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Responses of Some Arid Zone Grasses to Brackish Water

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Abstract

Key words: Brackish water, grass species, salinity tolerance, variation.

Salinity tolerance of five grass species, *Cenchrus pennisetiformis* Hochst. & Steud., *Leptochloa fusca* (L.) Kunth., *Panicum turgidum* Forssk., *Pennisetum divisum* (Gmel.) Henr. and *Puccinellia distans* (L.) Parl. was assessed after 6 weeks growth at four salinity treatments, 2.4 (control), 8, 16, and 24 dS m^{-1} which were prepared by mixing four salts, $NaHCO_3$, $MgSO_4$, $7H_2O$, $CaCl_2$, $2H_2O$ and NaCl in 1:5:10:30 ratio in half strength Hoaglands's nutrient solution.

Shoot biomass production in *L.fusca* and *P.distans* was not affected by salinity in both mean and relative terms and they had significantly greater shoot fresh and dry matter than the other species at all salinity treatments. *Pennisetum divisum* was the worst affected since it had the lowest fresh and dry biomass of both shoots and roots of all the species, whereas *C.pennisetiformis* and *P.turgidum* were intermediate in biomass production. *Leptochloa fusca* accumulated relatively greater concentrations of Na^+, Cl^-, K^+ and Ca^{2+} in the shoots than the other species. By contrast, *P.distans* contained relatively high Cl^-, and low Na^+ and K^+ in the shoots. *Cenchrus pennisetiformis* absorbed relatively greater amounts of Na^+ and Ca^{2+} in the shoots, but restricted the Cl^- accumulation in the shoots and had moderate shoot K^+ concentration. *Panicum turgidum* was relatively intermediate in Na^+ and Cl^- accumulation in the shoots but was the highest in accumulation of Na^+, Cl^- and K^+ in the roots. *Pennisetum divisum*, which was the poorest in biomass production contained relatively moderate amount of Na^+ in the shoots but had high K^+ and Cl^- at different salt treatments. It was established that *C.pennisetiformis* and *P.turgidum* were intermediate in tolerance to salinity, whereas *P.divisum* was sensitive in relation to *L.fusca* and *P.distans*.

1 Introduction

The low precipitation combined with the summer heat is responsible for a scanty vegetation in most deserts of the world. In a survey of the Cholistan desert, one of the largest deserts in Pakistan, Ashraf & Bokhari (1987) have recorded many grass species which are

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widely used as fodder for all types of livestock. Of these, *Cenchrus pennisetiformis* Hochst. & Steud., and *Panicum turgidum* Forssk. have high forage value. But their growth is severely affected with the onset of summer. Another grass species, *Pennisetum divisum* (Gmel.) Henr. was recorded from the Thal desert in Pakistan which naturally grows on dry sand dunes (BOKHARI - personal communication).

An analysis of the subsoil water samples collected from different localities of the Cholistan desert (ASHRAF & BOKHARI 1987) showed that electrical conductivity ranges from 1.3 to 29.8 dS m^{-1}. Despite high salinity of the subsoil water various methods are available to utilize brackish water for irrigating normal crops, as have been previously used (GALE 1982, GALE & ZERONI 1989).

The three grass species mentioned earlier are well adapted to the prevalent drought and high temperature conditions of the deserts. If they possess variability for salt tolerance, they could be successful forage crops under irrigation with subsoil saline water.

With this aim in mind present study was undertaken to determine the degree of salinity tolerance of the three native grasses with respect of two grass species, *Leptochloa fusca* (L.) Kunth. and *Puccinellia distans* (L.) Parl. whose degree of salt tolerance is already known (*L.fusca*, MALIK & al. 1986, *P.distans*, ASHRAF & al. 1986, VENABLES & WILKINS 1978).

2 Materials and Methods

Seeds of *Cenchrus pennisetiformis* Hochst. & Steud. and *Panicum turgidum* Forssk., and *Pennisetum divisum* (Gmel.) Henr. were collected from the Cholistan and Thal deserts in Pakistan, respectively. Seed of *Puccinellia distans* (L.) Parl. was obtained from England, whereas that of *Leptochloa fusca* (L.) Kunth. was collected from a derelict field near the Botanic Gardens of the Bahauddin Zakariya University, Multan, Pakistan.

Seeds of all the species were surface sterilized in 5% sodium hypochlorite solution for five minutes before further experimentation. During the early March seeds of each species were sown in plastic Petri dishes. After two weeks five seedlings of comparable size of each species were transplanted equidistant from each other into 18 cm size plastic pots containing 4.0 kg thoroughly washed and dried sand. The experiment was placed in a randomized complete block design with four blocks in a naturally-lit glasshouse with natural photoperiod of 10-10.5 h and day and night temperatures were $26 \pm 4^{\circ}C$ and $11 \pm 3^{\circ}C$. Each block contained five species and four salt treatments. The salt treatments used were 2.4 (control), 8, 16, and 24 dS m^{-1} that were prepared by mixing four salts, $NaHCO_3$, $MgSO_4 . 7H_2O$, $CaCl_2 . 2H_2O$ and NaCl in 1:5:10:30 in half strength Hoagland's nutrient solution prepared in tap water (Chemical composition, Na= 3.68, K = 2.46, Ca = 1.78, Mg = 0, Cl = 1.2 meq L^{-1}). The ratios of these salts were determined from the analysis of composition of the subsoil water from the Cholistan desert. Salinity treatment was started four weeks after transplantation of the plants. Salinity treatment was increased step-wise with an increase of 4 dS m^{-1} per day. After the appropriate concentrations were attained, two litres of the appropriate treatment solution were applied to each pot after every two days. This volume was sufficient to wash through the salts already present in the sand.

Six weeks after the start of salt treatments, plants were harvested and washed briefly with deionized distilled water. After recording fresh weights, plant material was dried at 65°C for one week after which time dry weights were recorded.

2.1 *Analysis of ions*

For the analysis of Na^+, K^+, and Ca^{2+}, 100 mg of well ground dry material of both shoots and roots was digested in 1-2 mL of conc. HNO_3. Na^+, K^+ and Ca^{2+} were determined with a flame photometer (Jenway PFP7). For Cl^- determination 100 mg of well crushed shoot and root material was extracted in 10 ml of distilled deionized water at 80°C for 4 hours. Cl^- was determined with a chloride analyzer (Corning 925).

2.2 *Statistical analysis of data*

The results of all the parameters were subjected to two-way analysis of variance, and least significant differences (LSD) were calculated following Snedecor & Cochran (1980) for comparing mean values.

3 Results

The mean data for shoot fresh and dry weights and root dry weights of five grass species (Fig. 1) and their analyses of variance show that salinity treatments had a significant effect on shoot and root biomass production of all five grass species. (Shoot f.wt., $p \leq 0.05$; shoot and root dry wt., $p \leq 0.001$).

Species responded differently to increasing salt treatment ($p \leq 0.001$). Increasing salt treatment markedly reduced the shoot fresh and dry weights of *C.pennisetiformis*, *P.turgidum* and *P.divisum*, whereas those of *L.fusca* and *P.distans* remained unchanged at all salt treatments. *Leptochloa fusca* had significantly ($p \leq 0.05$) greater shoot fresh and dry matter than the other four grass species at 16 and 24 dS m^{-1}. By contrast, *P.divisum* had significantly ($p \leq 0.05$) lower shoot fresh and dry mater at 24 dS m^{-1} than the other species.

The root dry weight of *P.divisum* and *C.pennisetiformis* decreased with increase in salt treatments, whereas that of *P.turgidum*, *L. fusca* and *P.distans* remained unaffected. *Panicum turgidum* produced significantly greater ($p \leq 0.05$) root dry matter than the other four species at all salt treatments.

Since the species differ considerably at the control treatment the mean biomass data was transformed into percent of control (Table 1). The percent fresh and dry matters of *L.fusca* and *P.distans* remained unaffected at all the salt treatments. By contrast, percent biomass production in *P.divisum* was severely inhibited by salinity. *Cenchrus pennisetiformis* and *P.turgidum* were intermediate in percent shoot biomass production. Percent root biomass was inhibited in all the species except *P.turgidum*.

Mean shoot/root ratios of five grass species (Table 2) show that increasing salt treatments had no significant effect on shoot/root ratios of all five grass species. Species differed significantly ($p \leq 0.001$), but this difference was attributable to their inherent differences between controls.

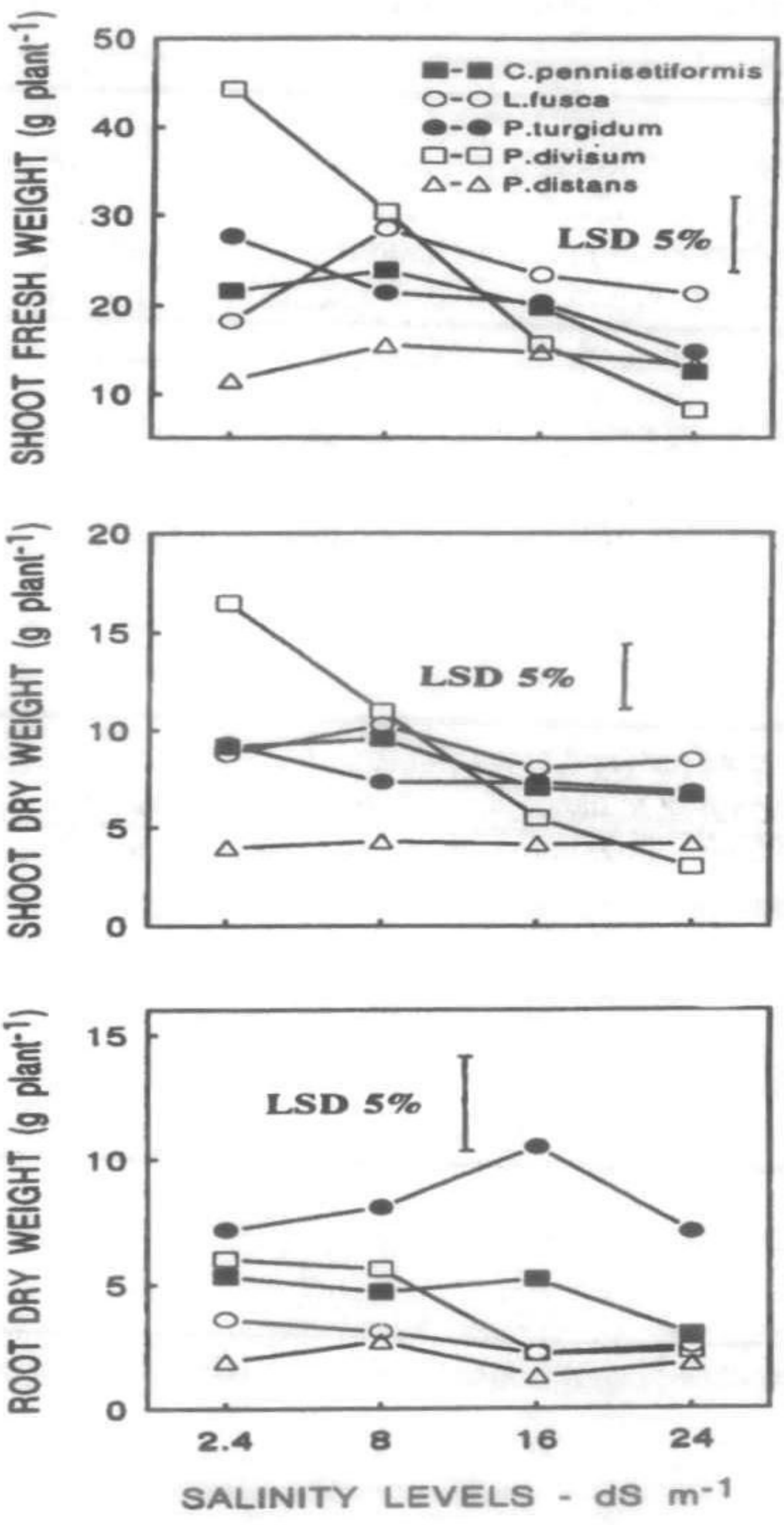

Fig. 1. Mean fresh and dry weights of shoots and dry weights of roots of 5 grass species after 6 weeks growth at varying salinity levels in sand culture.

Table 1: Percent fresh and dry weights of shoots and percent dry weights of roots of 5 grass species after 6 weeks growth in different concentrations of salinity in sand culture.[1]

Species	**Salinity as electrical conductivity - dS m^{-1}**								
	8	16	24	8	16	24	8	16	24
	Percent shoot fresh weight			**Percent shoot dry weight**			**Percent root dry weight**		
C.penniset-iformis	110.6 a	91.7 a	57.9 a	104.3 a	77.2 a	61.9 a		98.1 a	56.6 ac
L.fusca	156.6 b	128.6 b	116.5 b	117.1 a	92.0 ac	96.6 bd	86.1 a	61.1 bd	69.4 ab
P.turgidum	77.3 c	73.3 a	53.4 a	79.6 b	79.6 a	74.2 ab	112.5 a	145.8 c	98.6 b
P.divisum	68.4 c	35.4 c	18.5 c	66.7 b	33.3 b	18.2 c	93.3 a	36.7 d	38.3 c
P.distans	135.6ab	128.7 b	115.7 b	107.5 a	105.0 c	105.0 d	142.1 b	68.4 b	94.7 b
	LSD 5% = 28.6			LSD 5% = 23.2			6 LSD 5% = 29.4		

Number of tillers/plant (Table 2) of *P.distans* and *C.pennisetiformis* increased only at 8 dS m^{-1}, whereas at the other salt treatments it remained unaffected. There was a significant reduction in number of tillers/plant in *P.turgidum* due to salinity. But the number of tillers/plant of *L.fusca* remained unchanged at all salt treatments. *Puccinellia distans* had the highest, whereas *P.turgidum* and *P.divisum* lowest number of tillers/plant of all five species at all salt treatments. The remaining two species had intermediate number of tillers/plant.

Table 2: Mean shoot/root ratios and number of tillers/plant of 5 grass species after 6 weeks growth in different concentrations of salinity in sand culture.[1]

Species	**Salinity as electrical conductivity - dS m^{-1}**							
	2.4	8	16	24	2.4	8	16	24
	Shoot/root ratios				**Number of tillers/plant**			
C.penniset-iformis	1.74	2.04	1.37	1.90	15.2 a	26.2 a	14.7 a	13.7 ab
L.fusca	2.44	3.32	3.64	3.40	19.2 a	26.2 a	27.5 b	21.0 b
P.turgidum	1.29	0.91	0.71	0.97	37.0 b	10.0 b	11.0 ac	9.0 a
P.divisum	2.75	1.96	2.50	1.30	10.3 a	11.3 b	5.0 c	5.3 a
P.distans	2.11	1.59	3.23	2.33	57.0 c	75.2 c	62.2 d	55.2 c
	LSD 5% = NS							

Mean data for shoot and root Na^+ concentrations are presented in Fig. 2. Increasing salt treatments had no significant effect on shoot Na^+ concentration, whereas there was a significant effect on root Na^+ concentration. *Cenchrus pennisetiformis* and *P.divisum* had significantly ($p \leq 0.05$) higher and *L.fusca* and *P.turgidum* lower shoot Na^+ at 16 dS m^{-1}, whereas at 24 dS m^{-1} difference in Na^+ concentrations in all the species was not significant. Root Na^+ of all five species increased with increase in salt treatments. *Panicum tur-*

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[1] Means with the same letters in each column within each treatment do not differ significantly at the 5% level.

gidum had a sgnificantly ($p \leq 0.05$) greater amount of root Na^+ than all the other species at all salt treatments. At 8 dS m^{-1} *P.divisum* and *L. fusca* had intermediate and *C.pennisetiformis* and *P.distans* lowest root Na^+.

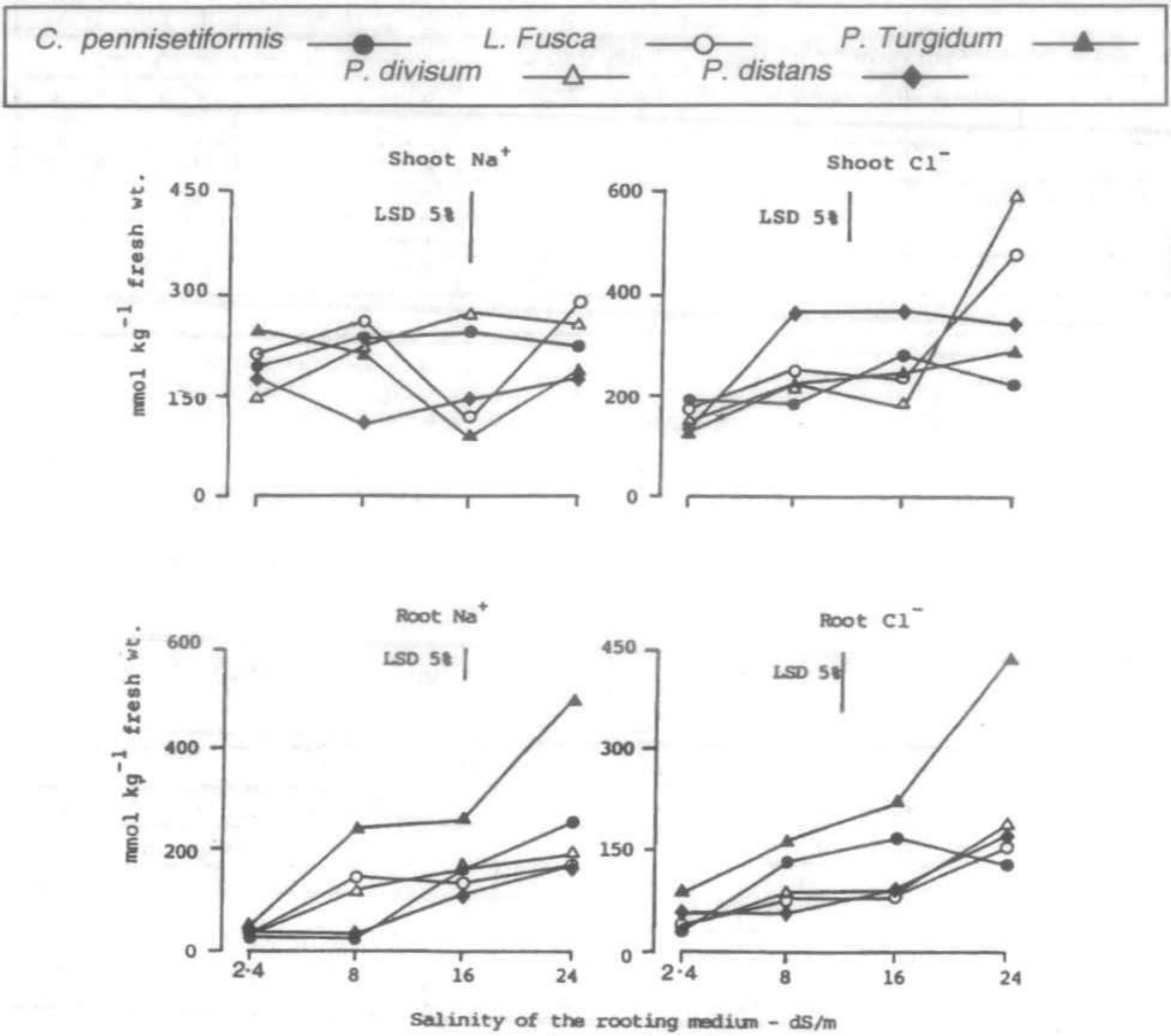

Fig. 2. Na^+ and Cl^- concentrations (mmol kg^{-1} fresh wt.) of shoots and roots of 5 grass species after 6 weeks growth at varying salinity levels in sand culture.

Cl^- concentrations in the shoots and roots (Fig. 2) of all five species increased with increase in salt treatment of the growth medium except in the shoots of *C.pennisetiformis* which had Cl^- almost equal to its control at 8, and 24 dS m^{-1}. *Puccinellia distans* and *P.divisum* had significantly ($p \leq 0.05$) higher shoot Cl^- than the other species at 8 and 16, and 24 dS m^{-1}, respectively. *Pennisetum divisum* and *C.pennisetiformis* had significantly ($p \leq 0.05$) lower shoot Cl^- at 16, and 24 dS m^{-1}, respectively. *Panicum turgidum* had the highest root Cl^- concentration of all five species at all salt treatments.

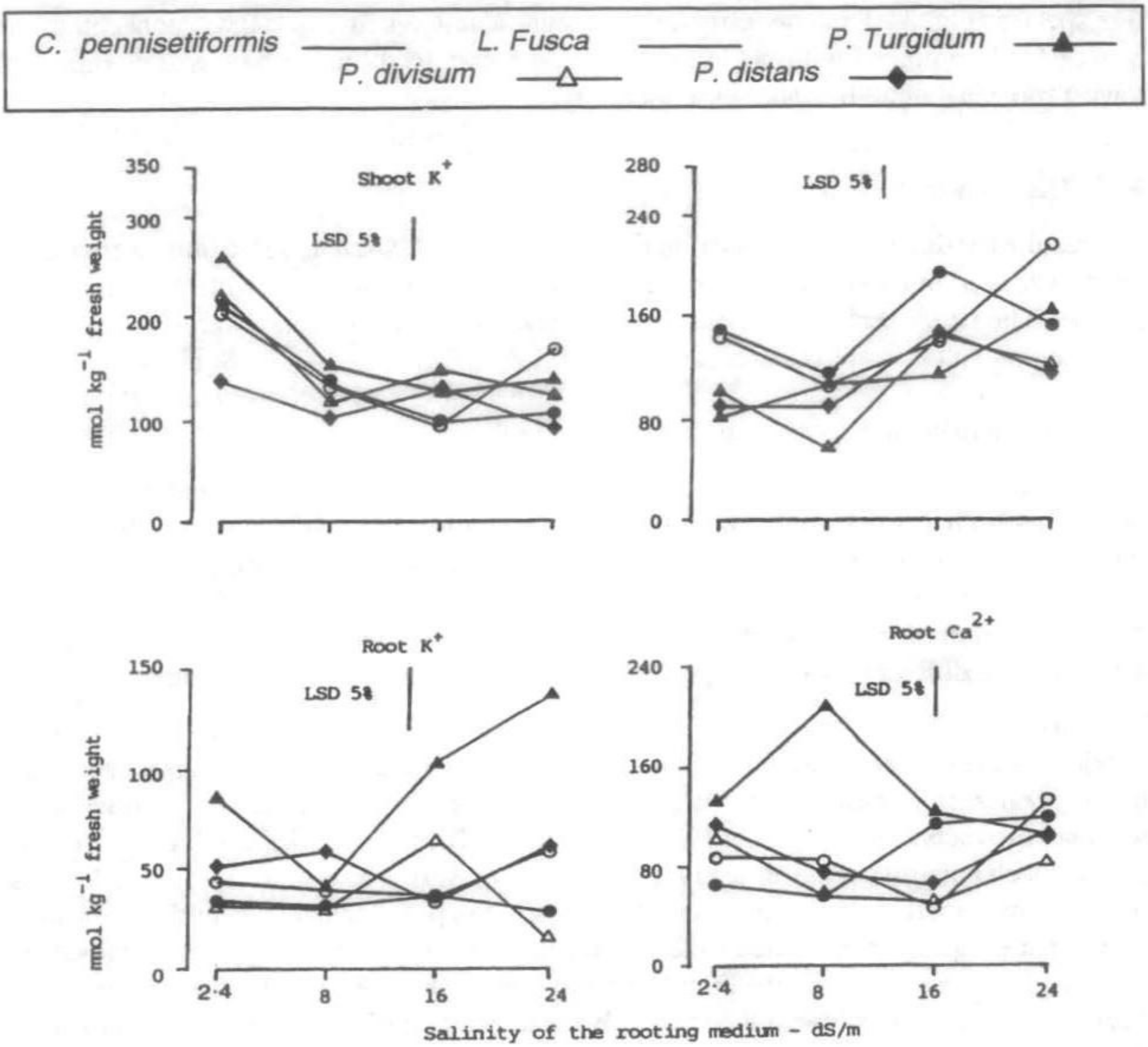

Fig. 3. K^+ and Ca^{2+} concentrations (mmol kg^{-1} fresh wt.) of shoots and roots of 5 grass species after 6 weeks growth at varying salinity levels in sand culture.

Shoot K^+ concentrations of all the species (Fig. 3) decreased significantly with increase in salt treatment, whereas root K^+ of all the species remained unaffected at all salinity treatments. *Pennisetum divisum* and *L. fusca* contained relatively higher shoot K^+ at 16, and 24 dS m^{-1}, respectively, and *P.distans* lower shoot K^+ at 8, and 24 dS m^{-1}. *Panicum turgidum* had highest root K^+ of all five species at 16 and 24 dS m^{-1}.

Increasing salinity treatments had a significant effect ($p \leq 0.001$) on shoot Ca^{2+} of all five species (Fig. 3). Shoot Ca^{2+} concentrations of *P.turgidum* and *P.distans* increased with increase in salt treatment, whereas the remaining three species did not show any consistent pattern of increase or decrease in shoot Ca^{2+}. *Cenchrus pennisetiformis* and *L.fusca* accumulated relatively greater amount of shoot Ca^{2+} than the other species at 8 and 16, and 24 dS m^{-1}, respectively. By contrast, at 8 dS m^{-1} *P.divisum* had lower shoot Ca^{2+} than the other species. Increasing salinity treatments had no significant effect on root Ca^{2+} of all five species (Fig. 3). *Panicum turgidum* had significantly greater ($p \leq 0.05$) concentrations of root Ca^{2+} compared with the other species at 8 and 16 dS m^{-1}, whereas *P.divisum* had lowest root Ca^{2+} of all five species at 24 dS m^{-1}.

4 Discussion

The results for the biomass production clearly show that *L.fusca* and *P.distans* were highly tolerant to varying salinity levels of the growth medium compared with the other three species. The better performance of the two species is expected as they were already found to be highly salt tolerant (*L.fusca*, MALIK & al. 1986, *P.distans*, ASHRAF & al. 1986). *Pennisetum divisum* was the poorest of all species, whereas *C.pennisetiformis* and *P.turgidum* were intermediate in performance in response to salinity.

Mesophytes are known to respond to salt stress either by excluding salt and synthesizing organic osmotica or by accumulating high concentration of ions to maintain their turgor (MAAS & NIEMAN 1978, GREENWAY & MUNNS 1980, Wyn JONES 1981). In the present study the salinity treatments were prepared by mixing different salts in ratios which correspond to the composition of subsoil saline water from the Cholistan desert. Therefore, considerable interaction of different ions in all species has been observed at each salinity level.

Each species has used its own specific selective ion transport mechanism in response to varying salinity treatments. For instance, the highly tolerant *L.fusca* accumulated relatively greater concentrations of Na^+ and Cl^- in the shoots at the highest salinity level, whereas these concentrations were low in the roots. Thus the species used a typical halophytic mechanism (FLOWERS & al. 1977, GREENWAY & MUNNS 1980). Since the species possesses characteristic salt glands (MALIK & al. 1986) it is possible that Na^+ and Cl^- absorbed by roots are rapidly translocated to leaves for onward excretion through salt glands. *Leptochloa fusca* also accumulated high concentrations of both K^+ and Ca^{2+} for maintaining Na/K and Na/Ca ratios low in the shoots. Because high Na/K and Na/Ca ratios have been found responsible for increasing membrane permeability in plants (VAN STEVENINCK 1965, LÄUCHLI & EPSTEIN 1970, GREENWAY & MUNNS 1980, HANSON 1984, MUHAMMAD & al. 1987).

By contrast, the second highly salt tolerant species, *P.distans* partially excluded Na^+ from both shoots and roots but accumulated high concentration of Cl^- in the shoots. A parallel situation was observed in the salt tolerant line of *Holcus lanatus* (ASHRAF & al. 1990). The low concentration of both Na^+ and K^+ in the shoots of *P.distans* show that it does not show selectivity to both K + Na as was suggested by Greenway and Munns (1980) that some mesophytes are selective to K^+ while others are selective to both K + Na.

The relatively most salt sensitive species, *P.divisum* shows a clear relationship between its poor growth and patterns of ion accumulation under saline conditions. Its high accumulation of both Na^+ and Cl^- in the shoots can be related to the early findings of Wyn Jones & al. (1984) who demonstrated that *Agropyron intermedium* was salt sensitive compared with *A.junceum* because it efficiently accumulated both Na^+ and Cl^- in its leaves. In addition low Na/K and Na/Ca ratios were not maintained by this species at varying salinity treatments.

The other two species, *C.pennisetiformis* and *P.turgidum* were relatively intermediate in salinity tolerance. *Cenchrus pennisetiformis* absorbed large amount of Na^+ in the shoots but at the same time it accumulated high concentration of Ca^{2+} in shoot so as to maintain Na/Ca ratio low. By contrast, *P.turgidum* maintained low concentrations of both Na^+ and Cl^- in the shoots, although the concentrations of these ions were high in its roots. This type of mechanism is very common in many salt tolerant mesophytes (Maas & Nieman 1978, Greenway & Munns 1980, Winter & Preston 1982). The same authors advocated that salt excluders have the ability to restrict the uptake of salt into the shoot. This might be due to the phenomenon that toxic ions such as Na^+ are absorbed in considerable amount but are reabsorbed from the root or the shoot and is either stored in the roots or retranslocated to the soil.

Taken overall it is not difficult to say that *C. pennisetiformis* and *P. turgidum* intermediate in salt tolerance, can be grown in those areas of the Cholistan desert having moderately saline subsoil water for irrigation. These species have high forage value for all types of livestock and are already well adapted to the prevailing environmental conditions of the area (Ashraf & Bokhari 1987). Thus these two species could be of great value for economic utilization of the desert area. The other two highly salt tolerant species *L. fusca* and *P. distans* may not be suitable for the area as they both are adapted to entirely different environmental conditions than those of Cholistan. The former species have been found to be highly sensitive to drought (Ashraf & Yasmin 1991) because it commonly occurs on waterlogged saline-sodic soils (Malik & al. 1986) and bears specific characteristics such as aerenchyma (H. Yasmin, unpublished data) which help tolerate waterlogged conditions. Therefore, *L. fusca* may not be colonizer of the desert. *Puccinellia distans* is an exotic species. Although it is highly salt tolerant, it is surprisingly highly sensitive to even mild drought stress (N. Yasmin, unpublished data). Apparently this species also does not seem to be suitable for Cholistan.

5 Acknowledgement

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Die Auswirkung von Brackwasser auf einige Grasarten der ariden Zone

Zusammenfassung

Die fünf Grasarten *Cenchrus pennisetiformis* Hochst. & Steud., *Leptochloa fusca* (L.) Kunth., *Panicum turgidum* Forssk., *Pennisetum divisum* (Gmel.) Henr. and *Puccinellia distans* (L.) Parl.wurden auf ihre Salzverträglickeit untersucht.

Die Auswertung erfolgte nach sechswöchiger Behandlung in vier verschiedenen Salzkonzentrationen 2,4 (Kontrolle), 8, 16, und 24 $dS\ m^{-1}$ in Hoaglands Nährungslösung.

Die Grashalmbiomasse bei *L. fusca* und *P. distans* war durch die Salzkonzentration nicht beeinträchtigt und sie hatten eine signifikant höhere Stengelbiomasse und Trokkenmasse als die anderen Arten in allen Salzkonzentrationen. *Pennisetum divisum* war stark angegriffen, hatte die geringsten Werte, sowohl in Stengel- und Wurzelmasse, *C. pennisetiformis* und *P. turgidum* produzierten im Versuch eine mittlere Biomasse.

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