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COMPARATIVE SALINITY TOLERANCE OF *FIMBRISTYLIS DICHOTOMA* (L.) VAHL AND *SCHOENOPLECTUS JUNCOIDES* (ROXB.) PALLA, THE CANDIDATE SEDGES FOR REHABILITATION OF SALINE WETLANDS

IQRA ZAHOOR, M. SAJID AQEEL AHMAD, MANSOOR HAMEED, TAHIRA NAWAZ AND AYESHA TARTEEL

Department of Botany, University of Agriculture, Faisalabad, Pakistan 38040
**Corresponding author's e-mail: sajidakeel@yahoo.com*

Abstract

Two aquatic halophytic sedges, *Schenoplectus juncoides* (Roxb.) Palla and *Fimbristylis dichotoma* (L.) Vahl, were collected from salt-affected habitats and evaluated hydroponically for salt tolerance. Three salinity levels (0, 100, 200 mM NaCl) were maintained in half-strength Hoagland's nutrient solution during the experiment. Although both species showed high degree of salt tolerance, they had varied mechanisms of salt tolerance. *Fimbristylis dichotoma* showed high uptake of Ca^{2+} and accumulation of organic osmotica to combat with high salinity, while *S. juncoides* relied on high uptake of K^+ in addition to organic osmotica. The stem succulence in *S. juncoides* provided additional advantage to this species to survive under extreme saline regimes. It was concluded that both these species have considerably potential to rehabilitate of salt-affected wetlands.

Introduction

Sedges (family Cyperaceae) grow in a variety of habitats like polluted and saline soils and waters. Most of them are however, associated with wetlands or with nutrient poor soils containing adequate moisture (Khan & Qaiser, 2006). In Pakistan, family Cyperaceae is represented by 22 genera and 179 species, of which many are weeds (Kukkonen, 2001). Sedges can tolerate a variety of habitats, more frequently aquatic habitats like swamps, marshes, pools, ponds either salt/brackish or freshwater (Ranganath & Sheeba, 2001). Although they can mostly tolerate salt stress as they grow in salt marshes, they can also tolerate the summer-dry conditions (Bernhardt & Kropf, 2006).

It is now widely recognized that natural populations are better adapted to environmental stresses. On these basis, such adaptive populations are considered as an excellent source for exploiting the adaptive components (Ashraf, 2004; Munns & Tester, 2008; Hameed *et al*., 2010). By using adaptive species as a source of genes, salt tolerance of conventional crops can be improved through selection and breeding programmes.

One of the most effective methods for rehabilitation and re-vegetation of salt affected soils is the selection of halophytic species, in addition to proper soil and irrigation management (Saikachout *et al*., 2009). This approach can be strengthened by identification of markers for salinity tolerance and evaluation of the potential of halophytes like sedges to re-vegetate salt affected area (Colmer *et al*., 2009). The present study was, therefore, focused on the evaluation of degree of salinity tolerance in two aquatic halophytes, *Schoenoplectus juncoides* and *Fimbristylis dichotoma*, and identification of physiological markers relating to their salt tolerance.

Materials and Methods

Schenoplectus juncoides (Roxb.) Palla was collected from a saline drain near Jhang district the electrical conductivity of the water being was collected (EC) 21.84 dS m^{-1}. *Fimbristylis dichotoma* (L.) Vahl from saline aquatic ponds near Sahianwala, Faisalabad the EC of the water being 17.92 dS m^{-1}. The material was established in stagnant water in the Botanic Garden, University of Agriculture, Faisalabad. Ramets (with three tillers of equal size) were detached from each species and grown hydroponically in half-strength Hoagland's for one month until they were fully established. Then they were treated with three salt levels (0, 100, 200 mM NaCl) and grown for further two months under natural conditions. Plants were carefully uprooted from the hydroponics after the completion of the study period and washed with tap-water. Morphological characteristics such as shoot and root lengths, tillers per plant, shoot and root fresh and dry weights were recorded. For dry weight, plants were oven-dried at 65°C until constant weight achieved. Physiological parameters studied during the experiment were chlorophyll content (chl. *a*, chl. *b*, carotenoids), ionic content of root and shoot (K^+, Ca^{2+}, Na^+), and organic osmolytes (total proteins, free amino acids, soluble sugars and proline). For detailed methodology of measurement of physiological parameters see Hameed & Ashraf (2008). The experiment was conducted in a completely randomized design (CRD) with two factors (plant species and salinity levels) and three replications. Data were subjected to analysis of variance (ANOVA) using Microsoft Excel software and a COSTAT computer package (CoHort Software, 2003, Monterey, California). The LSD values were calculated for the comparison of means.

Results

Generally, both aquatic sedges, *Fimbristylis dichotoma* and *Schoenoplectus juncoides,* showed more or less similar response to different salt levels relating to different morpho-physiological characteristics. However, the sedges differed slightly with respect to degree of salt tolerance. Shoot parameters like length and fresh and dry weights increased at 100 mM NaCl level (Fig. 1), but significantly decreased at 200 mM NaCl in both species. Shoot length was relatively more affected than overall plant biomass. Number of tillers per plant, in contrast, increased consistently with increase in salt level of the medium. Root length significantly increased at 100 mM NaCl, but 200 mM NaCl imposed a negative effect on root length in both *F. dichotoma* and *S. juncoides* (Fig. 2). Root fresh and dry weights, however, increased significantly with a gradual increase in salt concentration of the cultural medium.

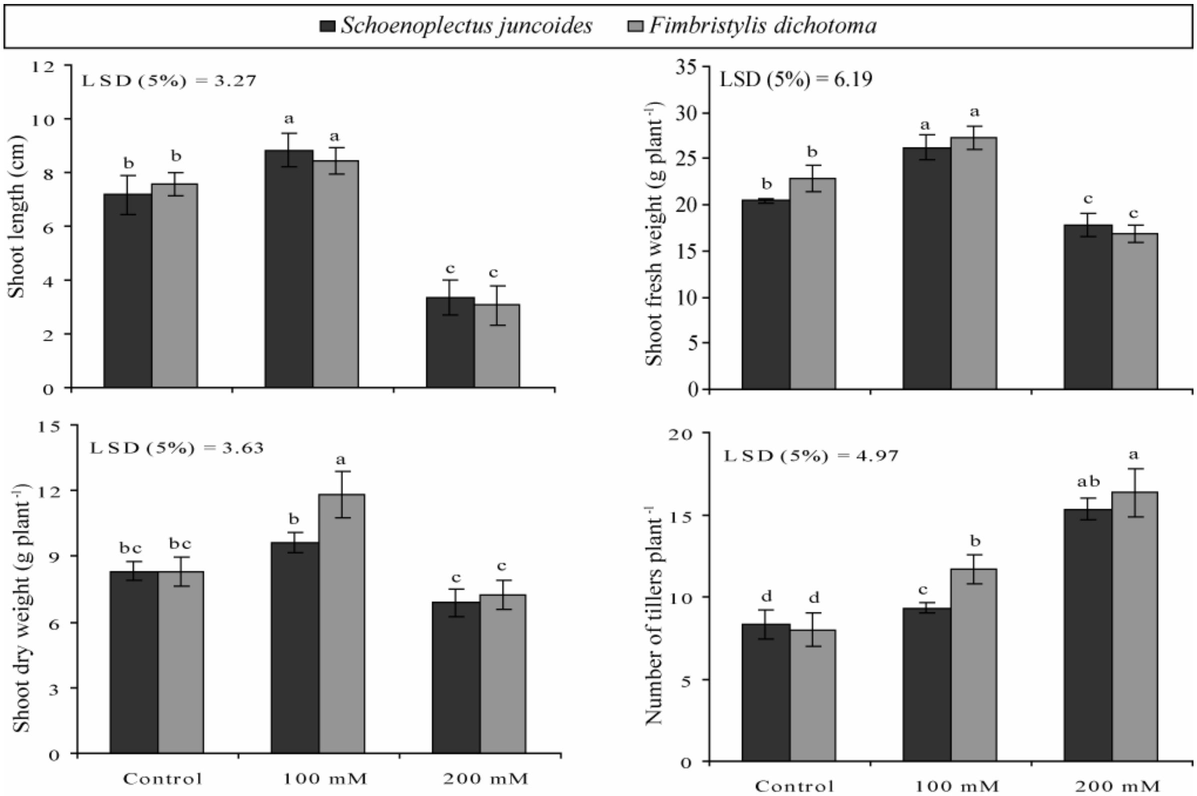

Fig. 1. Shoot morphological characteristics of *Fimbristylis dichotoma* and *Schoenoplectus juncoides* grown hydroponically under three different salt levels (n=3, means ± SE).

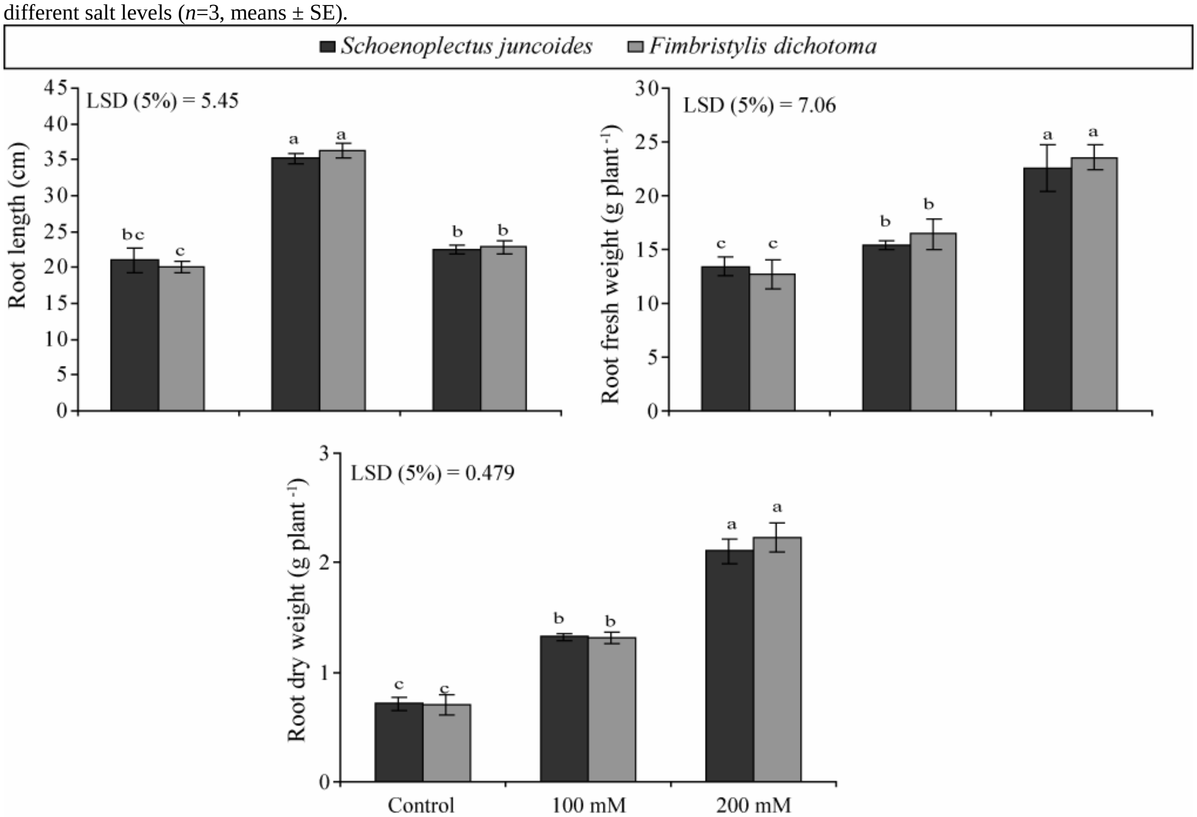

Fig. 2. Root morphological characteristics of *Fimbristylis dichotoma* and *Schoenoplectus juncoides* grown hydroponically under three different salt levels (n=3, means ± SE).

Although, the concentrations of photosynthetic pigments were negatively affected by salt stress in both sedges, the impact of salt stress was more adverse in *F. dichotoma* than that of *S. juncoides* (Fig. 3). In *S. juncoides,* 100 mM NaCl level significantly reduced chlorophyll and carotenoid contents, but further increase in salt concentration in the growth medium had non-significant effects. In *F. dichotoma*, on the other hand, all pigments decreased consistently with increasing in external salt level.

There was a substantial increase in shoot and root Na^+ as the concentration of salts in the culture medium increased (Fig. 4). However, both *F. dichotoma* and *S. juncoides* showed non-significant variations within species at each level. *Fimbritylis dichotoma* accumulated significantly higher K^+ in its roots and shoots than that in *S. juncoides*, but generally, the accumulation of K^+ was the highest at 100 mM NaCl in both species. Similarly, shoot and root Ca^{2+} significantly increased at 100 mM NaCl in both species, but 200 mM level restricted the uptake of this ion. *Schoenoplectus juncoides* accumulated significantly higher Ca^{2+} in shoot than that recorded in *F. dichotoma*. Root Ca^{2+} was significantly higher in *S. juncoides* at 100 mM NaCl, while at 200 mM level *F. dichotoma* accumulated higher Ca^{2+} contents in roots.

Both *F. dichotoma* and *S. juncoides* showed a significant increase in concentration of organic osmolytes as the concentration of salts increased in the growth medium (Fig. 5). *Schoenoplectus juncoides* accumulated relatively more proteins and free proline content, whereas *F. dihotoma* accumulated significantly higher amino acids and soluble sugars. However, variation in the two species with respect to accumulation of inorganic osmotica was non-significant at all levels of salt stress.

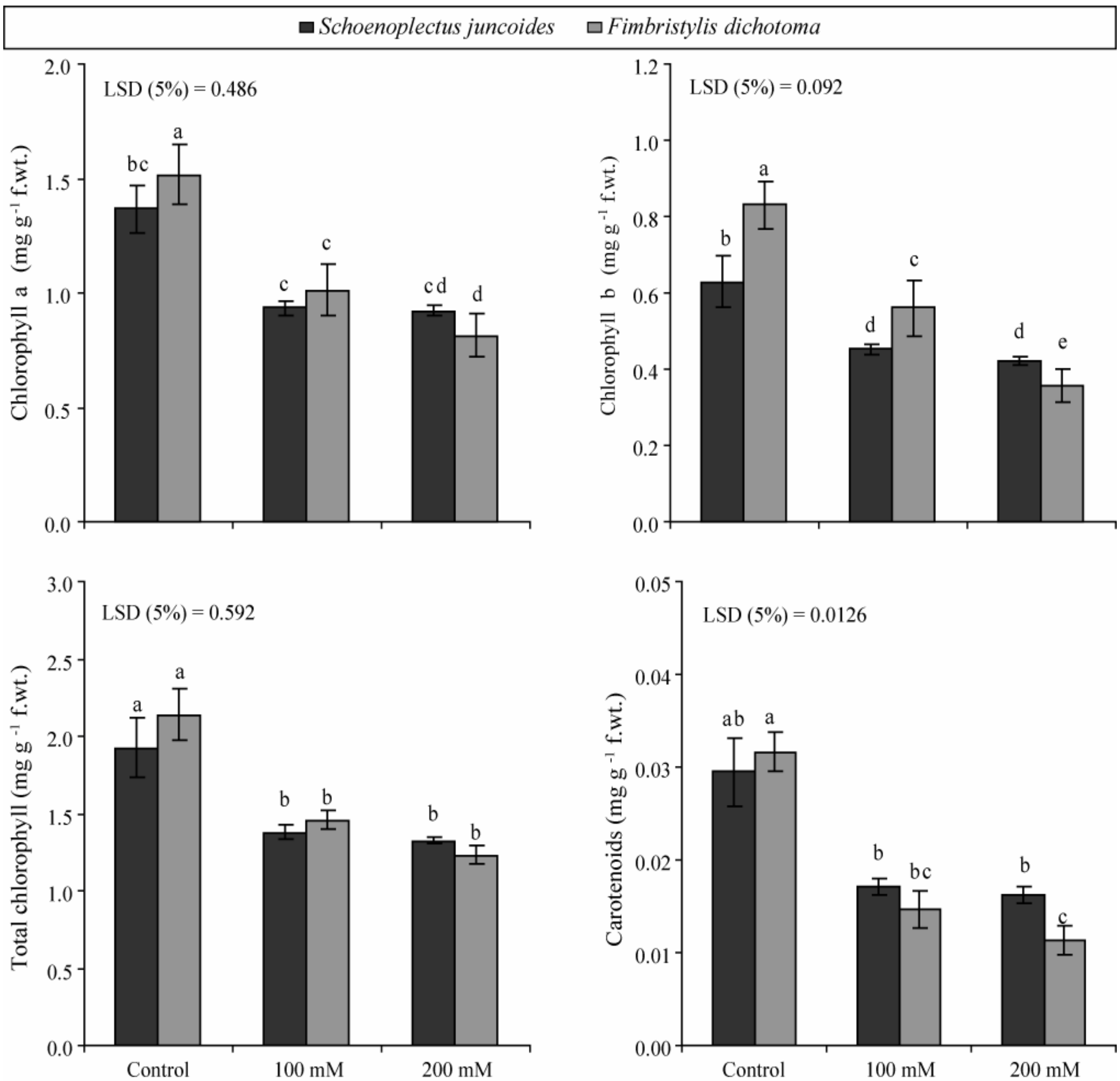

Fig. 3. Chlorophyll pigments of *Fimbristylis dichotoma* and *Schoenoplectus juncoides* grown hydroponically under three different salt levels (n=3, means ± SE).

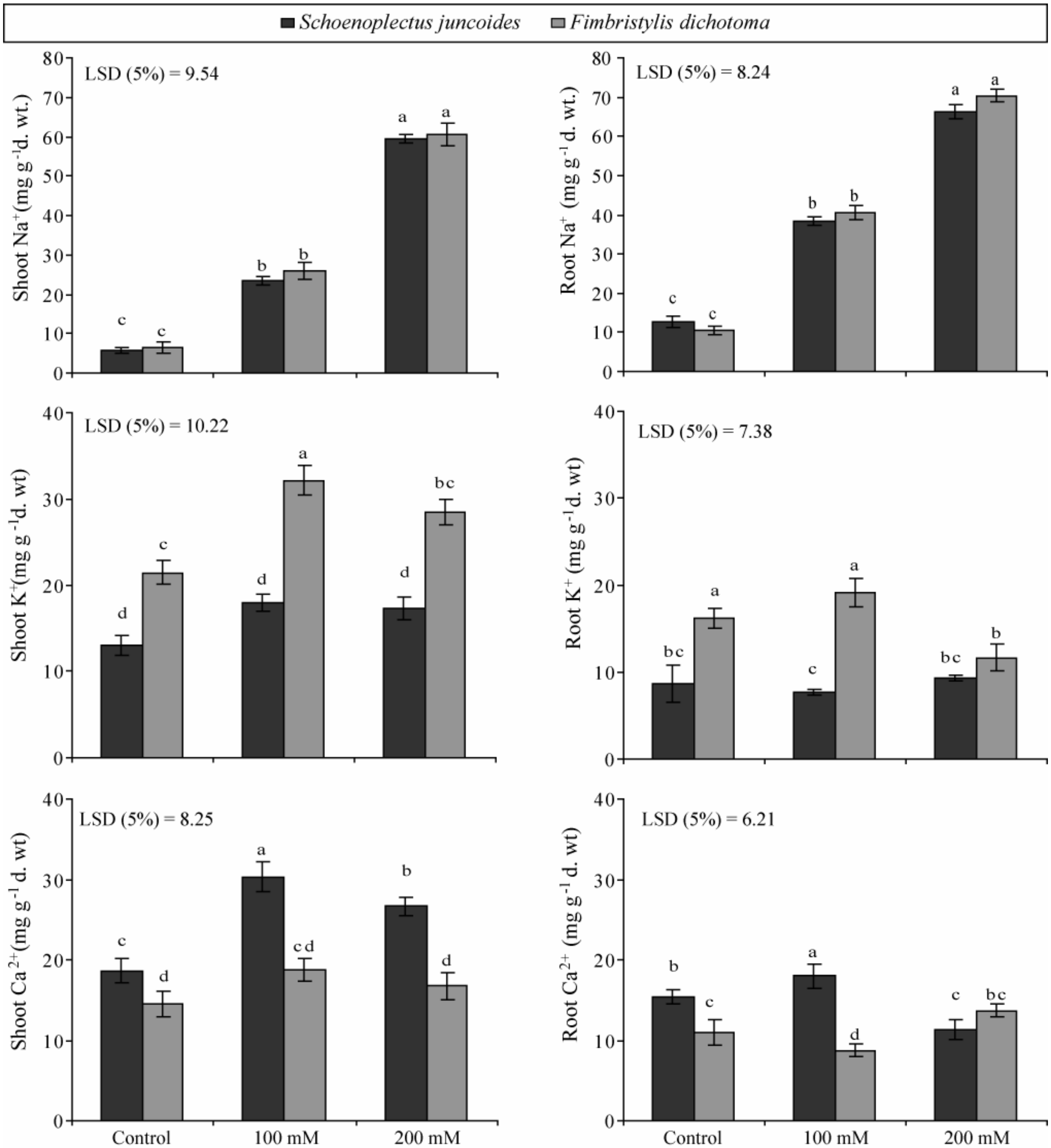

Fig. 4. Ionic content of shoot and root of *Fimbristylis dichotoma* and *Schoenoplectus juncoides* grown hydroponically under three different salt levels (n=3, means ± SE).

Discussion

Both species, *Fimbristylis dichotoma* and *S. juncoides*, are aquatic halophytes, but their habit is considerably different. For example, *Schoenoplectus juncoides* is a stem succulent that grows well in saline waterlogged areas (Kukkonen, 2001). In contrast, *Fimbristylis dichotoma* a non-succulent plant inhabits dry-lands with saline sodic soil as well as waterlogged saline areas (Zhang *et al*., 2010). Pure stands of both species were recorded in their specific habitats, which were highly salt affected.

In this study, moderate level of salt stress (100 mM) stimulated growth of both sedges. Such growth stimulation under moderate salt stress had already been reported by some researchers in highly salt tolerant plants in addition to halophytes, e.g., *Prosopis juliflora* (Viégas *et al*., 2004) and *Cynodon dactylon* (Hameed & Ashraf, 2008). In this study as well, vegetative growth in terms of shoot and root lengths and plant biomass was enhanced at lower salt level (100 mM NaCl), which showed salt-loving or halophytic nature of both species. Shoot length was severely affected in both these species at 200 mM NaCl, but tillering capacity was significantly increased even at this higher salt level. Restricted growth is an adapted strategy of most plants towards tolerance to adverse climatic conditions like salinity, as they utilize more energy towards survival rather than vegetative growth (Hameed *et al*., 2008). Moreover, high tillering would have certainly boosted the reproductive capacity of these species, and that may also increase population size in their specific habitats that could be a reason of their dominance in their natural habitats. In comparison, root length decreased at high salt level, but fresh and dry biomass increased. As both *F. dichotoma* and *S. juncoides* were aquatic halophytes, deep roots may not be the requirement, but profuse root system may certainly give ecological significance. Well-developed root system is not only a characteristic feature of drought tolerant of xerophytic plants, but also those inhabiting habitats facing physiological droughts like salinity and waterlogging (Akram *et al*., 2011).

Chlorophyll contents have been reported to be negatively affected due to salt stress, not only in glycophytes but also in highly tolerant plants and halophytes (Flowers & Colmer, 2008;). Both *F. dichotoma* and *S. juncoides* showed a significant decrease in concentration of photosynthetic pigments, but *S. juncoides* was relatively less affected, particularly at higher salt level. Similar findings have also been reported by Hameed *et al*., (2009) in *Imperata cylindrica* and Ahmad *et al*., (2009) in *Panicum antidotale* indicating a negative correlation between salt tolerance and photosynthetic capacity of stressed plants.

Excessive accumulation of toxic Na$^+$ was recorded in both species in their shoot, as well as roots. These species seemed to be dependent on dumping off excessive toxic Na$^+$ in shoots and they may also utilize Na$^+$ in metabolic processes rather than restricting the uptake of this ion. *Schenoplectus juncoides* being a stem succulent had more capacity to dump off toxic ions in stem than *F. dichotoma* (Munns & Tester, 2008; Koyro *et al*., 2011). Similarly, *S. juncoides* accumulated excessive amount of Ca^{2+} along with Na$^+$ and *F. dichotoma* accumulated more K$^+$. This can be due to the reason that both these beneficial ions can neutralize the toxic effect of Na$^+$, as earlier reported by Ashraf and Harris (2004) and Flowers & Colmer (2008).

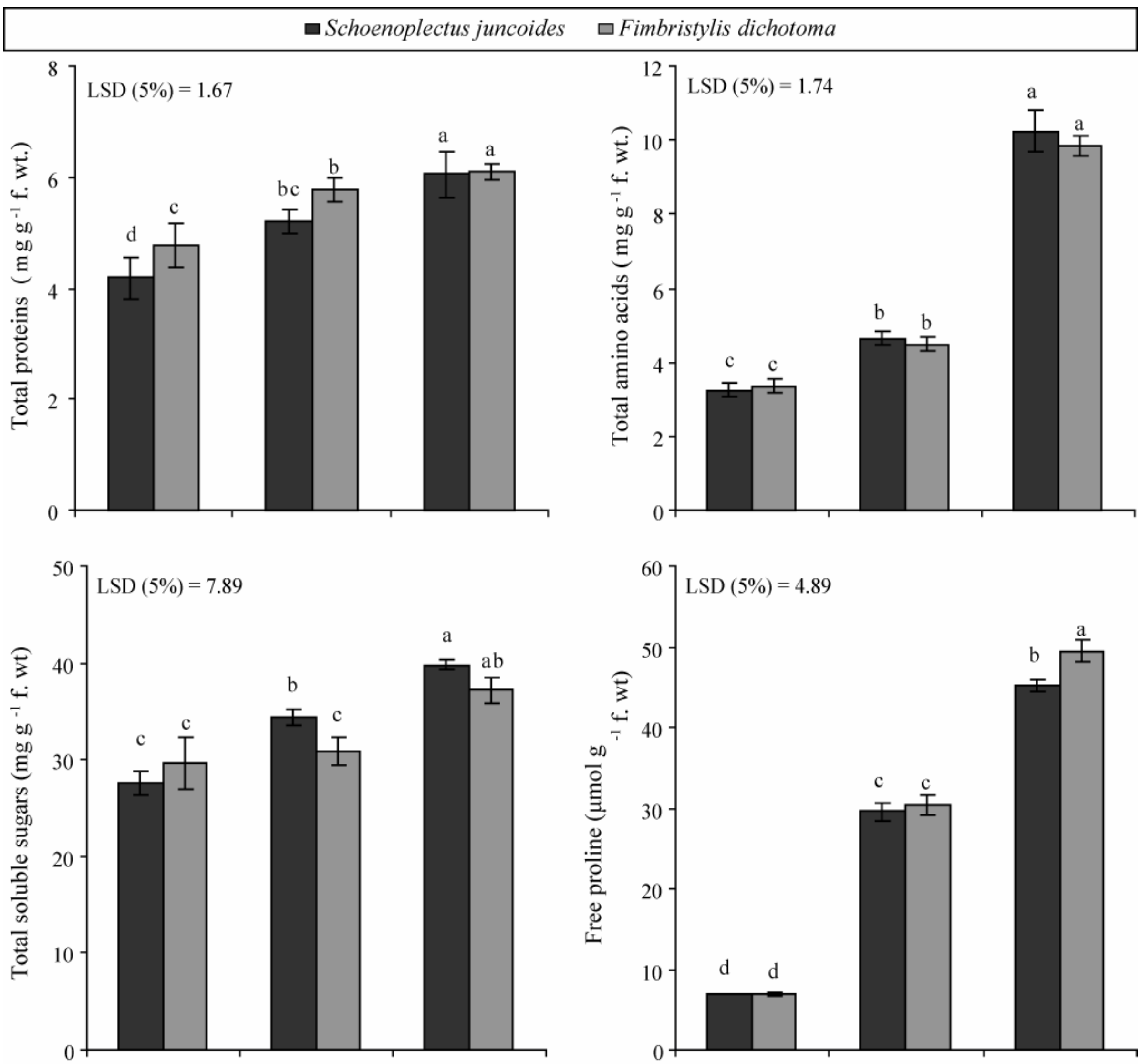

Fig. 5. Organic osmolytes in *Fimbristylis dichotoma* and *Schoenoplectus juncoides* grown hydroponically under three different salt levels (*n*=3, means ± SE).

Osmotic adjustment in salt affected plants can be achieved by the accumulation of organic osmolytes like proline, free amino acids, soluble sugars and proteins (Ashraf, 2004; Mezni *et al*, 2010). In this study, both *F. dichotoma* and *S. juncoides*, accumulated significantly higher amounts of organic osmolytes (particularly amino acids and proline), which may indicate their high degree of salt tolerance via osmotic adjustment (Ahmad *et al*., 2006; 2009).

In conclusion, it was found that both species had high degree of salinity tolerance, but the mechanism of salt tolerance varied in the species. *Fimbristylis dichotoma mainly* relied on high uptake of Ca^{2+} and accumulation of organic osmotica to combat with high salinity. In contrast, *S. juncoides* depended on high uptake of K^+ in addition to organic osmotica. Moreover, the stem succulence in *S. juncoides* may also provide additional advantage to survive under extreme salinity. Thus, both these species have a potential to rehabilitate highly saline wetlands.

Acknowledgments

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