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# SEASONAL VARIATION IN ECOPHYSIOLOGY OF *AVICENNIA MARINA* POPULATIONS GROWING IN POLLUTED ARABIAN SEA COAST AROUND KARACHI

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**Abstract**

Seasonal variation in water relations and nutrient content of six *Avicennia marina* populations in various creeks of the Arabian Sea near Karachi, Pakistan was studied. Extra nutrients, both in sediments and plant samples increased with the onset of monsoon during July-August. Highest concentrations of nutrients were recorded in samples collected from Korangi creek population while lowest values were from Rehri. Ammonium and sodium concentrations were highest both in plant and sediment samples. Water potential of plants was more negative during the dry and more saline period, while stomatal conductance substantially decreased.

## Introduction

The recent industrial development of various tropical regions has become a potential threat to mangrove ecosystems and the fisheries they support (Lacerda & Abrao, 1984; Odum, 1984). Among the many pollutants, by-products of industrialization and heavy metals have received special attention (Lacerda & Abrao, 1984). Accumulation of these products induces toxic effects in protected coastal zones and estuaries where mangroves are best developed. Several studies in salt marshes, however, have suggested that these areas may act as natural sinks for metals (Oenema *et al.*, 1988; Orson *et al.*, 1992; Cacador *et al.*, 1992). Plants may act as important sink for metals and extra nutrients in salt marshes. Metals are transported to the salt marshes by tidal currents and incorporated into the soil sediments (Bourg, 1987). Wetland systems receive a large amount of sewage sludge through municipal wastewater and the vegetation is adapted to filter nutrients from the water (Boyt *et al.*, 1977).

Mangroves in intertidal zones also experience considerable spatial and temporal variation in soil salinity, besides the influx of by-products of the industries. Responses associated with salt effects include changes in sap osmotic pressure, variation in leaf size, salt exclusion at the root level and active salt excretion through leaves (Lugo *et al.*, 1981; Popp, 1984; Stewart & Popp, 1987). Mangroves like other halophytes adjust their tissue water to adapt themselves to saline habitats (Munns, 1988; Popp & Polania, 1989; Popp, 1984; Stewart & Ahmed, 1983). In coastal Northern Venezuela it was observed that osmotic potential and xylem tension of *Avicennia germinans* became more negative to maintain turgor in the dry season in comparison to the rainy season because of increased salinity (Smith *et al.*, 1989).

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Millions of gallons of untreated sewage (both domestic and commercial) are being dumped in coastal waters every day. This dumping has considerably increased nutrient level in water and soil sediments. In this study we have selected six local coastal populations of *A. marina* and examined the effect of seasonal variations in salinity and nutrients on osmoregulation of A. *marina* growing under natural conditions.

## Materials and Methods

Six *Avicennia marina* populations growing around the Karachi coast were selected for the study viz., Rehri, Korangi, Sandspit I, Sandspit II, Hawksbay and Clifton creek. Among these populations only Rehri faces the open sea whereas all the other sites are confined to the creeks.

Experiments for water relations were performed in the field during March to February 1996. Leaf water potential was measured by using a dew point microvoltmeter (Wescor HR33T). Stomatal conductance and quantum flux was measured using AP-4 porometer (Delta-T devices) on the adaxial surface of fully expanded leaves.

To study seasonal variation in ion and nutrient contents of plants and soil samples were randomly collected for 12 months. Plant samples were brought to the laboratory in pre-weighed plastic bags and stored on dry ice. Fresh weight was immediately taken and then samples were oven dried at $80^0$C for 24 hours. Hot water extracts from plant samples were prepared for nutrients and ion analysis. A half gram of plant material 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 of each sample was diluted with distilled water and ions and nutrients like $Cu^{++}$, $NO_3^-$ and $NH_4^+$ were measured with the help of an Ion analyzer (Ion-86, Radiometer). Soil extracts were prepared (using 10 g soil in 50 ml distilled water), diluted at different concentrations to analyze ions, nutrients, soil electrical conductivity and soil pH with the help of same device. The results of ion analysis, nutrients and water relations were analyzed using a two - way ANOVA to determine if significant differences existed among means (Anon., 1999).

## Results

Concentration of all nutrients i.e., $Cu^{++}$, $NO_3^-$ and $NH_4^+$ in soil sediments was higher during the monsoon period (July/August) in all sites studied (Figs. 1 & 3). Similar results were obtained for plant samples, which showed a concentration of nutrients during July and August (Figs. 2 & 4). Values for $Cu^{++}$, $NO_3^-$ and $NH_4^+$ were lowest in Rehri for both soil sediments and plant samples and highest in Korangi creek followed by Clifton creek whereas, in Sandspit I, Sandspit II and Hawksbay samples their range was intermediate. A two way ANOVA showed a significant individual effect of sites ($P < 0.05$) and months ($P < 0.01$) in affecting nutrient accumulation in soil and plants (Table 1 & 2), however, the effect of sites was non-significant for ammonium and nitrate accumulation in plants (Table 2). Two-way interactions of sites and months also showed a significant difference ($P < 0.05$) for both soil and plant samples (Table 1 & 2). Among the nutrients observed for all sites, $NH_4^+$ was higher both in soil and plant samples whereas, accumulation of $NO_3^-$and $Cu^{++}$ content was low (Figs. 1-4).

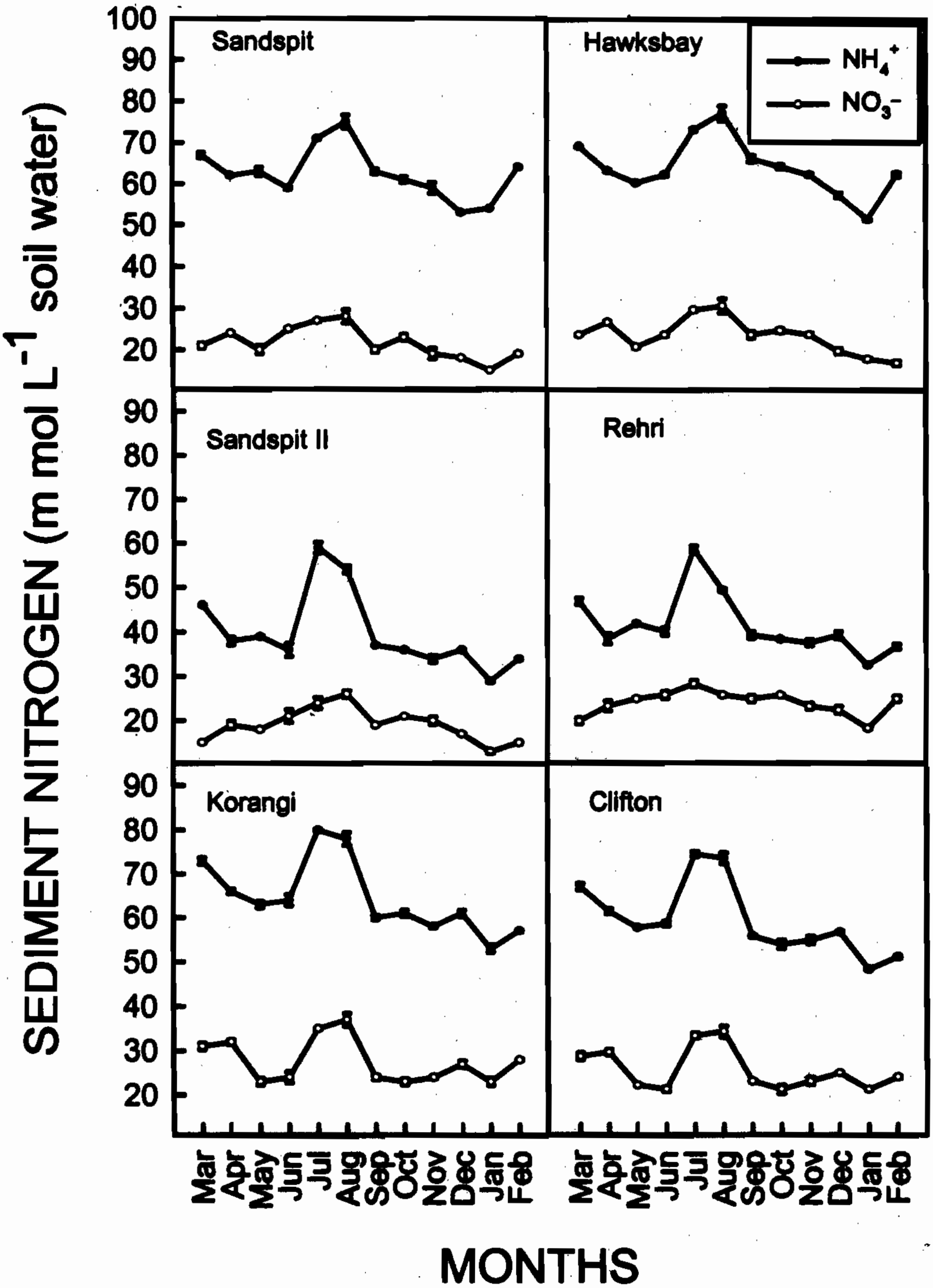


Fig. 1. Concentration of Nitrogen (m mol L$^{-1}$ soil water) in soil sediments. Data points represent means ± standard errors for different months.

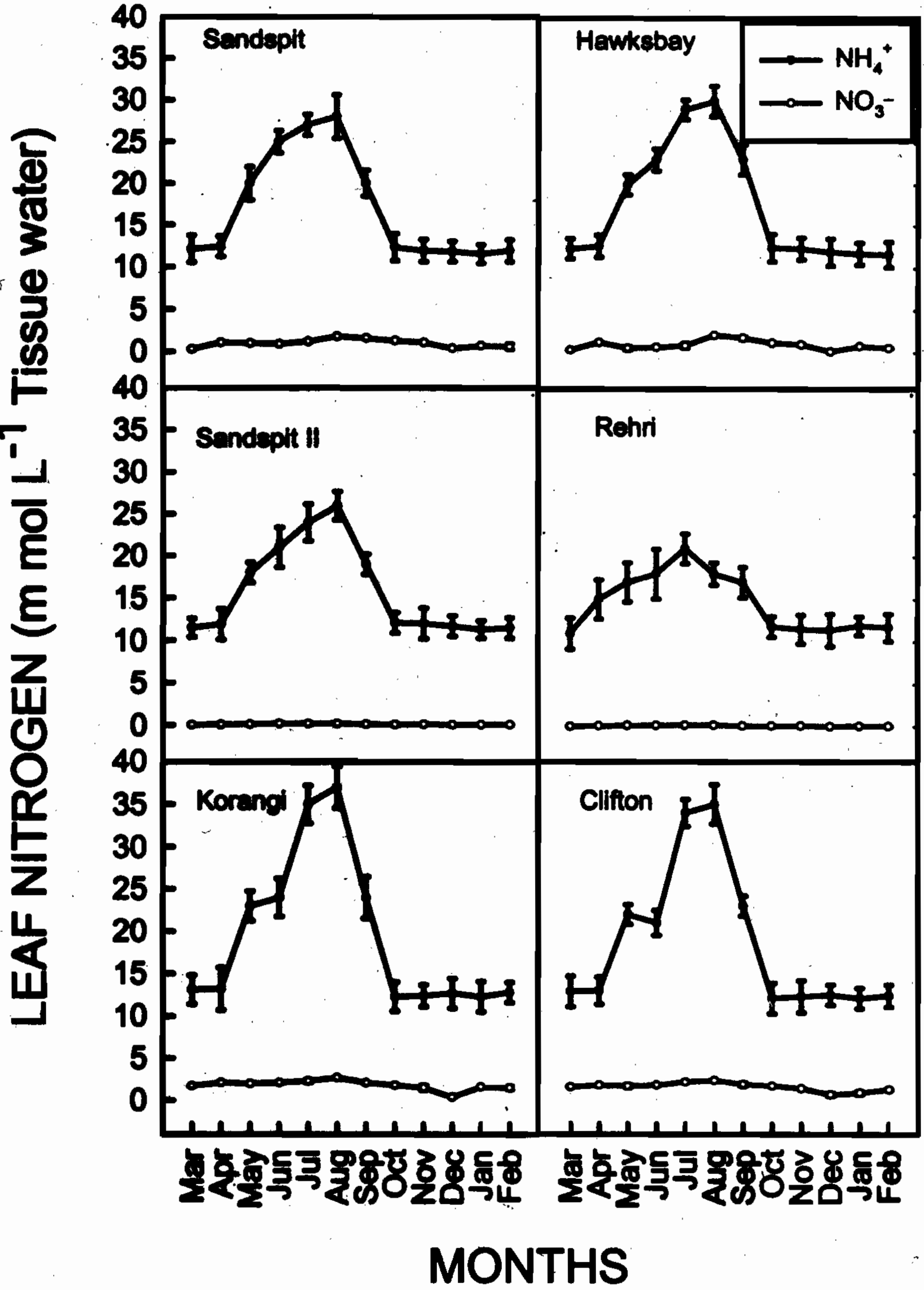


Fig. 2. Concentration of Nitrogen (m mol L$^{-1}$ tissue water) in plant tissues. Data points represent means ± standard errors for different months.

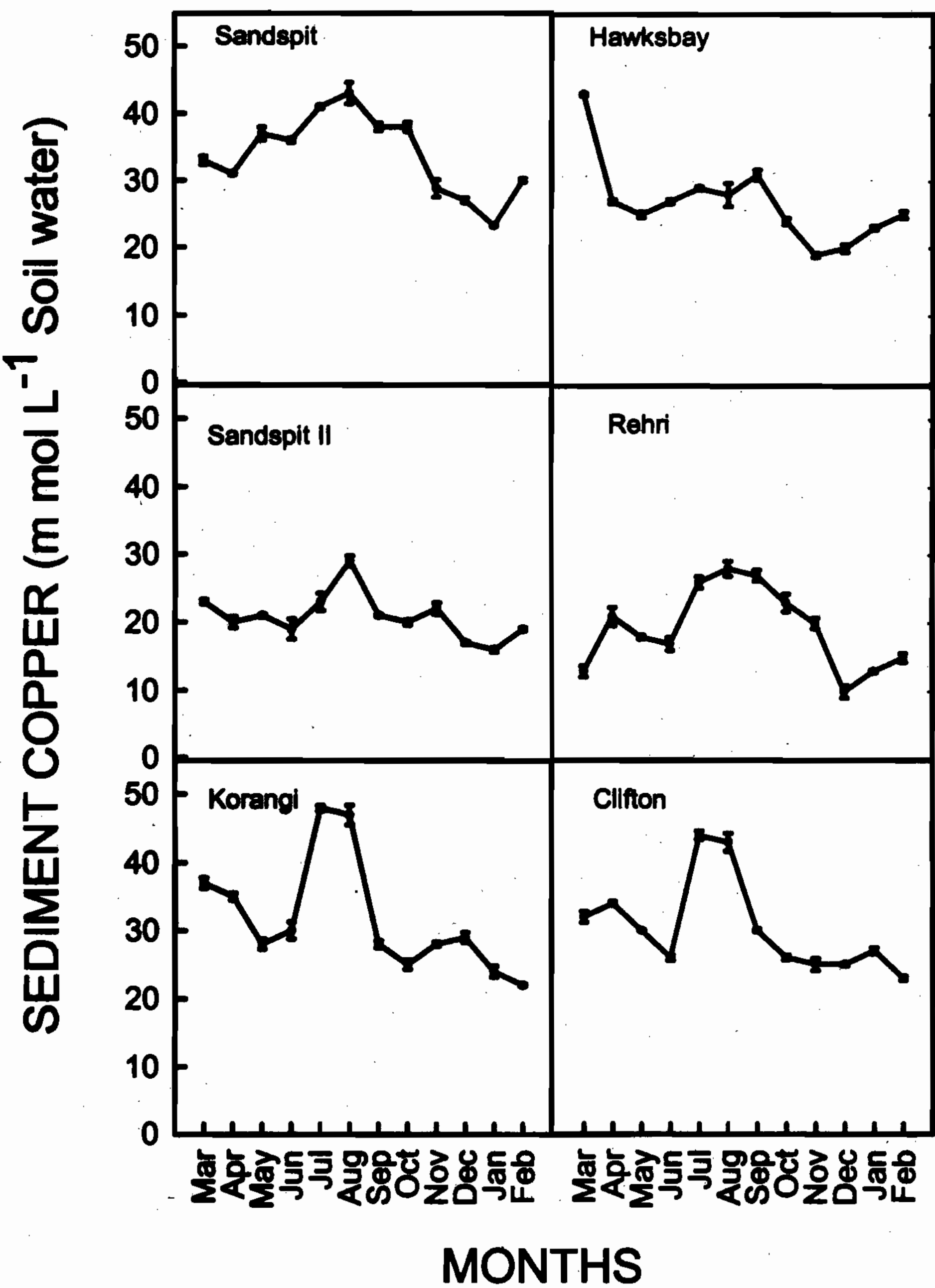


Fig. 3. Concentration of Copper (m mol $L^{-1}$ soil water) in soil sediments. Data points represent means ± standard errors for different months.

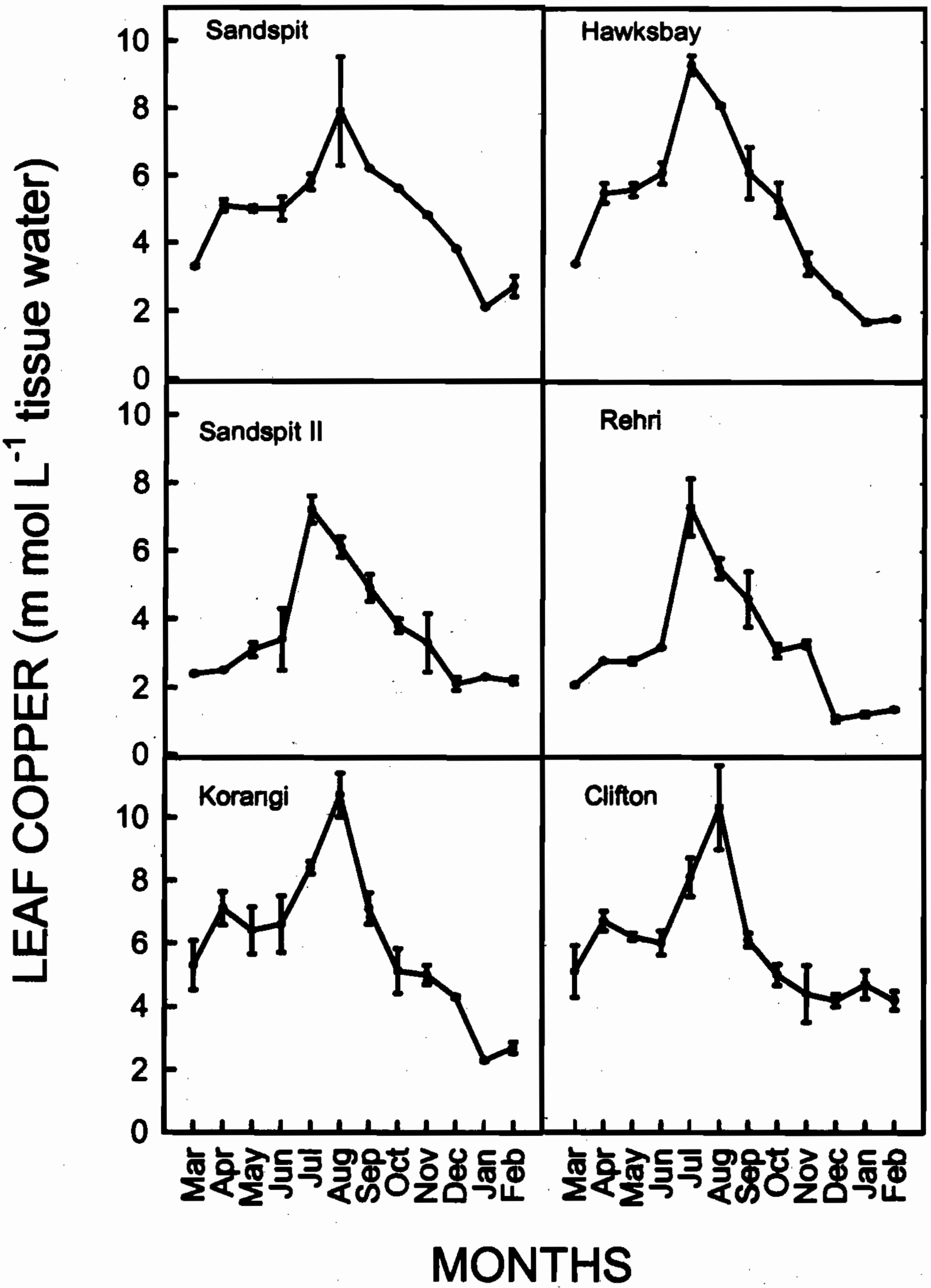


Fig. 4. Concentration of Copper (m mol $L^{-1}$ tissue water) in plant tissues. Data points represent means ± standard errors for different months.

A two way ANOVA showed a significant individual effect ($P < 0.01$) of sites and months in affecting tissue water potential (Table 3). Two-way interaction of sites and months also was significant ($P< 0.05$) for water potential (Table 3). Water potential substantially decreased during the dry and more saline period of December and January (Fig. 5) and increased during the wet and relatively less saline period (July/August). The Korangi creek population showed the most negative value for water potential while the Rehri creek population showed the least negative values.

Stomatal conductance and quantum flux densities were significantly different ($P < 0.001$) by variations in both place and time and their interaction (Table 3). Stomatal conductance was higher during the wet period and it was lower during the dry and more saline period (Fig. 6). Variations in sodium and chloride ions in soil were significantly different ($P< 0.05$) by months but not among sites (Table 3). Calcium and potassium ion concentrations did not show any significant variation. Soil electrical conductivity was lower during the wet period and higher during the dry and saline period (Fig. 7). Soil pH always remained at or above 8 and there was no significant difference in the pH of all study sites.

Sodium and chloride accumulation was significantly higher ($p< 0.05$) in leaves during the dry and saline period (Table 4), whereas, no significant change was observed for calcium and potassium in all sites studied. The individual effect of site in affecting ion concentration was also not significant.

## Discussion

The accumulation of extra nutrients like $Cu^{++}$, $NH_4^+$ and $NO_3^-$ in plant tissues corresponds to their level in the sediments at our study sites. Mangroves existing in salt marsh estuaries and creeks act as natural sinks for such nutrients, including some heavy metals (Oenema *et al.*, 1988; Orson *et al.*, 1992; Cacador *et al.*, 1992). Many salt marshes of the world lie close to heavily industrialized areas facing discharges of toxic wastes and heavy metals (Otte, 1991). Korangi and Clifton creeks are the most polluted sites because heavy sewage and industrial discharges are accumulated both in plants and soil sediments. Ammonium concentration was highest in all sites followed by $Cu^{++}$ and $NO_3^-$. Similar results were observed for heavy metals in salt marshes of Tagus estuaries, Portugal (Cacador *et al.*, 1996). The concentration of nutrients usually increases during the high tide in salt marshes (Lacerda *et al.*, 1988). High tidal currents transport heavy metals and toxic wastes both in dissolved and particulate forms (Bourg, 1987). In our study sites, the concentration of all nutrients increased during the high tides of the monsoon period (July and August) whereas, lower concentrations were observed during the dry and saline period (December and January). Plants accumulated little nutrients from sediments among which a relatively higher fraction of $NH_4^+$ and lower of $NO_3^-$ nitrogen was observed, because nitrate is usually lost as a result of denitrification in estuaries and mangrove swamps. Further, a high level of sodium in mangrove soil could displace $NH_4^+$ in the cation exchange sites resulting in the enhancement of $NH_4^+$ mobility (Chiu *et al.*, 1996).

Mangroves can withstand high concentration of pollutants such as $Cu^{++}$, $Zn^{++}$, $Pb^{++}$ and $Cr^{+++}$ (Lin & Chen, 1990; Zheng *et al.*, 1992) and the amount of $Cu^{++}$ is usually high in areas, rich in sewage effluents (Bubb & Lester 1995). In our results, $Cu^{++}$ content was higher in Korangi creek and Clifton, which receives a lot of sewage effluent. Pollutants

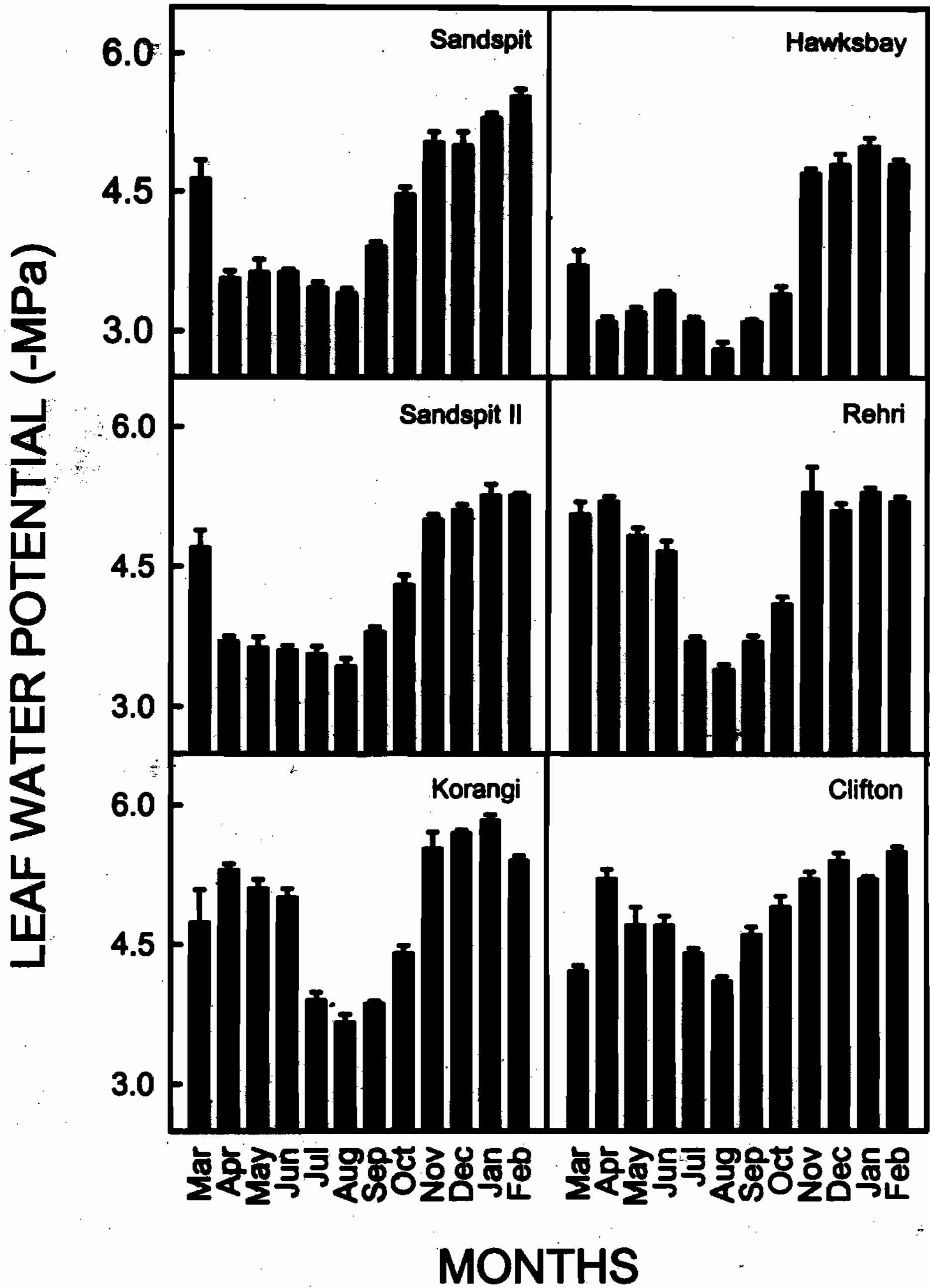


Fig. 5. Water potential (-MPa) in leaves of *A. marina*. Bars represent means ± standard errors for different months.

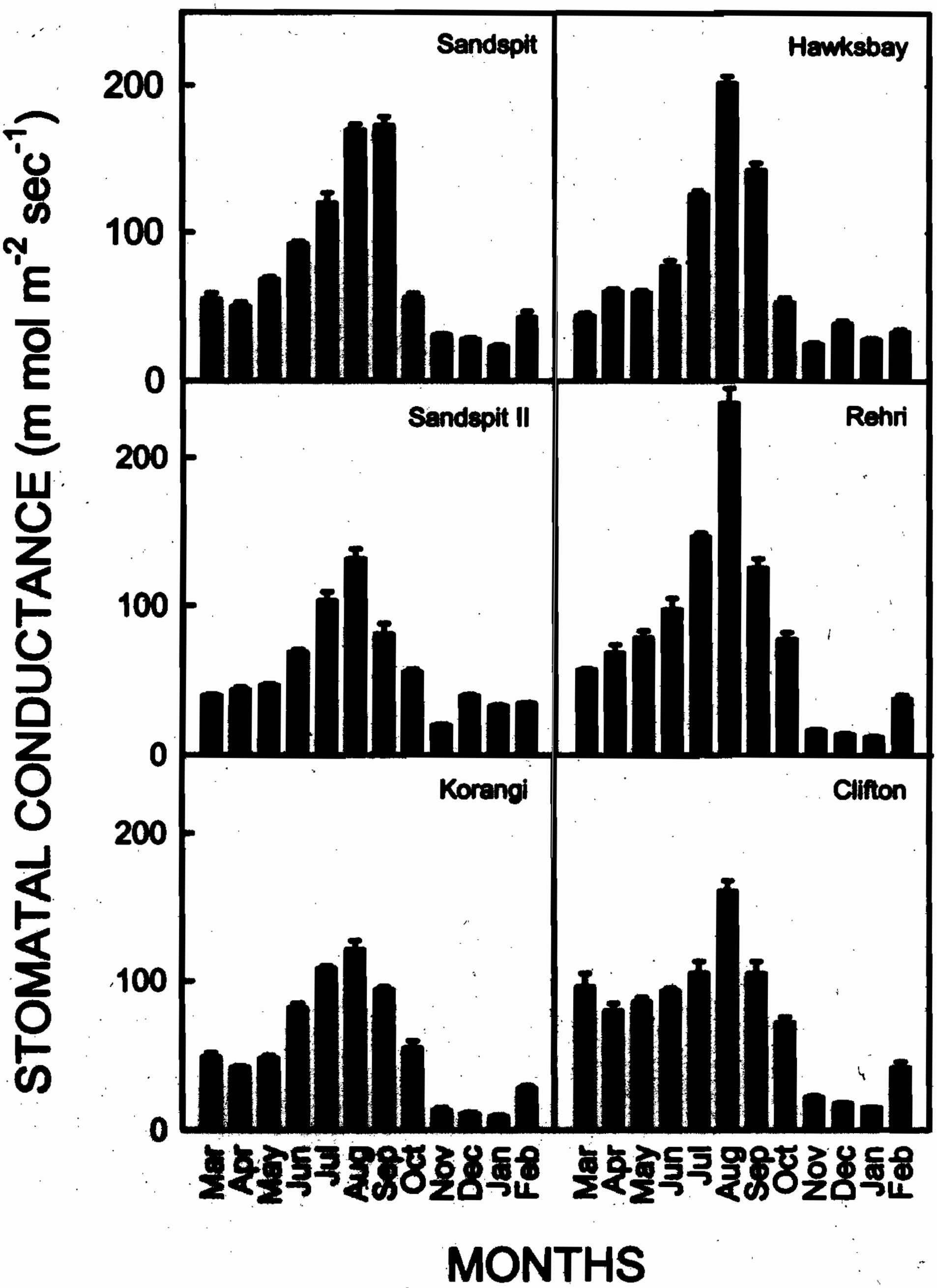


Fig. 6. Stomatal conductance (m mol $m^{-2}$ $sec^{-1}$)in *A. marina* leaves. Bars represent means ± standard errors for different months.

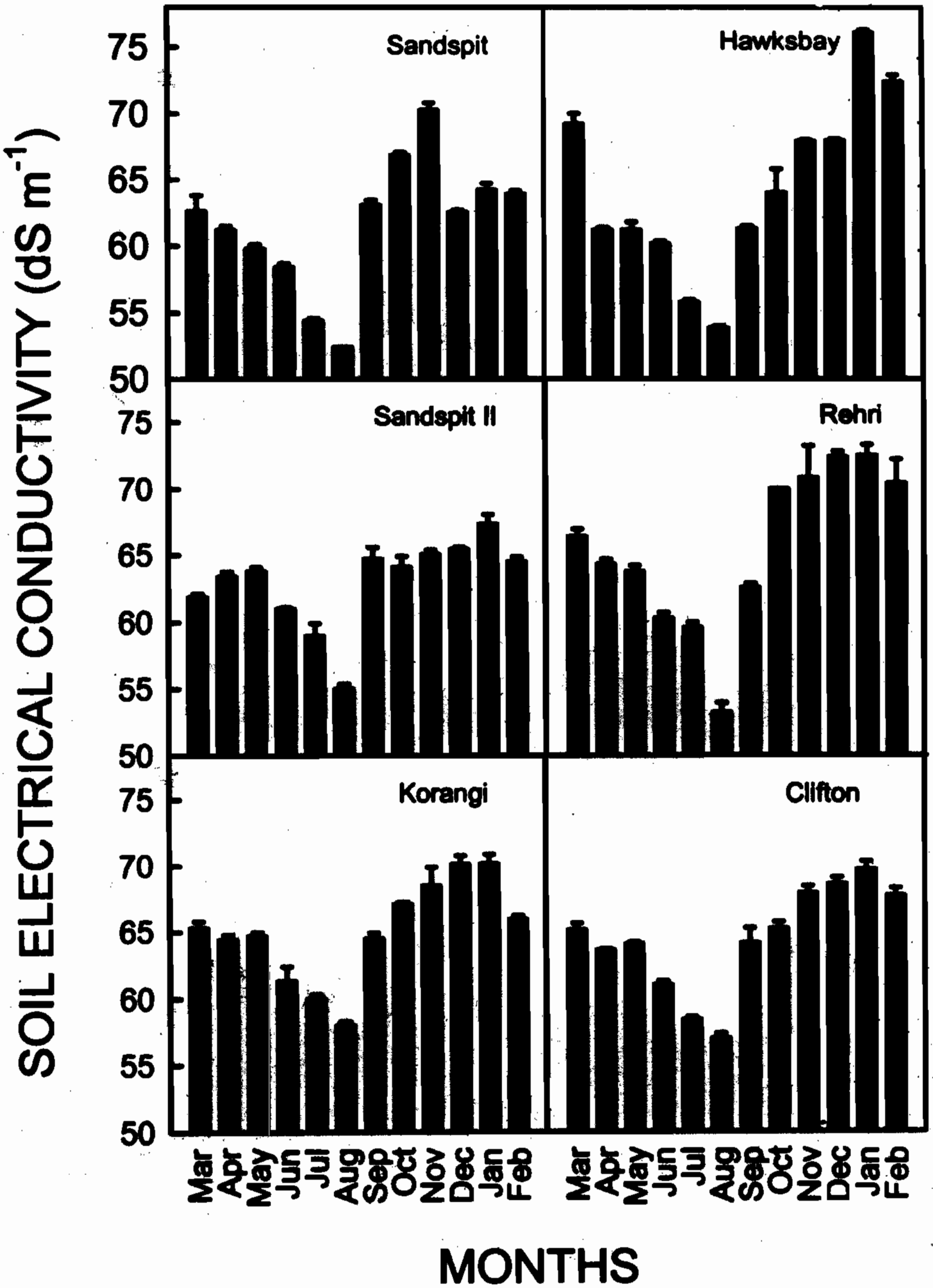


**Fig. 7. Electrical conductivity (dS m$^{-1}$) in soils of different *A. marina* populations. Bars represent means ± standard errors for different months.**

from mangrove populations are usually removed through a variety of complex biological, physical and chemical processes, in particular, the combination of saturated soils, plants and micro-organisms, which provide a reduction of pollutants from overlying waste water (Legget *et al.*, 1995; Dunbabin & Bowmer, 1992; Gale *et al.*, 1993). The discharge of municipal waste has no apparent effect on the growth of mangroves. Because of their extensive root systems and high productivity mangroves may be helpful in trapping nutrients from wastewater. Plants are adapted to the stressed environment, characterized by high temperatures, fluctuating salinities and shifting an-aerobic / aerobic substrate (Wong *et al.*, 1995).

Tissue water potential was more negative during the dry and more saline period when the soil electrical conductivity was also higher. Osmotic potential and xylem tension of *Avicennia germinans* both dropped to more negative values in the dry season in comparison to the rainy season because salinity increases during the dry season and plants are exposed to more stress (Smith *et al.*, 1989). A decrease in water and osmotic potentials in mangroves is observed when there is an increased salinity in the soil medium (Aziz & Khan, 2000, 2001; Suarez *et al.*, 1998; Clough, 1984; Naidoo, 1987).

Stomatal conductance declines in salt tolerant species under drought and salinity stress to increase water use efficiency (Sharma, 1977; Werner & Stelzer, 1990; Gordon, 1993). An increase in stomatal conductance is observed under low salinities (Ball & Farquhar, 1984). Stomatal conductance in our study sites was higher during the wet and less saline period and lower during the dry and saline period. These results correspond to the increased electrical conductivity of the soil when plant water uptake is minimized. Soil electrical conductivity increased during the dry period when the ionic concentration ($Na^+$ and $Cl^-$) also increased in all sites. High internal salt concentrations provide potential benefits to plants growing under conditions where the soil osmotic potential is far lower (more negative) than that of seawater on account of high salinity (Ungar, 1991) since it is the plant water potential to permit water uptake. Our results also showed an accumulation of $Na^+$ and $Cl^-$ ions during the dry period when the salt concentration was higher in the external medium.

Tissue water potential was higher in plants during the dry period when soil salinity was also high, whereas, the concentration of nutrients was low. It might be due to the high chloride content along with heavy metals which could promote the formation of metallic chloro-complexes in the soil (Hahne & Kroontje, 1973), hence reducing metal activity and availability of nutrients to the plants during periods of high salinity (McLaughin & Tiller, 1994). Moreover, nutrients such as $NH_4^+$ may also be immobilized during the dry and saline period. Due to the dryness of the soil environment, a thin aerobic layer is formed around soil boundaries and the process of nitrification is increased, hence $NH_4^+$ is lost (Chiu *et al.*, 1996). The coastal populations around Karachi seem to show similar seasonal patterns of nutrient availability.

Our data showed that populations of *A. marina* growing around the Arabian Sea coast tolerate high salinity and also act as natural sinks for sewage flux and extra nutrients especially near Korangi and Clifton creeks. Hence, they are serving as an efficient barrier against heavy metal pollution. During the wet period of the year, high tidal currents result in more sewage flux and low salinity, which causes increased levels of nutrients in sediments as well as plant tissues. It appears that during the months of high tide, higher stomatal conductance and increase in water potential might be due to the incorporation of nutrients (nitrogen and copper) and low salinity stress. It indicates that water use efficiency of plants increase during this period, while during the dry period high salinity interacts with these nutrients, reducing their availability to the plants and disturbs osmoregulation.

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