be within economic limit at certain salinity). The growth of the plant, as is evident from our data, is greatly reduced in winter (minimum mean monthly temperature of coolest month: 8.6 - 10.9 ^{o}C, though the temperature seldom dropped to as low as 5 ^{o}C for a short period). The plant regenerated very well after rains when maximum biomass was recorded in 20 % amended seawater (646.66 ± 8.82 $g.drum^{-1}$ – 21% more than the respective control). Regeneration of biomass, in monsoon period, generally took place from axillary buds situated on the nodes of aerial stems although a number of tillers were also produced from sub-soil rhizomatous parts. The interaction between salinity and harvest seems to arise due to the fact that this species has evolved in hot summer precipitating areas and undergoes dormancy during winter. The reduction in growth during higher temperature as reported by Bernstein and Ayers (1951) due to enhanced evapo-transpiration does not seem to involve in our experiment because weekly over irrigation was practiced that excluded the possibility of moisture depletion.

In our experiment *Panicum* was although irrigated with highly saline water, no significant difference was observed in moisture content which indicated that some mode of salt tolerance other than succulence and moisture accumulation operates in this species. A decrease in chlorophyll content under salinity could be due to inhibition of iron-containing enzymes which activates the biosynthesis of chlorophyll as suggested by Rubin and Artiskhovaskaya (1964). A decrease in sugar content was associated with the increase in salinity with slight irregularity at 20% seawater. This is contradictory to several reports where increase in sugar concentration is observed, particularly at lower salinities (Rozema, 1978; Ahmad *et al.*1987; Khan and Ahmad, 1998, 2002). The decrease in sugar content has, however, been reported in *Melia azedarach* under saline conditions by Ahmad *et al*. (1985). It seems that the translocation of sugar to roots is more efficient in *P. turgidum* and also breakdown of complex molecules occurs rapidly for the supply of metabolic energy for growth processes. Translocation of sugars should provide more respiratory substrate to roots and energy yielding products thus could control the ion-fluxes during mineral uptake (Chimiklis and Karlander, 1973).

A regards protein-amino acid metabolism, though protein content remained quite unaffected, proline level increased under salinity. Accumulation of proline has been reported under different stressful conditions and its accumulation in saline environment (Strogonov, 1964; Rozema, 1978 ; Rains *et al.,* 1982; Joshi *et al.,* 2005) is considered beneficial for plant growth (Rozema, 1978 ; Rains *et al.,* 1982). Proline accumulation may take place either due to protein degradation or inhibition of proline conversion under salinity (Singh *et al.,* 1973). It is assumed that proline increases the protein solubility (Schobert and Tschesche, 1978), it is compatible in permeability to cytoplasm and prevents the dehydration of enzymes and other essential structures (Gorham *et al.*,,1981), it controls the ion-fluxes (Stewart and Lee, 1974) and regulates the storage of nitrogen (Jeffereies, 1980).

Our experiment disclosed a differential preference of cations uptake in this plant. In spite of Na being present in larger concentration in the irrigation medium, the plant managed to absorb K, Ca and Mg due to selective permeation operating in the roots. Besides Na, uptake of divalent ions such as Ca and Mg was also quite substantial. These ions were more allocated to shoot than root. However, Ca / Mg ratio in shoot and root remained more or less unaffected with salinity. Plants like *Zygophyllum simplex*, *Hammada recurva*, *Cressa cretica* and *Heliotropium curassavicum*, when growing in highly saline soils, are also reported to accumulate greater amounts of Ca in shoot (Ahmad and Zaheer, 1985). Lazaroff and Pitman (1966), on the other hand, reported that *Hordeum vulgare* shoots show preference to Mg whereas Ca is more preferentially accumulated by the roots. It may be pointed out that uptake of divalent cations (Ca and Mg) is reported to be largely proportional to the concentration of these ions in the culture medium (Lazaroff and Pitman (1966). Larger concentration of Ca and Mg

in the foliar tissue of *Panicum* could be due to the enrichment of irrigation media with these ions to reduce sodium toxicity.

The concentration of Na in the root and shoot was observed to be almost equal, though obviously very much lower than that in the irrigation medium. It indicated that the plant attempted to check the entry of Na into the system through ion regulation and once Na entered the system, it was translocated to the shoot in a manner that its concentration in root and shoot was almost equal. The amendments employed to ameliorate the concentration of K , Ca , and Mg in the irrigation medium could also have retarded the movement of sodium and have intensified the availability and uptake of K , Ca, Mg. It is known that K -Na exchange and selective uptake of K depend upon the presence of Ca in the rooting medium (Elzam and Epstein, 1969).

Although *P. turgidum* showed a tendency of rapid translocation of K from root to shoot, Na concentration remained substantially high in the shoot (leaf). To effectively counteract the toxic and osmotic effects of increased Na level, the role of vacuole as hypothesized by Jennings (1968) could be of utmost physiological significance in this species. Under saline conditions sequestration of Na in vacuole i.e., intracellular compartmentalization of cations and Na -K exchange at cellular membrane are known processes in many halophytes and glycophytes as well (Jeschke, 1984). Furthermore, under such conditions the increased concentration of proline could not only prevent dehydration and degradation of enzymes and proteins within cytoplasm counteracting the osmotic effects of the increased vacuolar sap, but also could be important in regulating the intracellular Na distribution (cf. Ahmad *et al*., in Jeschke, 1984).

It follows from the results that *P. turgidum*, a moderately productive and valuable desert grass, may be grown with moderately saline water in arid sandy areas. It is, of course, somewhat less productive than *S. arabicus* (Khan and Ahmad, 2002) but comparable to *Leptochloa fusca* in productivity (Ahmad *et al*., 1987). It can be of much economic use in arid and semi-arid areas.

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