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Salinity tolerance in some mangrove species from Pakistan

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Abstract

Growth, ionic and water relations of three mangrove species viz. *Avicennia marina, Ceriops tagal* and *Rhizophora mucronata* were studied in different seawater concentrations (0, 25, 50, 75 and 100%). All mangrove species showed optimal growth at 50% seawater. Relatively more biomass was accumulated by *R. mucronata* while *C. tagal* had the tallest individuals. Tissue water potential became more negative with the increase in salinity and stomatal conductance was decreased in all plants. Higher stomatal conductance was noted in *R. mucronata*, followed by *A. marina* and *C. tagal*. Sodium and chloride ions increased with the increase in salinity and this accumulation was much higher in *A. marina.*

Introduction

The mangrove forest in Sindh extends from Korangi to the Seer creek touching Indian border with total area of almost 600,000 hectares (Ansari, 1987). The present mangrove forest is almost entirely dominated by *Avicennia marina* (95%) with few populations of *Aegiceras corniculatum, Ceriops tagal,* and *Rhizophora mucronata* (Saifullah et al., 1994). The growth and physiological mechanisms of mangroves differ in nature due to their complexity of structure and differences in flooding regime, tidal inundation, rapid influx of extra nutrients as well as type of soil (Clough, 1984; Naidoo, 1987). They adapt themselves to the fluctuating environment in several ways such as salt exclusion from roots (Scholander, 1968; Hegemayer, 1997), salt secretion (Fitzgerald et al., 1992) and accumulating organic acids as osmotica to counter toxic effects of salinity (Popp, 1984). Mangroves like other halophytes also decrease their water and osmotic potentials to maintain turgor at higher salinity (Naidoo, 1987; Khan et al., 1999; Khan et al., 2000ab). There is a great deal of variation in the level of salinity required for optimal growth which varies from 10% to 50% seawater (Downton, 1982; Clough, 1984; Naidoo, 1987; Lin and Sternberg, 1992; 1995; Karim and Karim, 1993; Ball and Pidsley, 1995; Smith and Snedaker, 1995) and a decline in their overall growth is observed with a further increase in salinity. Similarly, decreased stomatal conductance, lower water potential and accumulation of inorganic ions are the result from extreme saline environments for most of the plants (Ball and Farquhar, 1984; Naidoo, 1987).

In our coastal regions, the increase in salinity due to the diversion of Indus river water to irrigation system has resulted in poor growth of mangroves. Further, localized extinction of some mangrove species has occurred due to chemical pollution and overgrazing (Kogo et al., 1986). Little information exists on the salt tolerance of Indus delta mangroves and this information is crucial to the success of rehabilitation effort in the region. The present study is designed to investigate the relative salt tolerance of three mangrove species viz. *Avicennia marina, Ceriops tagal* and *Rhizophora mucronata* from Pakistan.

Material and methods

Propagules of *A. marina,* and *C. tagal* were collected during the summer from the Indus delta populations near Karachi, Pakistan and *R. mucronata* from the Miani Hor estuary, on the Balochistan coast near Karachi. They were immediately transferred to 36-cm diameter plastic pots filled with acid washed beach sand. Plants were grown in a greenhouse under natural temperat-

Table 1. Results of two-way ANOVA of characteristics by Salinity (S) treatments and all plant species (P).

Independent variable	S	P	S × P
Dry weight	51.3***	66.2***	45.2**
Sodium	48.1***	28.4**	21.4*
Chloride	67.3***	71.2**	31.8*
Water potential	81.2**	38.6*	11.2 n.s
Stomatal conductance	53.4***	93.2**	36.4**

Note: Numbers represent F-values. * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; n.s = non-significant.

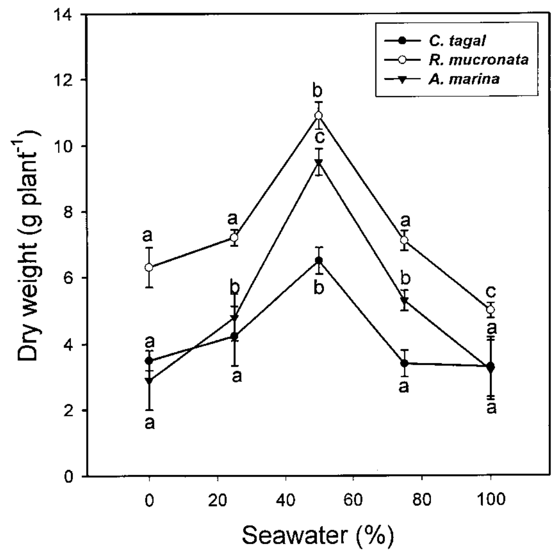

Figure 1. Effect of NaCl (0, 25, 50, 75 and 100% seawater) on the dry weight of *Avicennia marina, Ceriops tagal* and *Rhizophora mucronata* plants (6 months old). Lines represent means ± standard errors. Different letter above bars represent significant differences ($p < 0.05$) between treatments (Bonferroni test).

ure and light. Plants were irrigated with fresh water for two weeks through sub-irrigation. After two weeks plants were treated with various concentrations of seawater (0, 25, 50, 75, and 100%) fortified with nitrogen (Popp and Polania, 1989). Plants were grown in 5 replicate pots with 5 propagules each. Plants were arranged in a completely randomized design within treatments trays. Water level was adjusted daily to correct for evaporation. Seawater (Seawater concentration at Karachi coast ranges between 38,000 to 40,000 mg/L) was completely replaced and flushed with fresh water once a week to avoid built up of salinity in pots. At the initiation of the experiment, seawater concentrations were gradually increased by 25% seawater at 2-d intervals to reach the maximum salinity levels of 100% seawater after 10 days.

Plants were grown for six months and then the growth parameters total dry weight and plant height were recorded. Water potential was measured by a plant water status console (Arimad-2, Wagtech International Limited, UK) on five shoots from each treatment. Stomatal conductance was measured using A-4 porometer (Delta-T devices) on the adaxial surface of fully expanded leaves at first node.

Half gram of the leaves was boiled in 10 ml of water for two hours at 100 °C using a dry heat bath. This hot water extract was cooled and filtered using Whatman no. 42 filter paper. One ml of hot water extract was diluted with distilled water for ion analysis (N = 25 for each treatment). Sodium and chloride ions were detected by Radiometer Ion- 85, ion analyzer. The data passed the normality test. The results were analyzed with a two way ANOVA to determine if significant differences were present among means. A Bonferroni test was carried out to determine if significant ($p < 0.05$) differences occurred between individual treatments (SPSS, 1996).

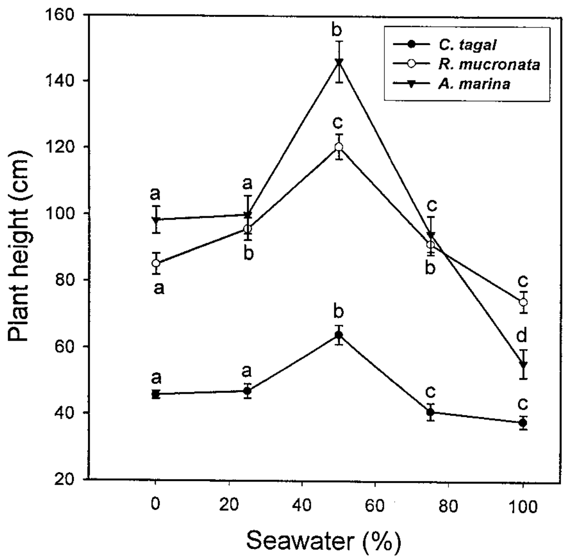

Figure 2. Effect of NaCl (0, 25, 50, 75 and 100% seawater) on the plant height of *Avicennia marina, Ceriops tagal* and *Rhizophora mucronata* plants (6 months old). Line represent means ± standard errors. Different letter above bars represent significant differences ($p < 0.05$) between treatments (Bonferroni test).

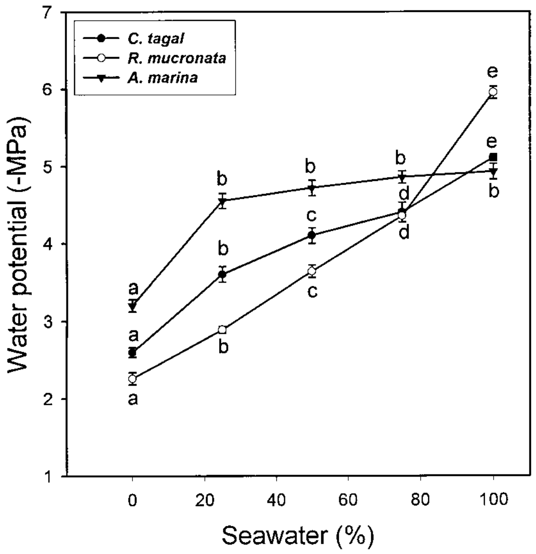

Figure 3. Effect of NaCl (0, 25, 50, 75 and 100% seawater) on the water potential of *Avicennia marina*, *Ceriops tagal* and *Rhizophora mucronata* plants (6 months old). Line represent means ± standard errors. Different letter above bars represent significant differences ($p < 0.05$) between treatments (Bonferroni test).

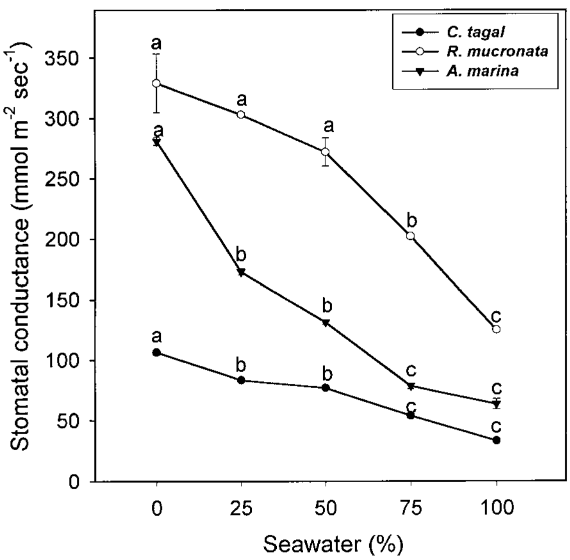

Figure 4. Effect of NaCl (0, 25, 50, 75 and 100% seawater) on the stomatal conductance of *Avicennia marina*, *Ceriops tagal* and *Rhizophora mucronata* plants (6 months old). Line represent means ± standard errors. Different letter above bars represent significant differences ($p < 0.05$) between treatments (Bonferroni test).

Results

A two way ANOVA showed that the main effects and their interaction (salinity × species) significantly ($p < 0.001$) affected the dry weights of plants (Table 1). Plant dry weights were optimal in 50% seawater (Figure 1). At higher salinity (100% seawater) there was no difference with the control except in *R. mucronata* where significant growth inhibition was recorded. *Rhizophora mucronata* accumulated more biomass in comparison to *A. marina* and *C. tagal* (Figure 1). Plant height was promoted at 50% seawater and declined with a further increase in salinity in all three species (Figure 2). Plants were tallest in *A. marina* followed by *R. mucronata* and *C. tagal*.

A two way ANOVA showed significant main factor effects of salinity ($p < 0.01$), and species ($p < 0.05$) on tissue water potential (Table 1). The salinity × species interaction was not significant. Water potential became rapidly more negative in *A. marina* and progressively more negative in *C. tagal* and *R. mucronata* with the increase in media salinity (Figure 3).

A two way ANOVA showed significant main effects of salinity ($p < 0.001$) and species ($p < 0.01$) on stomatal conductance (Table 1). The salinity × species interaction was also significant ($p < 0.01$). *Ceriops tagal* had lowest stomatal conductance at all salinity levels and *R. mucronata* showed highest stomatal conductance of all three species (Figure 4).

A two way ANOVA showed significant main effects of salinity ($p < 0.001$) and species ($p < 0.01$) on sodium and chloride accumulation (Table 1). The salinity × species interaction was also significant ($p < 0.05$, Table 1). Ionic content was maximum in *A. marina* followed by *R. mucronata* whereas, *Ceriops tagal* accumulated lowest amount of both sodium and chloride ions (Figures 5 & 6).

Discussion

Biomass production of all mangrove species was significantly stimulated at 50% seawater (22,000 mg/L NaCl). Similar results were obtained in *Avicennia marina* from Sundarban (Karim and Karim, 1993) and for *Sonneratia alba* from Australia (Ball and Pidsley, 1995). However, other studies showed growth stimulation at 25% seawater for *Avicennia marina* and *Rhizophora stylosa* (Clough, 1984; Downtown, 1984; Naidoo, 1987; Burchett et al., 1989). This clearly indicates that *Avicennia marina*, *Ceriops tagal* and *Rhizophora mucronata* growing along the most arid region of Karachi coast are more tolerant to salinity and have the ability to produce higher biomass when seawater mixes with Indus river discharge. Greater

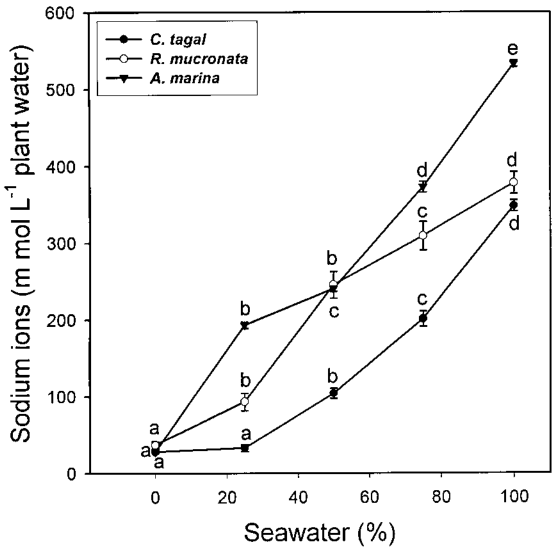

Figure 5. Effect of NaCl (0, 25, 50, 75 and 100% seawater) on the sodium contents of *Avicennia marina, Ceriops tagal* and *Rhizophora mucronata* plants (6 months old). Line represent means ± standard errors. Different letter above bars represent significant differences ($p < 0.05$) between treatments (Bonferroni test).

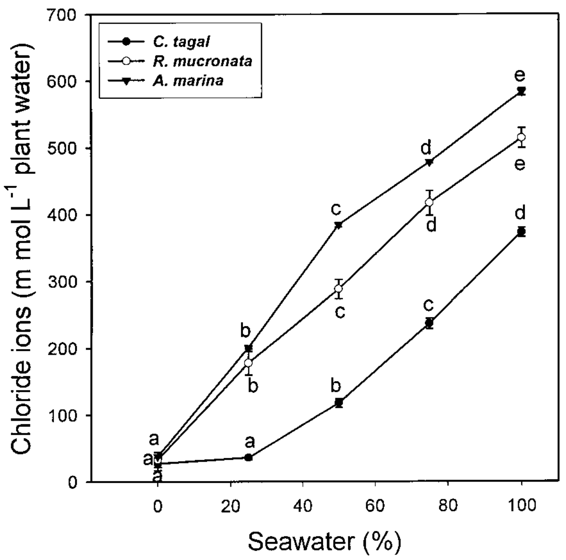

Figure 6. Effect of NaCl (0, 25, 50, 75 and 100% seawater) on the chloride contents of *Avicennia marina, Ceriops tagal* and *Rhizophora mucronata* plants (6 months old). Line represent means ± standard errors. Different letter above bars represent significant differences ($p < 0.05$) between treatments.

biomass was accumulated by *R. mucronata* whereas, *A. marina* was the tallest.

High media salinity affects plant growth due to low water potentials, ion toxicities, nutrient deficiencies or a combination of all these factors (Khan et al., 2000a). Halophytes are characterized by their capacity to adjust tissue water potential to a level that is more negative than that of the soil water potential of the habitat in which they are growing (Ungar, 1991). Growth and survival of halophytes are dependent on the high levels of ion accumulation in its tissue for the maintenance of turgor and osmotic adjustment (Flowers et al., 1977). *Avicennia marina* attained very negative water potential at the introduction of salinity and any further variation in salinity had little effect. Halophytes using this strategy are usually referred to as osmoregulators and most highly salt tolerant halophytes like *Salicornia europaea* (Karimi, 1984) and *Allenrolfea occidentalis* (Gul et al., 2000) are included in this group. *Ceriops tagal* and *R. mucronata* progressively decreased their water potential with the corresponding increase in media salinity. Those halophytes, which follow this strategy, are called osmoconformers and include species like *Atriplex triangularis* (Karimi, 1984).

Mangroves accumulate high concentrations of inorganic ions like most other salt tolerant plants that function in the osmoregulation of leaves and other tissues (Popp, 1994). Our results show that *A. marina* accumulated the highest concentrations of ions followed by *R. mucronata* and *C. tagal*. *Avicennia marina* has the ability to regulate salt content by secreting it through the glands, while *R. mucronata* and *C. tagal* have the ability to exclude salts via root ultrafiltration (Hegemayer, 1997) but do not have the ability to secrete salt through leaves.

Stomatal conductance declines in salt tolerant species under drought and salinity stress (Werner and Stelzer, 1990; Gordon, 1993) in order to increase water use efficiency. The lowering in conductance decreases the rate of carbon dioxide accumulation and uptake (Aphalo and Jarvis, 1993) decreases the rate of transpiration, and decrease water potential (Ball and Farquhar, 1984). In our results, all plant species studied substantially reduced their stomatal conductance with the increase in salinity. The stomatal conductance was highest in *R. mucronata,* followed by *A. marina* and *C. tagal*. The lowering of stomatal conductance along with slow growth in *C. tagal* possibly indicates that low carbon assimilation and low water-use efficiency could be the reason for reduced growth in this species. In *R. mucronata* and *A. marina*, a better growth response than *C. tagal*, reflects the high water-use efficiency in both species, even though one of them is salt secretor and the other is a salt excluder.

Our results clearly showed that all three-mangrove species are highly salt tolerant and could survive full-strength seawater and perhaps even higher salinity of the medium. It appears that the growth of all the species would be better if fresh water from the Indus River allowed mixing with seawater. Although all the species studied are good candidates for mangrove rehabilitation in the Indus delta, *A. marina* is best equipped to deal with highly arid conditions of the Pakistani coast since this species maintains very negative water potential under saline conditions. This also partially explains why it is the most dominant species in the entire coastal belt of Pakistan.

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