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The Growth and Physiological Responses of *Paspalum vaginatum* S.W. and *Paspalum scrobiculatum* Linn. in Relation to Salinity

Olusola O. Shonubi and O.T. Okusanya
Department of Botany and Microbiology, Faculty of Science,
University of Lagos, Akoka-Yaba, Lagos, Lagos State, Nigeria

Abstract: The dominance of *Paspalum vaginatum* in mangrove swamp at the University of Lagos, Nigeria, was investigated by determining its growth and physiological responses to various salinity levels. *P. scrobiculatum* which occurs further inland was included for comparison. Uniform cuttings of each species were subjected to salinity levels of 0-400 mM NaCl using artificial seawater in one-fifth strength Hoagland solution in a glasshouse for 28 days. The results showed that *P. vaginatum* behaved like a halophyte showing enhanced growth at low salinity and tolerating high salinity with no significant decrease in water content but with significant increase in chlorophyll content as salinity increased. On the other hand, *P. scrobiculatum* behaved like a non-halophyte with decreased growth and significant reduction in water content but with significant increase in chlorophyll content as salinity increased and is incapable of tolerating high salinity. The results indicate that *P. vaginatum* tolerated salinity by regulating the amount of salt in the shoot while retaining enough water for osmotic adjustment. *P. scrobiculatum* could neither regulate salt uptake, nor retain enough water for osmotic adjustment. It was concluded that these responses may be partly responsible for the ability of the species to inhabit their different environments.

Key words: Halophytes, *Paspalum*, salinity, tolerance, growth, response

INTRODUCTION

Field observation showed that the coastal flood plain around the University of Lagos is dominated by the monocotyledon, *Paspalum vaginatum* along with other salt marsh species like *Avicenia nitida*, *Rhizophora racemosa* and *Drepanocarpus lunatus*. The marsh is inundated at high tide thus the area is highly saline. Nwanko (1984) recorded salinities up to that of sea water during the dry season. We were thus interested in finding out how *P. vaginatum* is able to dominate the saline flood plain. Further inland, *P. vaginatum* is absent but there is the abundance of a closely related species, *P. scrobiculatum*. In view of this, we decided to include *P. scrobiculatum* in the investigation for comparison. *P. vaginatum* is a troublesome weed on rice lands in Sierra Leone and it has already been identified as a good fodder grass (Stanfield, 1970). The United States Golf Association (USGA) is considering using it on golf courses that are prone to salinity (Lee *et al*., 2002).

A major factor that we decided to test was the tolerance of the species to salinity. Greenway and Munns (1980) reported that the growth of many monocotyledonous halophytes is progressively inhibited with increasing salinity unlike the dicotyledonous halophytes where growth is often optimal in the presence of about 50% sea water. However, other grasses show slight increase in growth at low salinity (Blits and Gallagher, 1991; Short and Colmer, 1999; Lee *et al*., 2002). Flowers and Yeo (1988) also elucidated the physiological basis of salt tolerance in monocotyledonous halophytes. Lee *et al*. (2005) proposed criteria for assessing tolerance in *Paspalum*.

Our aim in this study was to test how the growth of the two species is affected by various levels of salinity and to determine their physiological responses to salinity. Relatively little information is available for temperate monocotyledonous halophytes, more so for tropical halophytes. This investigation will add to the meager literature on tropical monocotyledonous halophytes.

Paspalum vaginatum S.W. is a practically hairless perennial with creeping shoots. It has erect stems with closely overlapping leaf sheaths and green to dark green leaf blades. The inflorescence has two branches at the apex of the central stalk, occasionally with one lower down. It usually colonizes new areas by producing seeds

Corresponding Author: Olushola O. Shonubi, Department of Botany and Microbiology, University of Lagos, Yaba-Lagos, Lagos State, Nigeria Tel: 0119-732-740-1647/ 011234-802-320-1342

in the rainy season but propagates vegetatively by stolons in well established stands. It can be found in southern Nigeria in states along tidal flats in the mangrove vegetation (Lowe, 1989).

Paspalum scrobiculatum Linn. is a more or less tufted, strangling perennial, approximately 60 cm high. It has variably hairy leaf blades and ribbon-like inflorescence with two to ten branches (Lowe, 1989). It is widespread and abundant throughout the wetter parts of Nigeria in moist and shady places.

MATERIALS AND METHODS

The growth response of *P. vaginatum* and *P. scrobiculatum* to salinity was tested using uniform cuttings from each species as the seeds do not germinate easily. Each cutting contained three nodes with no tillers. The cuttings were planted in acid washed sand medium in 8.8 cm diameter and 8 cm deep plastic pots. They were allowed to establish for one week during which time they were watered with one-fifth strength Hoagland's solution. (Hoagland and Arnon, 1950).

After one week, the plants were treated with saline solutions at concentrations of 0, 50, 100, 200, 300 and 400 mM NaCl. The saline solutions were prepared by mixing different proportions of Artificial Sea Water (ASW) with one-fifth strength Hoagland solution. The pH of the solutions was adjusted to 6.5 with dilute nitric acid. Each treatment had ten replicates.

The plants at high salinities were brought up to their salinities by step-wise increment of 50 mM at 2 day interval. Watering was done by dipping the sand medium in the appropriate solution for about 15 min every other day. The solutions were changed weekly and the sand medium leached weekly to prevent salinity buildup.

The experiment was carried out in 1999, in the greenhouse of the University of Sussex, England with 12 h photoperiod. The greenhouse has a photo flux of between 400 and 1000 μmoles m^{-2} sec^{-1} in the range of Photosynthetic Active Radiation (PAR). Solar lighting was from high-pressure sodium lamps (GEC Son T 400W, Complex plant care Ltd.). Daytime temperature ranged between 23 and 25°C and night temperature was between 15 and 18°C. Relative humidity was 58% during the day and 62% at night.

At the end of the experiment, total fresh weights and chlorophyll contents from sub-samples were determined, and then the roots and shoots were dried for 24 h in a fan oven (Townsend and Mercer Ltd., Croydon) at 70°C, weighed and analyzed for mineral content. Chlorophyll was estimated using the method of Arnon (1949). Water content was calculated as difference between fresh and dry weights of the plants.

Extraction in 100 mM acetic acid was used for the mineral content analysis. Mineral cations namely sodium, potassium, calcium and magnesium were estimated using a Pye Unicam Atomic Absorption Spectrophotometer model SP9 with computer attachment.

Chloride was estimated with the EIL chloride electrode used in conjunction with a vibron electrometer. The ion contents in the dead and young leaves, culms and roots of each species were determined separately.

Data obtained from dry weight values were used to calculate the Leaf Weight Ratio (LWR), Stem Weight Ratio (SWR), Root Weight Ratio (RWR) and shoot root ratio (S:R). The University of Sussex computer and statistical package Minitab were used for the analysis of the data.

RESULTS

Analysis of variance (ANOVA) of the effect of salinity on mean total dry weight showed that there was a significant effect of salinity on the growth of each species. ($p<1\%$ for *P. vaginatum* and $p<0.1\%$ for *P. scrobiculatum*). In *P. vaginatum*, there was a slight increase in dry weight (growth) up to 100 mM salinity, thereafter, there was a significant decrease as salinity increased ($p<1\%$ for 200 mM and $p<0.1\%$ for 300 mM and 400 mM). In *P. scrobiculatum*, there was a decrease in dry weight as salinity increased. Above 50 mM salinity, the decrease was significant ($p<0.1\%$) (Fig. 1).

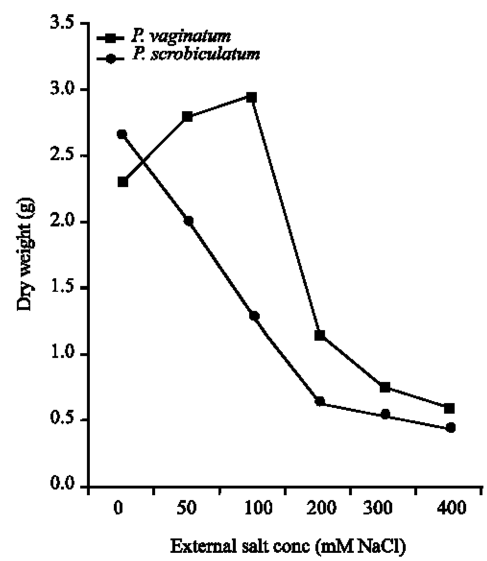

Fig. 1: The dry weight of *Paspalum vaginatum* and *P. scrobiculatum* in relation to salinity

Table 1: Effect of salinity on proportion of matter in the leaves (LWR), stem (SWR) and roots (RWR) of *Paspalum vaginatum* and *P. scrobiculatum*. Mean of ten replicates (±SE)

	Salinity (mM)					
Parameters	0	50	100	200	300	400
Leaf Weight Ratio (LWR)						
P. vaginatum	0.190±0.04	0.180±0.02	0.173±0.06	0.143±0.01	0.136±0.01	0.110±0.03
P. scrobiculatum	0.212±0.03	0.202±0.03	0.195±0.01	0.159±0.04	0.138±0.02	*
Stem Weight Ratio (SWR)						
P. vaginatum	0.629±0.01	0.618±0.03	0.601±0.02	0.535±0.01	0.524±0.04	0.520±0.05
P. scrobiculatum	0.557±0.08	0.548±0.05	0.536±0.01	0.467±0.03	0.451±0.07	0.422±0.09
Root Weight Ratio (RWR)						
P. vaginatum	0.178±0.07	0.202±0.07	0.203±0.03	0.280±0.03	0.340±0.08	0.370±0.09
P. scrobiculatum	0.231±0.03	0.240±0.05	0.263±0.02	0.373±0.05	0.411±0.05	0.547±0.09
Shoot/Root ratio (S:R)						
P. vaginatum	4.601±0.11	3.950±0.09	2.953±0.06	2.893±0.20	1.941±0.07	1.702±0.05
P. scrobiculatum	3.329±0.08	2.394±0.03	2.151±0.05	1.271±0.10	1.448±0.11	1.757±0.06

*: Leaves dead

Table 2: Effect of salinity on chlorophyll concentration, magnesium concentration and water content of *Paspalum vaginatum* and *P. scrobiculatum*

	Salinity (mM)					
Chlorophyll (mg g^{-1} f.wt.)	0	50	100	200	300	400
P. vaginatum	1.90±0.11	2.10±0.15	2.31±0.33	4.30±0.41	6.56±0.70	9.71±1.02
P. scrobiculatum	2.96±0.41	3.56±0.10	4.69±0.13	4.81±0.09	8.34±1.22	*
Magnesium concentration (mMol^{-1} g-d.wt.$^{-1}$)						
P. vaginatum	0.33±0.05	0.36±0.02	0.42±0.04	0.44±0.04	0.46±0.07	0.64±0.08
P. scrobiculatum	0.34±0.04	0.46±0.06	0.51±0.07	0.66±0.10	0.78±0.07	0.92±0.11
Water content (g g^{-1} d.wt.)						
P. vaginatum	2.68±0.33	2.64±0.32	2.57±0.13	2.55±0.12	2.15±0.19	1.80±0.013
P. scrobiculatum	2.61±0.22	2.22±0.17	2.11±0.21	1.67±0.11	0.47±0.04	*

*: Leaves dead

The proportion of dry matter in leaves, stem and roots expressed in relation to the total dry weight (LWR, SWR and RWR) are shown in Table 1. In both species, LWR decreased with increasing salinity, but *P. vaginatum* had lower values than *P. scrobiculatum* where no leaves survived at 400 mM salinity. The SWR values in both species showed a decrease with increasing salinity. The values in *P. vaginatum* were higher than in *P. scrobiculatum* at all treatments. In both species, there was a gradual increase in RWR values as salinity increased. *P. vaginatum* however had lower values than *P. scrobiculatum*. The S:R values in both species decreased as salinity increased, but with the values in *P. vaginatum* being higher than in *P. scrobiculatum* (Table 1).

Chlorophyll concentration increased with increasing salinity in both species, but *P. vaginatum* had lower values than *P. scrobiculatum* at all salinity levels. The decrease in water content as salinity increased was insignificant in *P. vaginatum* and the values were higher than in *P. scrobiculatum* where there was significant decrease as salinity increased (Table 2).

Mineral element content:

Sodium ion concentration: Analysis of variance (ANOVA) showed that there was a significant effect of salinity on sodium concentration in the whole plant of *P. vaginatum* ($p<0.1\%$) as its total concentration increased with increase in salinity. The amount found in the root was much higher than that in either the stem or the fresh leaves, but it was lower than in the shoot (stem + leaves). The amount found in the dead leaves increased with increasing salinity and is much higher than those found in the fresh green leaves (Table 3).

ANOVA showed that there was a significant effect of salinity on the sodium concentration in the whole plant of *P. scrobiculatum* ($p<0.1\%$). The accumulation of sodium in *P. scrobiculatum* followed the same pattern as that found in *P. vaginatum*, in that the concentration in the whole plant increased with increase in salinity. It is noteworthy that the total amounts in *P. scrobiculatum* at higher salinities (200-400 mM) were significantly higher than in *P. vaginatum* despite the smaller dry matter of *P. scrobiculatum* (Table 3).

The amounts of sodium ions in the roots of *P. scrobiculatum* were higher than those found in the stem, which were also higher than those found in the leaves except at 0 mM (Table 3). *P. scrobiculatum* also had a higher amount of sodium in the shoot than in the root. The amounts in the dead leaves increased with increasing salinity and were much lower than those in the fresh leaves, stem and root. Again, it is noteworthy that at virtually all salinities, *P. scrobiculatum* had higher sodium content values than *P. vaginatum*.

Table 3: Concentration of sodium and chloride ions in the plant of *Paspalum vaginatum* and *P. scrobiculatum*

	Salinity (mM)					
Ions (mMol g^{-1} d.wt.$^{-1}$)	0	50	100	200	300	400
Sodium						
P. vaginatum						
Fresh leaves	0.28	0.46	0.70	0.71	0.89	1.28
Stem	0.35	0.49	0.62	0.68	1.09	1.54
Shoot (stem+leaves)	0.63	0.95	1.32	1.39	1.98	2.82
Root	0.58	0.72	0.98	1.21	1.49	2.36
Whole plant	1.21	1.67	2.30	2.60	3.47	5.18
Dead leaves	0.50	0.70	1.48	1.50	1.58	1.73
P. scrobiculatum						
Fresh leaves	0.41	0.58	0.72	0.82	1.76	*
Stem	0.32	0.53	0.89	1.19	1.85	2.17
Shoot (stem+leaves)	0.73	1.11	1.61	2.01	3.61	3.72
Root	0.18	1.03	1.11	1.61	2.06	2.44
Whole plant	0.91	2.14	2.72	3.62	5.67	6.16
Dead leaves	0.03	0.04	0.06	0.68	1.35	1.55
Chloride						
P. vaginatum						
Fresh leaves	0.32	0.52	0.62	0.67	1.01	1.43
Stem	0.38	0.55	0.68	0.70	1.06	1.62
Shoot (stem+leaves)	0.70	1.07	1.30	1.37	2.07	3.05
Root	0.64	1.25	1.36	1.74	1.89	2.29
Whole plant	1.34	2.32	2.66	3.11	3.96	5.34
Dead leaves	0.85	1.31	1.60	1.80	1.95	2.46
P. scrobiculatum						
Fresh leaves	0.53	0.65	0.67	1.17	2.09	*
Stem	0.41	0.71	0.95	1.25	1.83	2.50
Shoot (stem+leaves)	0.94	1.36	1.62	2.42	3.92	4.90
Root	0.20	1.22	1.27	1.34	1.67	1.83
Whole plant	1.14	2.58	2.89	3.76	5.59	6.73
Dead leaves	0.04	0.56	0.66	0.84	1.50	1.80

*: Leaves dead

Chloride ion content: The total ion concentration of chloride among treatments in the whole plant of *P. vaginatum* was significantly different ($p<0.1\%$), with the values increasing as salinity increased (Table 3). Like the sodium ions, the concentration of chloride ions in the root was higher than the amount in the stem, which was also higher than that in the fresh leaves. The amounts in the dead leaves increased with increased salinity and they were higher than those in the fresh green leaves (Table 3).

There was a significant effect of salinity on chloride concentration in the whole plant of *P. scrobiculatum* ($p<0.1\%$). The amount in the whole plant and plant parts also followed the same patterns as those of sodium, increasing with increased salinity (Table 3). Its concentrations in the dead leaves were lower than those in the fresh green leaves, stem and root at all salinity levels, much like the sodium ions (Table 3).

The chloride values in the fresh leaves and stem and consequently the shoot, were higher at all salinities in *P. scrobiculatum* than in *P. vaginatum*, but the reverse was the case in the root (Table 3). Thus for the whole plant in both species, there was not much difference in the sodium and chloride ion concentrations at low salinity (0-100 mM), but at higher salinities, *P. scrobiculatum* accumulated significantly greater amount of salt than *P. vaginatum* (Table 3).

Potassium ion content: ANOVA of the data on the effect of salinity on potassium ion concentration in the whole plant of *P. vaginatum* showed that there was a significant effect between treatments ($p<5\%$). Its concentrations in the whole plant, the shoot, stem and root of *P. vaginatum* decreased as salinity increased. The values however increased in the fresh and dead leaves with increasing salinity (Table 4).

In *P. scrobiculatum*, there was also a significant effect on the amounts of potassium ion in the whole plant at each treatment ($p<0.1\%$). The concentration of potassium ion in the fresh leaves, stem, root and consequently the whole plant of *P. scrobiculatum* decreased with increasing salinity (Table 4). Its concentration in the dead leaves however increased with increasing salinity. Comparing both species, the values in *P. vaginatum* were generally higher than those in *P. scrobiculatum* at all salinities (Table 4).

Na:K: Sodium to potassium ratio increased with increasing salinity in both species. At all salinity levels, *P. scrobiculatum* had higher values than *P. vaginatum*

Table 4: Potassium ion content and Na:K ratios in the plant parts of *Paspalum vaginatum* and *P. scrobiculatum*

	Salinity (mM)					
Ions (mMol^{-1} g^{-1} d.wt.$^{-1}$)	0	50	100	200	300	400
Potassium						
P. vaginatum						
Fresh leaves	0.44	0.44	0.46	0.50	0.56	0.64
Stem	0.50	0.49	0.45	0.40	0.34	0.25
Shoot	0.94	0.93	0.91	0.90	0.90	0.89
Root	0.52	0.48	0.44	0.36	0.24	0.21
Whole plants	1.46	1.41	1.35	1.26	1.14	1.10
Dead leaves	0.25	0.28	0.34	0.47	0.50	0.61
P. scrobiculatum						
Fresh leaves	0.40	0.29	0.25	0.22	0.19	*
Stem	0.60	0.42	0.37	0.35	0.29	0.24
Shoot	1.00	0.71	0.62	0.57	0.48	0.24
Root	0.29	0.25	0.18	0.13	0.10	0.08
Whole plants	1.29	0.96	0.80	0.70	0.58	0.32
Dead leaves	0.04	0.05	0.06	0.10	0.24	0.34
Na:K ratios (in whole plant)						
P. vaginatum	0.83	1.28	1.70	2.06	3.04	4.71
P. scrobiculatum	0.71	2.23	3.40	5.17	9.78	19.25

*: Leaves dead

especially at high salinities where the values were more than double those in *P. vaginatum* (Table 4).

Magnesium ion concentration: Like the other ions, the concentrations of magnesium in the whole plants of both species were affected by salinity ($p<0.1$). Its concentrations in both species increased with increasing salinity, but the values for *P. scrobiculatum* were significantly higher than for *P. vaginatum* (Table 2).

DISCUSSION

Growth as measured by dry weight of the more extreme dicotyledonous halophytes is typically stimulated by salinity, being optimal at low to moderate concentrations (50-250 mM) of NaCl (Okusanya, 1979; Okusanya and Ungar, 1984; Short and Colmer, 1999; Debez *et al*., 2004). Some halophytes like the Atripex species (Chenopodiaceae), (Longstreth and Nobel, 1979) and *Plantago maritima* (Plantaginaceae) (Erdei and Kuiper, 1979) do not show any increase in growth in response to increasing salinity. The results of this experiment showed that *P. vaginatum* behaved like a true halophyte showing slight increase in dry weight at low salinity while *P scrobiculatum* behaved like a non-halophyte with decreased dry weight as salinity increased (Fig. 1). The presence of *P. vaginatum* in saline mangrove environment shows a relationship to its ability to grow well at low salinity and to survive at high salinity as found out in this experiment. The converse seems to be true for *P. scrobiculatum*.

For the monocotyledonous halophytes, growth is not generally stimulated by saline conditions, but if it is, the stimulation is mild. (Munns *et al*., 1983; Blits and Gallagher, 1991; Lee *et al*., 2002). This is seen to be true in this experiment for the monocotyledonous *P. vaginatum*, where there was a slight increase in growth at 50-100 mM NaCl (Fig. 1).

The better performance of *P. scrobiculatum* than *P. vaginatum* in the control set up, (0 mM) (Fig. 1) might be explained in terms of their natural habitat. Since *P. scrobiculatum* does not live naturally in saline soil as it grows further inland than *P. vaginatum*, the non-saline culture medium is a more natural condition. Unlike *P. vaginatum* which may require low salinity for maximum growth as reported for some other halophytes. (Okusanya, 1980; Flowers, 1985; Matoh *et al*., 1988; Yeo and Flowers, 1990).

In the present study, all the growth data suggested that *P. scrobiculatum* was more sensitive to salinity than *P. vaginatum*, especially at high salinities. At low salinity, *P. scrobiculatum* had less than half the dry weight of *P. vaginatum.* By the end of the experiment, the leaves of *P. scrobiculatum* were all dead at the highest salinity while those of *P. vaginatum* were still alive, albeit rolled up at the edge, a condition which promotes greater water-use efficiency in halotolerant grasses (Blits and Gallagher, 1991). This shows that *P. vaginatum* is better able to tolerate higher salinity than *P. scrobiculatum.* This is probably another reflection of their ecological habitats. The salinity of the Lagos Lagoon which floods the marsh where *P. vaginatum* grows, can reach nearly that of sea water during the dry season (Nwankwo, 1984). *P. scrobiculatum* grows further inland where there is little or no salinity.

The increased Root Weight Ratio (RWR) exhibited by both species (Table 1) is a response to salinity stress. (Okusanya, 1979; Okusanya and Ungar, 1984; Donovan and Gallagher, 1985). Increased RWR in plants results in an effort to absorb more nutrients and water. The greater RWR in *P. scrobiculatum* than in *P. vaginatum* indicated that it was under greater salinity stress.

The increased chlorophyll content with increased salinity probably indicated that both species were responding to salinity stress by increasing chlorophyll content with a view to making more matter. *P. scrobiculatum* again appears to be under greater stress by making more chlorophyll (Table 2). While the results for *P. vaginatum* agreed with those reported by Blits and Gallagher (1991), Ashraf and Bhatti (2000), Murillo-Amador *et al*. (2002) and El-Hendaw *et al*. (2005) for salt tolerant ecotypes and crops, the results for *P. scrobiculatum* were in contrast to the salt sensitive ecotypes and crops reported.

Both species appear to respond and adapt to salinity by lowering their osmotic potential through the absorption of ions. Reduction in water potential was achieved by an increase in the internal concentration of NaCl. However, a mechanism for tolerating salinity is to regulate the amount of salt uptake. Species must accumulate sufficient ions in their leaves for osmotic adjustment, while avoiding toxic effects of these ions (Gorham, 1995; Munns, 2002). Table 3 indicated that *P. scrobiculatum* accumulated more sodium and chloride ions in the shoot than *P. vaginatum*. In the root, the reverse was the case. Thus, it appears that *P. scrobiculatum* was unable to regulate salt uptake, a process that may result in build up of ions to toxic level. The death of leaves at the highest concentration in *P. scrobiculatum* and the high concentration of ions in such leaves support this assertion.

Munns (2002) and El-Hendaw *et al*. (2005) reported low sodium contents in the leaves of salt tolerant species and ecotypes. *P. vaginatum* has lower sodium content so it is able to regulate the uptake of ions into its shoot, keeping relatively large amount in the roots for osmotic adjustment. The high salt concentration in the older (dead) leaves in *P. vaginatum* (Table 3) seems to indicate that the species may also be removing excess salt through the older leaves while maintaining favorable levels in the fresh leaves. These processes make *P. vaginatum* a more salt tolerant species than *P. scrobiculatum* and it can thrive well in the saline environment. Munns (2002) concluded that most glycophytes have a poor ability to exclude salt and it concentrates to toxic levels in the transpiring leaves.

In some halophytes, ions principally sodium and chloride, can amount to between 30 and 50% of dry weight generating Na:K ratios in excess of 10. (Flowers *et al*., 1986). Higher Na:K ratios were observed in *P. scrobiculatum* than *P. vaginatum* (Table 4). This is an indication of sodium stress which further confirmed that *P. scrobiculatum* was unable to restrict the entry of sodium thus making it a non-halophyte. Hannon and Barber (1972), Flowers and Yeo (1988) and Al-Karaki (2000) observed low Na:K ratios in other halophytic grasses as was observed in *P. vaginatum*. The result is also in line with Albert and Kinzel (1973) concept of physiotypes in grasses and related groups with respect to salt tolerance. They reported that such physiotypes utilize potassium and sugar for osmotic adjustment, thus they have high concentration of potassium ion and low concentration of sodium ion resulting in low Na:K ratio as in *P. vaginatum* (Table 3, 4).

The consistently lower values for the accumulated ions in *P. vaginatum* than in *P. scrobiculatum* (Table 3) agrees with the observations that halotolerant ecotypes of Juncus and Festuca accumulated less NaCl than did the salt sensitive ecotypes (Rozema, 1976; Rozema *et al*., 1978). The more salt-tolerant *Agrostis stolonifera* and *Festuca rubra* from salt marshes had lower sodium contents than their less salt tolerant counterparts from non-saline areas (Tiku and Snaydon, 1971). The exclusion of harmful ions from the shoots contributes to salt tolerance (Munns, 1993).

As a component of chlorophyll, the increased magnesium concentration as salinity increased in both species (Table 3) correlates well with the increased concentration in chlorophyll. The higher values in *P. scrobiculatum* than in *P. vaginatum* may be a response to greater salinity stress. This result is in contrast to other results (Glenn *et al*., 1996; Khan *et al*., 2000; Debez *et al*., 2004) but it showed that the species may not be under magnesium deficiency.

The insignificant decrease in water content as salinity increased and the higher water content in *P. vaginatum* is probably another reason that makes it more salt tolerant than *P. scrobiculatum* since it would have more water to dilute the relatively low level content of absorbed ions in its shoot, thus keeping osmotic concentration to tolerable level. Debez *et al*. (2004) also reported no significant effect of salinity on leaf hydration but a significant increase in leaf succulence. These two processes may enhance better salt tolerance in *P. vaginatum*.

In conclusion, *P. vaginatum* is tolerant of salinity adopting a variety of methods including increased osmotic potential, keeping adequate water content in the shoot and regulating the amount of salt in the shoot. Other methods may include the ability to take up potassium and the removal of excess salt through the old leaves. Thus its halophytic nature may partly account for its dominance of the coastal saline mangrove around the University of Lagos and similar habitat. On the other hand, *P. scrobiculatum* behaved like a non-halophyte being intolerant of salinity largely because it cannot regulate the amount of salt in its shoot. It thus inhabits non-saline areas further inland from the mangrove. The results of other experiments will be published later.

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