

SEASONAL VARIATION IN WATER RELATIONS OF *HALOPYRUM MUCRONATUM* (L.) STAPF. GROWING NEAR SANDSPIT, KARACHI

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Abstract

Halopyrum mucronatum (L.) Stapf., is a salt tolerant grass found on the coastal dunes of Arabian Sea. Seasonal variations in water relations of *H. mucronatum* were studied near Sandspit, Karachi over a one-year period. Water and osmotic potentials were higher during the monsoon (July and August), stomatal conductance was high and plants maintained turgor. Water potential, osmotic potential and stomatal conductance decreased with increasing soil electrical conductivity. This indicates that plants minimize their water uptake during stress to achieve osmotic adjustment, which helps them to survive in desert ecosystem.

Introduction

Halopyrum mucronatum (L.) Stapf., a perennial coastal grass, is distributed from Egypt to Mozambique and Madagascar, through Arabia to Pakistan, India and Sri Lanka (Cope, 1982). *Halopyrum mucronatum* is a potential seed crop, which could also be used as a coastal dune stabilizer (Khan *et al.*, 1999). It shows luxuriant growth while inundated daily with seawater and flowers twice a year (Noor & Khan, 1995). Growth is optimum at 90 mmol L⁻¹ NaCl and the plant loses turgor at higher salinities (Khan *et al.*, 1999).

High salinity under moist conditions showed physiological drought due to osmotic stress. Lillebø *et al.*, (2003) found that seasonal variation in salinity affected survival of *Scirpus maritimus* population, which showed increased mortality with the increase in salinity. Plants vary in their response to salinity and water stress (Munns, 2002) and monocotyledonous species generally show a less than optimal response at higher salinities (Gulzar, 2002). Salt and drought tolerant plants lower their osmotic potential due to the net accumulation of osmotically active solutes (Aziz & Khan, 2001; Beena & Khan, 2002; Mulholland & Otte, 2002; Aziz & Khan, 2003) such as proline and glycinebetaine in high concentrations (Hasegawa *et al.*, 2000), although other osmolytes may also accumulate in different halophytes. During stress, halophytes not only reduce their leaf water potential but also minimize water loss (Naidoo & Mundree, 1993; Carrol *et al.*, 2001) by lowering their stomatal conductance (Naidoo *et al.*, 1995). The initial response to a rise in salinity is similar to an osmotic response. However, as the frequency and duration of stress increases, additional effects in older transpiring leaves cause a reduction in growth (Munns, 2002).

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At higher soil salinities, water use efficiency is increased as a result of reduced conductance and partial stomatal closure (Naidoo *et al.*, 1995; Robinson *et al.*, 1997). High water use efficiency also contributes to the long-term survival of plants in saline environments (Naidoo & Mundree, 1993). Naidoo *et al.*, (1995) examined the effect of salinity on the stomatal conductance of *Sporobolus virginicus* and found that transient changes in salinity cause stomatal limitations of photosynthesis as a mechanism of salinity tolerance. The seasonal variation in the water relations of grasses under saline conditions have been reported (Marcum & Murdoch, 1994; Mahmood *et al.*, 1996 and Khan *et al.*, 1999) but more information is needed to understand their water relations under various environmental regimes. The data presented here describes the seasonal water relations of *Halopyrum mucronatum* population from Arabian sea coast near Karachi.

Materials and Methods

The study was carried out on a *Halopyrum mucronatum* population present on the coastal sand dunes at Sandspit, Karachi. Water relations parameters like water potential, osmotic potential, turgor pressure and stomatal conductance were measured at monthly intervals for 12 months. Leaf water potential was measured using a dew point microvoltmeter (Model HR-33, Wescor Inc., Logan, Utah) on 5 mm diameter leaf disks placed in a sample chamber. Osmotic potential was measured by freeze-drying leaf disks in liquid nitrogen before placing them in the sample chamber. Stomatal conductance was measured with a cycling diffusion porometer (Model AP-4, Delta-T Devices Limited, Cambridge). Soil extracts (1:5 w/v) were prepared using oven dried soil (110°C for 24 h) and distilled water. Electrical conductivity and pH of this extract were determined with the help of an Ion-85, ion analyzer (Radiometer, Copenhagen) and a conductivity meter (Radiometer, Copenhagen), respectively. Soil moisture was calculated from the difference between fresh and oven dry weights of 50 g soil samples. The statistical package SPSS (Anon., 2002) was used for one-way ANOVA and for a post-hoc Bonferroni test (Anon., 2002) to determine if significant differences existed among treatment means.

Results

Water and osmotic potentials were higher during the monsoon period in July and August when plants faced high tides and became lower during the drier, more saline period in December and January (Fig. 1). Turgor pressure was higher during the monsoon and lower in December and January. Leaf stomatal conductance was also higher during the monsoon and lower during the dry and saline period (Fig. 3) indicating a water conservation strategy. Soil electrical conductivity varied significantly ($P < 0.05$), whereas, pH remained more or less same (≥ 8) throughout the year (Table 1). Soil electrical conductivity was high from November to February but it decreased with a rise in soil moisture content (Table 1). A significant ($P < 0.01$) increase in soil moisture was observed during the monsoon accompanied by a lowering of soil salinity (Table 1).

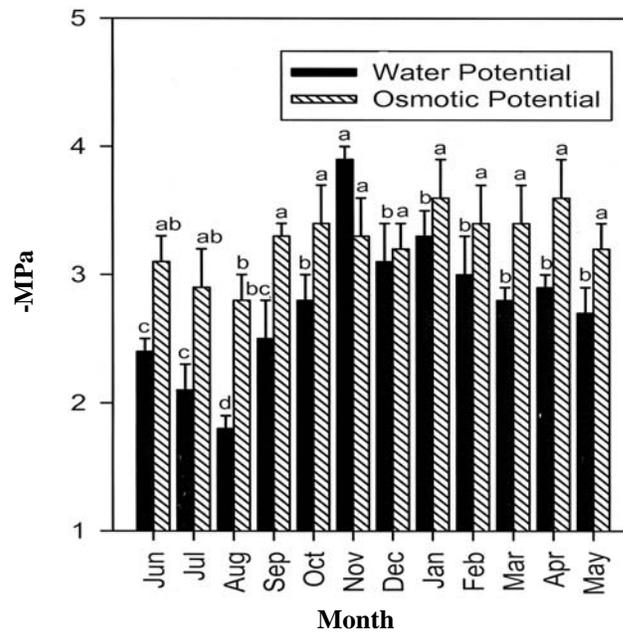


Fig. 1. Seasonal variation in water and osmotic potentials of *Halopyrum mucronatum*. Different letters on error bars represent significant differences at $p < 0.05$ (Bonferroni test).

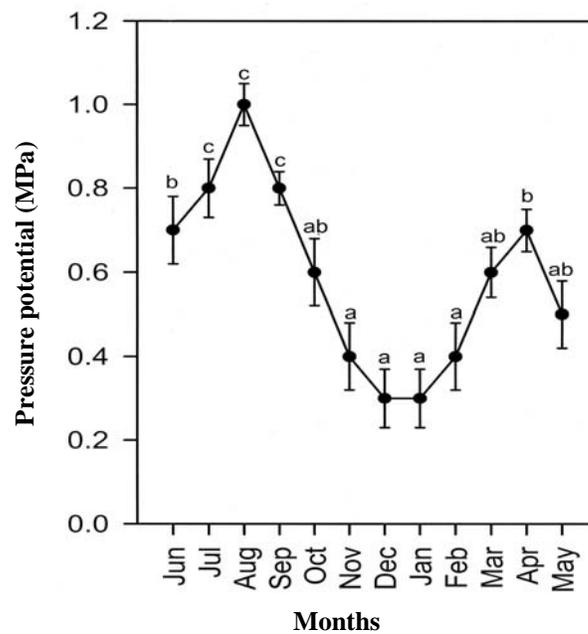


Fig. 2. Seasonal variation in turgor pressure of *Halopyrum mucronatum*. Different letters on error bars represent significant differences at $p < 0.05$ (Bonferroni test).

Table 1. Seasonal variation in soil properties of *Halopyrum mucronatum* community at Sandspit, Karachi.

Month	pH	EC (dS m ⁻¹)	Moisture (%)
Jun	8.4 ± 0.2	58.5 ± 0.1	19 ± 1.3
Jul	8.3 ± 0.5	54.8 ± 0.2	27 ± 2.3
Aug	8.4 ± 0.7	53.1 ± 0.4	28 ± 3.2
Sep	8.6 ± 0.2	62.4 ± 0.8	21 ± 4.5
Oct	8.5 ± 0.5	63.4 ± 0.8	17 ± 1.5
Nov	8.3 ± 0.3	68.4 ± 0.8	15 ± 2.5
Dec	8.2 ± 0.2	61.4 ± 0.8	15 ± 2.5
Jan	8.2 ± 0.4	63.4 ± 0.8	13 ± 1.5
Feb	8.1 ± 0.4	64.4 ± 0.8	18 ± 1.5
Mar	8.2 ± 0.5	62.4 ± 0.8	18 ± 2.5
Apr	8.3 ± 0.2	61.4 ± 0.8	16 ± 2.8
May	8.4 ± 0.3	59.4 ± 0.8	19 ± 2.7
ANOVA for months	n.s	*	**

Data are means (± SE), * $P < 0.05$; ** $p < 0.01$; n.s. = Non- significant.

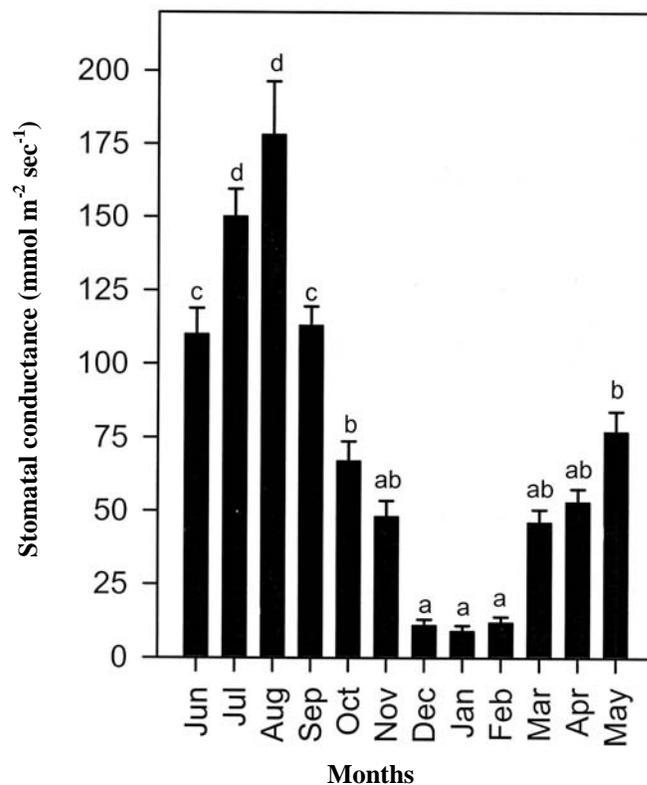


Fig. 3. Seasonal variation in stomatal conductance of *Halopyrum mucronatum*. Different letters on bars represent significant differences at $p < 0.05$ (Bonferroni test).

Discussion

The survival of plants in saline conditions depends on the maintenance of cell turgor mainly by decreasing osmotic potential thorough osmotic adjustments (Mulholland & Otte, 2002). In this study, *H. mucronatum* decreased its osmotic potential during the dry period to withstand salinity stress. Farrant (2000) believed that mechanisms to prevent physical damage from mechanical stresses imposed by turgor loss are also important for the survival of plants. Aziz & Khan (2000) also observed similar patterns for water relations in mangroves growing at the Arabian sea coast. The difference in leaf water potential in saline habitats is a result of different soil water potentials (Veste & Breckle, 1995). This change is usually observed as a result of rain especially in the dune systems when water penetration reaches its maximum by lateral movements along the dune slope (Yair, 1990).

The growth of perennial grasses is also enhanced after precipitation (Liang *et al.*, 2003). In our studies plant water status responded immediately to changes in the soil moisture content after rains during the monsoon that probably correlates with a decrease in salinity. These results indicate that reduced leaf water potential with increasing salinity was associated with decreases in both osmotic and pressure potential during the dry months. Gulzar *et al.* (2003a) found *Aeluropus lagopoides* plants having water potential of -3.0 MPa at about sea-level concentrations of 600 mM NaCl. Stomatal conductance was reduced to $17 \text{ mmol.m}^{-2}.\text{s}^{-1}$ at 200–600 mM NaCl from $24 \text{ mmol.m}^{-2}.\text{s}^{-1}$ in non-saline control. Similar values of water potential were reported for *Halopyrum mucronatum* after 90 days at 360 mM NaCl (Khan *et al.*, 1999).

In many dicotyledonous eu-halophytes such as *Suaeda fruticosa*, growth is enhanced at salt levels usually below 250 mM NaCl (Khan *et al.*, 2000) along with an increase in tissue water content (Flowers *et al.*, 1986). Sub-tropical grasses maintained low turgor, decreased stomatal conductance and reduced tissue water content at high salinities. It is generally reported for most grasses with the exception of a few such as *Sporobolus virginicus* (Bell & O'Leary, 2003), which showed salt-stimulated growth at 100–150 mM NaCl. They also found that water content of leaves and shoots increased substantially at optimum salinity of 125 mM NaCl as compared to control. Typically, grasses accumulate low concentrations of salt and reduce tissue water content to cope with rising soil salinity (Gulzar *et al.*, 2003ab, 2005).

Salt exclusion through leaf glands is an important feature in most perennial halophytes (Ball, 1988) with leaves persisting for a year or more than for annual species where leaves may live only for a month (Munns, 2002). Ramadan (2001) reported that under variable soil salinities, *Sporobolus spicatus* regulated the tissue ions at low levels by secreting more salt through leaves during the night and more than 67% of the absorbed NaCl was secreted by *Reaumuria hirtella* leaves during the day (Ramadan, 1998).

Halopyrum mucronatum belongs to the Na^+ accumulating physiotype and also maintains high levels of glycinebetaine under high salinity treatments (Khan *et al.*, 1999). Plants not only accumulate ions to adjust their osmotic potential but they also accumulate osmoprotectants that stabilize proteins and membranes of their tissues such as proline and low molecular weight carbohydrates in herbaceous halophytes (Popp & Albert, 1995) and proline and glycinebetaine in mangroves (Aziz & Khan, 2001). Such organic solutes cause minimal perturbation to macromolecular stability and protect photosystem complexes in plants (Allakhverdiev *et al.*, 2003).

Stomatal conductance was higher during the monsoon period and lower during the dry and saline period, perhaps as a mechanism to conserve water as stress increased (Gulzar & Khan, 1998). High stomatal conductance serves to maintain higher water potential to minimize unnecessary water loss (Carrol *et al.*, 2001; Beena & Khan, 2002). Many halophytes are capable of osmotic adjustments by accumulating proline (Mulholland & Otte, 2002; Zhu, 2002) and glycinebetaine (Allakhverdiev *et al.*, 2003). There is a considerable variation between environmental conditions of coastal and inland habitats and plants appeared to be more stressed at the coastal rather than at the inland sites (Gulzar & Khan, 1998). However, plants growing on saltlands are prone to a variety of common stresses like water and nutrient deficiencies, extreme pH values and high soil strength. In addition, plant growth could also be profoundly affected by salinity, water logging and inundation (Barrett-Lennard, 2003) and attempts at revegetation of salt land using halophytes have encountered several problems especially the accumulation of salt at the root zone. In the dune systems, the high tides during the monsoon season would flush away the excess salts accumulated in the root zone. This would allow plants not only to continue clonal growth but also flower twice a year even in the absence of rains for few consecutive years (Noor & Khan, 1995). But recruitment through seed is limited with high seedling mortality as countless dead seedlings were found in soil samples on the seaward side of the dune systems along the Arabian Sea coast.

Halopyrum mucronatum employs an osmo-conformer strategy during the monsoon period and appears to use osmotic adjustment during the dry and saline periods. Sand binder species should be used (Olukoye *et al.*, 2003) to rehabilitate and stabilize sand dunes. *Halopyrum mucronatum* could be considered as a low cost self-sustaining coastal dune stabilizer.

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