Influence of Sea Sprays on Growth and Visual Quality of Seashore Paspalum (*Paspalum vaginatum* O. Swartz) use in Beach Landscaping

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Abstract Growth and visual quality of *Paspalum vaginatum* O. Swartz were examined, to determine its responses to various levels of air-borne salinity and to have an insight in the ecophysiological adaptations underlying the responses. Potted plants were sprayed with air-borne seawater at: two sprays per week (2SS), four sprays per week (4SS) or six sprays per week (6SS), which equaled on average 4 mg, 8 mg and 12 mg NaCl dm⁻² leaf area day⁻¹ respectively. The control (CSS) plants were sprayed with deionized water. Plants responded to sea spray by leaf folding and no mortality occurred. Except stem girth that increased, growth parameters decreased with increasing seawater application level, but leaf width, root number and root length were not affected. It significantly decreased fresh and dry mass of aerial parts, total biomass and leaf total chlorophyll. It also induced leaf and stem succulence and decreased plant xylem water potential. It caused nutrient imbalance by accumulating Na⁺ and Cl⁻ ions but lowered Ca²⁺, Mg²⁺, K⁺ and Fe²⁺ in the aerial parts. Na: K ratio and N were significantly higher in leaf and stem of salt-treated plants than in control. It increased total nutrient and percentage ash, contributed mainly by Na⁺ and Cl⁻ ions, but decreased organic content in leaf and stem. Generally, roots were not affected by salt spray. Air-borne salt significantly increased necrotic leaf area but did not significantly affect plant visual ratings. The implications of the results on the growth and use of seashore paspalum for beach landscaping are discussed.

Keywords Salt spray; Growth; Visual quality; Ecophysiology; Seashore paspalum

Introduction *Paspalum vaginatum* O. Swartz (seashore paspalum) belongs to the family Poeceae. It grows along the coastline as strand vegetation in many tropical and subtropical areas of the world. It is a perennial creeping grass that is stoloniferous and rhizomatous. It forms a thick mat of growth and has dark-green leaves with shiny waxy leaf coat (Zinn, 2004). It is ecologically important in shoreline stabilization, erosion control and serves as fodder for livestock. It is used in numerous golf courses greens, tees, fairways and roughs. It is salt-tolerant, which informs its increasingly use in coastal sites where flooding and salt water intrusion are prevalent. Most research in seashore paspalum has been limited to examinations of tolerance to soil salinity, which has been widely documented (Bernstein et al., 1972; Harivandi, 1984; Dudeck and Peacock, 1985; Lee et al., 2002; Zinn, 2004; Lee et al., 2004; Lee et al., 2005). Little if any information specific to seashore paspalum and salt sprays related growth and quality exists in the scientific literature. Where public information exists, such was based on mere observations that are largely devoid of quantitative assessment (Environmental Turf, 2006). Unlike the salt marsh, where plant species are exposed to tidal inundation and thus to high salinity (Flowers & Colmer, 2008; De Vos et al., 2010), the beach is out of reach of mean high tide and only rarely flooded with seawater. Thus, salt exposure at the beach is mainly composed of salt sprays (Boyce, 1954; Rozema et al., 1985; Griffiths et al., 2006; Griffiths, 2006; De Vos et al., 2010). It is well documented that sea spray is an important natural selective abiotic factor on coastal plant communities (Boyce, 1954; Barbour et al., 1985; Rozema et al., 1985; De Vos et al., 2010) and plants are often more sensitive to saline spray than to salt applied at the root zone (Grattan et al., 1981; Elhaak et al., 1997).

Salt spray is formed by seawater droplets breaking in the zone of heavy surf and the small droplets are blown landward by wind (Boyce, 1954). The salts may enter the aerial organs of the plants, especially where small surface injuries are present (Boyce, 1954). In this way, it can disrupt the water balance of plants and cause necrosis or loss of leaves, resulting in
growth reduction (Sykes and Wilson, 1988; Tominaga and Ueki, 1991). Salt spray has been widely reported to reduce growth in many coastal plants (Cheplick and Demetri, 1999; Morant-Manceau et al., 2004; Scheiber et al., 2008). However, species growing in the vicinity of the tide line have adapted to salt spray in various ways (Rozema et al., 1985; De Vos et al., 2010). For example, increased succulence in the presence of salt is an adaptive mechanism for ion dilution (Debez et al., 2004). Salt spray disrupts plant water balance (Munns, 1993; Touchette et al., 2009) but tolerant plants can adjust osmotically to water stress through reduction in water potential (Griffiths & Orians, 2003; Griffiths, 2006; Touchette et al., 2009).

Griffiths & Orians (2003) reported that *Myrica pensylvanica* showed high resistance to necrotic damage caused by salt spray and attributed it to thick cuticle on leaf surface that limits salt entry. Reduction in leaf area brings about a decrease in the surface available for salt deposition and water loss through transpiration, which are strategies to cope with water stress (Morant-Manceau et al., 2004).

Landscaping and gardening projects in coastal regions have called for selection of plants that have the ability to cope with seawater sprays, considering the high level of the death of sea side horticultural plants (Scheiber et al., 2008; Conolly et al., 2010). However, landscape value is largely determined by the physical appearance of individual plants, and plants showing significant necrotic damage due to salt stress are inherently of less value than plants without such damage, regardless of the concentration of ions causing the necrosis (Conolly et al., 2010). With this in mind, a pot experiment was conducted in 2013 to investigate tolerance of seashore paspalum to sea spray at Adekunle Ajasin University, Akungba Akoko, Ondo State Nigeria (Lat. 7° N 28', Long. 5° 44' E). The objectives of this research are to (1) quantitavely determine the growth of seashore paspalum under sea water spray treatments, to have an insight in the ecophysiological adaptations underlying the responses and (2) to determine if the quality of seashore paspalum sprayed at different levels with seawater would be affected. This will provide researchers and end users with basic information regarding how tolerant *P. vaginatum* is to sea sprays and the underlying adaptive fissures.

1 Results

The morphological change observed in the plants under salt sprays was folding of leaves. All plants survived under salt spray but growth was inhibited (Table 1). With the exception of stem girth that increased under sea spray relative to the control, other growth parameters decreased with increase in salt spray level. Leaf width, root number and root length were however not affected by sea spray.

### Table 1: Percentage survival and some growth parameters of *Paspalum vaginatum* after 12 weeks of exposure to different levels of salt spray

<table>
<thead>
<tr>
<th>Level of salt spray (%)</th>
<th>Survival (%)</th>
<th>Stem girth (cm)</th>
<th>Number of leaves plant⁻¹</th>
<th>Number of branches plant⁻¹</th>
<th>Shoot length (cm)</th>
<th>Number of nodes plant⁻¹</th>
<th>Internode length (cm)</th>
<th>Leaf length (cm)</th>
<th>Leaf area (cm²)</th>
<th>Root length (cm)</th>
<th>Number of Roots plant⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS 100.00</td>
<td>100.00</td>
<td>1.71</td>
<td>48.25a</td>
<td>8.50a</td>
<td>66.78a</td>
<td>13.00a</td>
<td>4.13a</td>
<td>19.63a</td>
<td>0.58a</td>
<td>33.34a</td>
<td>14.04a</td>
</tr>
<tr>
<td>2SS 100.00</td>
<td>100.00</td>
<td>2.46b</td>
<td>31.50b</td>
<td>6.25b</td>
<td>54.26b</td>
<td>8.50b</td>
<td>2.58b</td>
<td>19.43b</td>
<td>0.48b</td>
<td>20.23b</td>
<td>16.20a</td>
</tr>
<tr>
<td>4SS 100.00</td>
<td>100.00</td>
<td>2.52b</td>
<td>13.75b</td>
<td>3.00b</td>
<td>45.10b</td>
<td>9.75b</td>
<td>2.78b</td>
<td>17.83b</td>
<td>0.47b</td>
<td>16.41b</td>
<td>13.14a</td>
</tr>
<tr>
<td>6SS 100.00</td>
<td>100.00</td>
<td>2.23b</td>
<td>9.75b</td>
<td>2.25b</td>
<td>25.67b</td>
<td>8.50b</td>
<td>2.70b</td>
<td>7.78b</td>
<td>0.48b</td>
<td>16.24b</td>
<td>13.75a</td>
</tr>
</tbody>
</table>

Note: Each value is a mean of 6 replicates; For each parameter, means with the same letter(s) in superscript in the same column are not significantly different at P>0.05 (Tukey HSD); CSS=deionized water sprays (control), 2SS=two salt sprays per week, 4SS = four salt sprays per week, 6SS=six salt sprays per week

Stems, leaves and shoot fresh mass decreased significantly in seawater-sprayed plants compared to the control (Table 2). Root fresh and dry mass values in plants under salt spray did not differ significantly from that of control. Total biomass, relative growth rate and leaf total chlorophyll (LTC) in plants exposed to salt spray were significantly lower than in plants sprayed with de-ionized water (Table 2).

Sea sprays induced leaf and stem succulence in the test plant (Table 3). When compared to the control, percentage moisture content increase was not significant for leaf but for stem while air-borne salt did not affect root moisture content. Plant xylem water potential was...
### Table 2: Fresh and dry mass, root: shoot ratio, relative growth rate (RGR) and leaf total chlorophyll (LTC) of *Paspalum vaginatum* after 12 weeks of exposure to different levels of salt spray

<table>
<thead>
<tr>
<th>Salt spray level</th>
<th>Leaf fresh mass (g)</th>
<th>Stem fresh mass (g)</th>
<th>Root fresh mass (g)</th>
<th>Shoot fresh mass (g)</th>
<th>Leaf dry mass (g)</th>
<th>Stem dry mass (g)</th>
<th>Root dry mass (g)</th>
<th>Shoot dry mass (g)</th>
<th>Total biomass (g)</th>
<th>Root: shoot RGR (gg⁻¹d⁻¹)</th>
<th>LTC (mg/g fresh leaves)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS</td>
<td>16.12a</td>
<td>27.93a</td>
<td>16.73a</td>
<td>44.05a</td>
<td>10.62a</td>
<td>16.42a</td>
<td>9.56a</td>
<td>27.05a</td>
<td>36.60a</td>
<td>0.35b</td>
<td>0.0392a</td>
</tr>
<tr>
<td>2SS</td>
<td>12.81b</td>
<td>15.89b</td>
<td>15.67a</td>
<td>28.70a</td>
<td>7.93b</td>
<td>8.56b</td>
<td>8.97a</td>
<td>16.49b</td>
<td>25.46b</td>
<td>0.54b</td>
<td>0.0301b</td>
</tr>
<tr>
<td>4SS</td>
<td>12.22b</td>
<td>13.25b</td>
<td>15.62a</td>
<td>25.47b</td>
<td>7.56b</td>
<td>7.03b</td>
<td>9.07a</td>
<td>14.69b</td>
<td>23.67b</td>
<td>0.62b</td>
<td>0.0232b</td>
</tr>
<tr>
<td>6SS</td>
<td>11.19b</td>
<td>12.08b</td>
<td>15.63a</td>
<td>23.27b</td>
<td>6.96b</td>
<td>6.35b</td>
<td>9.09b</td>
<td>13.32b</td>
<td>22.40b</td>
<td>0.68b</td>
<td>0.0219b</td>
</tr>
</tbody>
</table>

Note: Each value is a mean of 6 replicates; For each parameter, means with the same letter(s) in superscript in the same column are not significantly different at P ≥0.05 (Tukey HSD); LTC=leaf total chlorophyll, CSS=deionized water sprays (control), 2SS=two salt sprays per week, 4SS=four salt sprays per week, 6SS=six salt sprays per week

### Table 3: Water status of *Paspalum vaginatum* after 12 weeks of exposure to different levels of salt spray

<table>
<thead>
<tr>
<th>Salt spray level</th>
<th>Leaf moisture content (%)</th>
<th>Stem moisture content (%)</th>
<th>Root moisture content (%)</th>
<th>Pre-dawn water potential (-MPa)</th>
<th>Mid-day water potential (-MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS</td>
<td>35.73a</td>
<td>41.22a</td>
<td>42.87a</td>
<td>2.21d</td>
<td>2.98a</td>
</tr>
<tr>
<td>2SS</td>
<td>38.13a</td>
<td>46.12b</td>
<td>42.74a</td>
<td>4.13c</td>
<td>5.00b</td>
</tr>
<tr>
<td>4SS</td>
<td>38.13a</td>
<td>46.93b</td>
<td>41.91a</td>
<td>4.32b</td>
<td>5.80b</td>
</tr>
<tr>
<td>6SS</td>
<td>37.78a</td>
<td>46.41b</td>
<td>41.86a</td>
<td>4.08a</td>
<td>6.00a</td>
</tr>
</tbody>
</table>

Note: Each value is a mean of 6 replicates; For each parameter, means with the same letter(s) in superscript in the same column are not significantly different at P ≥0.05 (Tukey HSD); CSS=deionized water sprays (control), 2SS=two salt sprays per week, 4SS=four salt sprays per week, 6SS=six salt sprays per week

lower under seawater-sprayed plants than did control plants, and they significantly differed from each other as the spraying level increased (Table 3). The mid-day values were slightly lower than those of the predawn.

Air-borne salinity decreased Ca²⁺, Mg²⁺, K⁺ and Fe²⁺ in the aerial parts of test plants (Table 4). In comparison to the control, the reduction was significantly different except Mg²⁺ and Fe²⁺ in the leaf. Plant sprayed with seawater had significantly higher nitrogen content in leaf and stem than in those sprayed with de-ionized water. Salt spray resulted in a significant accumulation of Na⁺ and Cl⁻ in the leaf and stem of the test plant, as the application level increased. In addition, there was a significantly higher total nutrient and percentage ash content in the leaf and stem of sea-sprayed plants than in control (Table 4).

### Table 4: Effect of salt spray on nutrient content (mmol/g dry weight) and ash content (% dry weight) of the leaf, stem and root of *Paspalum vaginatum* after 12 weeks of exposure to salt spray

<table>
<thead>
<tr>
<th>Plant part</th>
<th>Salt spray level</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Cl⁻</th>
<th>Fe²⁺</th>
<th>N</th>
<th>Total</th>
<th>Na: K</th>
<th>Ash (%)</th>
<th>Organic (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf</td>
<td>CSS</td>
<td>0.91a</td>
<td>0.37a</td>
<td>0.02d</td>
<td>0.96d</td>
<td>0.14d</td>
<td>0.42d</td>
<td>3.43b</td>
<td>6.25b</td>
<td>0.02c</td>
<td>7.61b</td>
<td>92.84b</td>
</tr>
<tr>
<td></td>
<td>2SS</td>
<td>0.86a</td>
<td>0.33a</td>
<td>11.03b</td>
<td>0.89d</td>
<td>5.86d</td>
<td>0.36ab</td>
<td>5.17a</td>
<td>24.5b</td>
<td>12.39b</td>
<td>13.41ab</td>
<td>86.46b</td>
</tr>
<tr>
<td></td>
<td>4SS</td>
<td>0.65a</td>
<td>0.31ab</td>
<td>21.03b</td>
<td>0.81a</td>
<td>10.84b</td>
<td>0.27ab</td>
<td>5.87a</td>
<td>39.78b</td>
<td>25.96b</td>
<td>19.62b</td>
<td>80.26b</td>
</tr>
<tr>
<td></td>
<td>6SS</td>
<td>0.65a</td>
<td>0.22d</td>
<td>34.04b</td>
<td>0.86d</td>
<td>17.35a</td>
<td>0.21b</td>
<td>5.81a</td>
<td>59.14a</td>
<td>39.58b</td>
<td>21.65a</td>
<td>78.35b</td>
</tr>
<tr>
<td>Stem</td>
<td>CSS</td>
<td>0.88a</td>
<td>0.35a</td>
<td>0.14d</td>
<td>0.92a</td>
<td>0.14d</td>
<td>0.19a</td>
<td>1.59b</td>
<td>4.21c</td>
<td>0.15c</td>
<td>6.93c</td>
<td>93.05a</td>
</tr>
<tr>
<td></td>
<td>2SS</td>
<td>0.81a</td>
<td>0.32b</td>
<td>8.29a</td>
<td>0.87a</td>
<td>4.21c</td>
<td>0.15a</td>
<td>4.79b</td>
<td>19.44b</td>
<td>9.53b</td>
<td>11.92ab</td>
<td>86.11b</td>
</tr>
<tr>
<td></td>
<td>4SS</td>
<td>0.61a</td>
<td>0.29b</td>
<td>16.01b</td>
<td>0.79a</td>
<td>8.28b</td>
<td>0.14a</td>
<td>4.81b</td>
<td>30.93ab</td>
<td>20.27a</td>
<td>17.66a</td>
<td>82.42b</td>
</tr>
<tr>
<td></td>
<td>6SS</td>
<td>0.63a</td>
<td>0.24b</td>
<td>29.08b</td>
<td>0.84a</td>
<td>15.28a</td>
<td>0.15a</td>
<td>4.69b</td>
<td>40.91a</td>
<td>22.71a</td>
<td>20.95b</td>
<td>79.07b</td>
</tr>
<tr>
<td>Root</td>
<td>CSS</td>
<td>0.69a</td>
<td>0.25a</td>
<td>0.05a</td>
<td>0.88a</td>
<td>0.24a</td>
<td>0.74a</td>
<td>1.55a</td>
<td>4.39a</td>
<td>0.08a</td>
<td>5.74a</td>
<td>94.18b</td>
</tr>
<tr>
<td></td>
<td>2SS</td>
<td>0.66a</td>
<td>0.32a</td>
<td>0.09a</td>
<td>0.83a</td>
<td>0.28a</td>
<td>0.72a</td>
<td>1.73a</td>
<td>4.63a</td>
<td>0.11a</td>
<td>6.14a</td>
<td>93.32b</td>
</tr>
<tr>
<td></td>
<td>4SS</td>
<td>0.87a</td>
<td>0.35a</td>
<td>0.01a</td>
<td>0.90a</td>
<td>0.35a</td>
<td>0.75a</td>
<td>1.56a</td>
<td>4.791a</td>
<td>0.10a</td>
<td>6.31a</td>
<td>93.71b</td>
</tr>
<tr>
<td></td>
<td>6SS</td>
<td>0.93a</td>
<td>0.38a</td>
<td>0.41a</td>
<td>0.99a</td>
<td>0.42a</td>
<td>0.74a</td>
<td>1.64a</td>
<td>5.51a</td>
<td>0.10a</td>
<td>6.25a</td>
<td>93.69b</td>
</tr>
</tbody>
</table>

Note: Each value is a mean of 3 replicates; For each plant part and variable, means with the same letter(s) in superscript in the same column are not significantly different at P ≥0.05 (Tukey HSD); CSS=deionized water sprays (control), 2SS=two salt sprays per week, 4SS=four salt sprays per week, 6SS=six salt sprays per week
The percentage organic content however decreased with increase in the level of salt spray in leaf and stem. Na: K ratio values were significantly higher in leaf and stem of plants sprayed with seawater than in those sprayed with de-ionized water. Though, Na+ and Cl− increased slightly in the root of plants under salt spray, root nutrient content was generally not affected. As compared to the control treatment, salt spray led to a significant increase in the necrotic leaf area with increasing level of application (Table 5). It also resulted in a decline in the visual rating of the plant but ANOVA test showed that the reduction was not significant at all levels of sea spray in comparison to the control.

Table 5 Some anatomical parameters measured on the leaf of Paspalum vaginatum after 12 weeks of exposure to salt spray

<table>
<thead>
<tr>
<th>Level of salt spray</th>
<th>Necrotic leaf area (%)</th>
<th>Visual ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS</td>
<td>5.74b</td>
<td>5.00a</td>
</tr>
<tr>
<td>2SS</td>
<td>15.13b</td>
<td>4.68a</td>
</tr>
<tr>
<td>4SS</td>
<td>15.32b</td>
<td>4.49a</td>
</tr>
<tr>
<td>6SS</td>
<td>16.95b</td>
<td>3.85ab</td>
</tr>
</tbody>
</table>

Note: Each value is a mean of 6 replicates; Means with the same letter(s) in superscript in the same column are not significantly different at P ≥0.05 (Tukey HSD); CSS=deionized water sprays (control), 2SS=two salt sprays per week, 4SS=four salt sprays per week, 6SS=six salt sprays per week. Visual ratings scale: 1=no green foliage, 2=25% green foliage, 3=50% green foliage, 4=75% green foliage and 5=all green foliage

2 Discussion

The ratio 2:1 river sand to top soil is a sandy soil with low nutrient content typical of beach soil (Cheplick and Demetri, 1999; Khan et al., 2000). Beach plants grow naturally in very sandy soil that tends to be nutrient deficient, and because the soil is porous, leaching rate is high and salt does not accumulate in the root zone (Griffiths and Orians, 2003). The observed effect on the plant was not due to nutrient unavailability but salt spray, because no growth defect was observed in the control plants. Leaf folding in P. vaginatum is an adaptation to reduce salt deposition on leaf surface and minimize water loss through transpiration. Besides, shiny waxy leaf surface of some seashore grasses makes them not completely wettable, resulting in the beading of droplets on the leaf surface and reduce entrance of harmful chlorides (Alshammary et al., 2004; hunter and Wu, 2005). P. vaginatum was tolerant to salt spray because of its high survivorship at all levels of application. Similarly, Gagne and Houle (2002) recorded 100% survival in Leymus mollis sprayed with seawater. Salt spray tolerant plants occupy sea-side while sensitive species are eliminated and are found inland far away from the beach (Scheiber et al., 2008). Growth reduction in P. vaginatum sprayed with seawater agrees with what was reported on Leymus mollis (Gagne and Houle, 2002) and Myrica pensylvanica (Griffiths and Orians, 2003). Decreased stem length was affected by reduction in internode length. In earlier studies, shoot elongation as well as production of branches and leaves were observed to reduce in Miscanthus sinensis and Pennisetum alopecuroides (Scheiber et al., 2008), Crambe maritima (De Vos et al., 2010), Diodia maritima (Kekere and Bamidele, 2012), Commelina erecta var. maritima (Kekere et al., 2014) and Kyliliga peruviana (Kekere, 2014b). Interestingly, reduced plant size was assumed to be mechanism through which the characteristic dwarf stature of strand vegetation is maintained (Lee and Ignaciuk, 1985). This means that the reduction in the size of the test plant might be an adaptation to maintain the plant in an environment where salt spray is prevalent. Leaf number was also reported to reduce in Pinus rigida (Griffiths and Orians, 2004), Crambe maritima (De Vos et al., 2010), Diodia maritima (Kekere and Bamidele, 2012) and Commelina erecta subsp maritima (Kekere, 2014a) following exposure to salt sprays. Reduced leaf size was due to inhibition of leaf expansion and hence reduction of light interception (De Vos et al., 2010). However, reduction in P. vaginatum leaf size might be an adaptive fissure to cope with salt spray related damage. Reduced leaf size decreases the surface area available for salt deposition and loss of water through transpiration (Morant-Manceau et al., 2004). Reduction in total leaf chlorophyll was largely due to damage induced by salt. It might be caused by Na+ and Cl− ions toxicity leading to necrosis on the leaf surface. Necrotic spots on leaf resulted in a decrease in total photosynthesis and carbohydrate stored in the plant (Touchette, 2009). Application of NaCl to plant foliage induced fragmented cuticles, disrupted stomata, collapsed cell walls, coarsely granulated cytoplasm, disintegrated chloroplasts and nuclei, and disorganized phloem (Touchette, 2009). Besides, certain elements are important for normal growth and are part of chlorophyll ultrastructure. When such nutrients are limited, chlorophyll formation will be inhibited (Touchette, 2009). Similar
to the results obtained in this study, *Scaevola sericea* seedlings had reduced stem mass, leaf mass, shoot mass and total biomass with increasing level of sea spray (Goldstein et al., 1996). Reduction in growth parameters led to biomass reduction. Leaf and stem succulence increase by salt spray in *P. vaginatum* agrees with the study on *Crambe maritima* (De Vos et al., 2010), which is an adaptation for ion dilution (Rozema et al., 1985). Salt-tolerant plants reduce their xylem water potential as an adaptation against osmotic stress (Touchette, 2009). In an earlier study, there was a significant reduction in xylem water potential in *Solidago puberula*, *Solidago rugosa*, *Gaylussacia baccata*, *Myrica pensylvanica*, *Pinus rigida* and *Quercus ilicifolia* by salt sprays, indicating that salt spray caused water stress and might be inhibiting physiological processes in the plant (Griffiths and Orians, 2003). Na+ and Cl− ions accumulation as well as reduction in certain nutrients in the shoot indicated that high concentrations of seawater can influence ion distribution, so that they can contribute to the osmotic potential, and thereby increase the protection against osmotic stress (Touchette, 2009). Nitrogen increase in shoot was probably as a result of its use in the synthesis of specific N compounds such as amino acids (proline and aspartic acids), amides (glutamine and asparagine) and the stress-related proteins, which help in reduction of osmotic stress (Ashraf and Harris, 2004). Na+ accumulation on shoot is usually associated to salt spray, which interferes with the function of potassium as a cofactor in various reactions (Al-Karaki, 2000). They further stated that the K+ deficiency of salinized plants was inversely correlated to the increased accumulation of Na+, indicating the existence of competition effects between Na+ and K+ ions which most likely share the same transport system at the root surface. Not only Na+ and K+ contents, but also the Na: K ratio can be used as phyto-physiological parameters for screening less sensitive plants for NaCl stress (Al-Karaki, 2000). A high Na: K ratio indicates metabolic disorders such as a reduction in protein synthesis and enzyme activities and an increase in membrane permeability (Al–Karaki, 2000).

Lower visual ratings in plants sprayed with seawater are usually caused by salt damage on leaf. Salt spray led to chlorosis and necrotic damage of the leaves of *Miscanthus sinensis* and *Pennisetum alopecuroides* (Scheiber et al., 2008) thereby reducing its aesthetic value. However, high visual ratings recorded in *Kyllinga peruviana* (Kekere, 2014b) and *Alternanthera maritima* (Kekere, 2014c) under salt spray informed their recommendation for beach landscaping.

3 Conclusion

This study revealed that salt spray is an important factor that affects the growth of seashore paspalum (*Paspalum vaginatum*) in the coastline. Although, its growth was reduced by salt spray, it is a salt spray tolerant plant and has developed some adaptations for growth along the seashore. It folded its leaves and decreased the leaf size to reduce the surface area available for salt deposition and minimize water loss through transpiration. The shiny waxy leaf surface made it to reduce entry of salt. It adjusted osmotically to salt stress by accumulating Na+ and Cl− ions, and likely produced quaternary amino compounds in the shoot, evident by increased nitrogen level. It adjusted to water stress through reduction of xylem water potential. It increased leaf and stem succulence, which are adaptations for ion toxicity reduction through dilution. *P. vaginatum* is a good landscape plant in coastal beaches not only because it is tolerant to salt spray, but also as a result of its high aesthetic value, as determined by good visual ratings of the plant under different levels of salt spray. Besides, since landscape value largely determined by the physical appearance of individual plants, this research has revealed that the growth of *P. vaginatum* and its ability to maintain high aesthetic value under salt spray are largely responsible for its use as a landscaping plant in coastal beaches. It is therefore important to consider tolerance to salt spray in the selection of plants for landscaping projects in coastal beaches. These findings are important to the end users, ornamental growers, landscapers and residents of coastal communities.

4 Materials and Method

4.1 Pot preparation and experimental set up

Freshly rhizomes with 2 vegetative nodes of *P. vaginatum* were collected at Lekki Beach in Lagos Nigeria. They were immediately planted in 20×26 cm perforated plastic pots filled with 2:1 mixture (v/v) of river sand to topsoil (Cheplick and Demetri, 1999; Khan et al., 2000). Plastic pots were initially kept in shady, moist conditions to stabilize and later transferred and placed on the Greenhouse bench of Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba Akoko, Ondo State,
Nigeria (Lat. 7° N 28°, Long. 5° 44' E). The soil had 5.48 pH, 20.42 ppm N, 3.56 ppm P, 3.56 (meg/100 g) K, 2.32 (meg/100 g) Ca, 2.60 (meg/100 g) Mg, 8.2 (meg/100g) CEC, 3.67% C, 80.68% sand, 12.06% silt and 8.36% clay (Kekere, 2014a, 2014b). It is typical of a beach soil which is sandy and low in nutrient content, and because the soil is porous, leaching rate is high and salt does not accumulate in the root zone (Griffiths and Orians, 2003).

Air-borne seawater collected off the shore at Lekki Beach in Lagos Nigeria on a single day in late September 2013 was used. The seawater was collected by the conventional method of arranging salt spray collectors parallel to the coastline at about 10 m from mean seawater level (mean tide line). The salt spray collector was made up of polypropylene filter gauze wrapped over a 30 cm long plastic tube placed vertically in a beaker. The collectors were fixed on the ground with about 20 cm of the upper part exposed. The beaker was to collect precipitation and prevent loss of trapped water (Griffiths and Orians, 2003; De Vos et al., 2010; Conolly et al., 2010). The seawater was stored in plastic jug and kept in a refrigerator at 4°C and used for the duration of the experiment. It had salinity of 31 ppt, with sodium and chloride accounting for approximately 86% of the ions present. Spray treatments began on 30 September 2013 and lasted for 12 weeks. Plants were sprayed twice/week (6SS)-3 sprays on each of the two days, 4 sprays/week (4SS)-2 sprays on each of the two days or 2 sprays/week (2SS)-1 spray on each of the two days), 4 (on Mondays and Thursdays) with seawater at: de-ionized water, and the conductivity increase was also recorded after the same shoot was sprayed twice and three times respectively following immersion in 150 ml of de-ionized water. This was repeated for all the 5 plants. Salt deposition was estimated per leaf area surface for each of the three seawater treatments at each application. The accumulated salt onto shoot for 1 spray, 2 sprays and 3 sprays equaled on average 4 mg, 8 mg and 12 mg NaCl dm-2 leaf area day-1, which fall within the levels found in the natural habitat of beach plants (Barbour et al., 1985; Griffiths, 2006). Before each salt spray treatment, plastic discs were placed over the soil surface and around the base of each plant to prevent salt deposition on the soil. Also, plants were watered from the top of the soil surface at the base of the plants once per week to flush out any salts that might have been deposited onto the soil during misting, which did not remove the salts deposited onto the shoots. This was to ensure that the relative level of airborne salt deposited onto the shoots would be the primary cause of any observed effect rather than soil salinity or combined effect of both soil salinity and sea spray (Rozema et al., 1982; Cheplick & Demetri, 1999; Griffiths, 2006). Salt spray was allowed to accumulate throughout the experiment, which is realistic in the field because in years with infrequent rain, salt spray is not washed off during the summer growing season (Cheplick and Demetri, 1999; Cheplick and White, 2002).

4.2 Survival and growth measurement
At the end of the study, plant survival was recorded while plant height, leaf area and stem girth were measured with meter rule, leaf area meter (LI-COR 300 model) and digital vernier caliper (model 0~200 mm) respectively. The number of leaves and branches were counted. Number of roots was counted while their length measured after harvest. Fresh and dry mass of plant parts were weighed, while root: shoot ratio and relative growth rate (RGR) were calculated using the commonly used formulae: root mass/shoot mass and (ln mass2-ln mass1)/ time respectively.

4.3 Determination of water status
Moisture content and xylem water potential were the two aspects of water status determined. Moisture content was calculated with the commonly used formula: [(fresh mass– dry mass)/dry mass] x 100 while plant xylem water potential was measured with a plant moisture-stress instrument (PMS Instrument...
4.6 Statistical analysis

Statistical analysis was performed using the IBM SPSS software (SPSS Inc., Chicago, IL, USA) at P<0.05. The analysis included the application of an analysis of variance (ANOVA) followed by a post hoc comparison using the Tukey’s Honest Significant Difference (HSD) test using SPSS version 17.0. The means were separated with Tukey Honest Significant Difference (HSD) test using SPSS version 17.0.

4.4 Leaf chlorophyll and mineral content determination

Leaf total chlorophyll was extracted with 80% acetone following the method of Arnon (1949) and calculated with the formula: \((20.2 \times D_{645} + 8.02 \times D_{663}) \times (100/500) \times \frac{1}{2}\), where \(D\) = absorbance. Soil physochemical parameters and plant nutrient content were assayed following the standard methods of the Association of Official Analytical Chemists (AOAC, 1985) in the Central Laboratory of The National Institute for Oil Palm Research (NIFOR), Nigeria.

4.5 Necrosis and visual ratings determination

Necrotic damage was estimated on the leaves used for the determination of moisture content following the method described by Hwang & Chen (1995). The area of leaf tissue with necrotic damage was measured using a dot grid and expressed as the percentage of total leaf area showing necrosis (Griffiths & Orians, 2003; Griffiths et al., 2006). Visual ratings were conducted by six observers based on foliage appearance, with 1 = no green foliage, 2 = 25% green foliage, 3 = 50% green foliage, 4 = 75% green foliage and 5 = all green foliage (Scheiber et al., 2008). Although quality standards differ, researchers deem ratings of 1 and 2 as unacceptable, 3 as marginally acceptable, and ratings of 4 and 5 as acceptable in most professionally maintained landscape situations (Scheiber et al., 2008).

4.6 Statistical analysis

Data were subjected to single factor ANOVA and means were separated with Tukey Honest Significant Difference (HSD) test using SPSS version 17.0 software (SPSS Inc., Chicago, IL, USA) at P<0.05.

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