Biomass Characteristics As A Measure Of Growth And Productivity Of (Rhizophora Racemosa Meyer) Grown In Amended Soil Types And Exposed To Saline Water

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Abstract: The mangrove Rhizophora racemosa species was selected to study the survival, growth and response of seedlings grown under two contrasting soil salinity for 12 weeks and later exposed to shoreline saline water for 8 weeks. Matured propagules were grown for 12 weeks on mangrove and garden soil amended with saw dust (SD), rice husk (RH), NPK and RH+ SD+NPK combination treatments and exposed to shoreline saline water at the Botanical Garden of the University of Port Harcourt. Biomass accumulation characteristics such as total dry biomass, above ground biomass, below ground biomass, percentage water content and relative growth rate were determined at 12 weeks post-soil treatment and 8 weeks post-saline water treatment respectively. The result showed that Rhizophora racemosa propagules grown under high saline mangrove Soil (8,000 – 20000µS/cm) and high saline water (10,000 - 35,000ppm) were significantly lower at p<0.05 in terms of cumulative total dry biomass, mean above ground biomass, mean below ground biomass, mean percentage water content and mean relative growth rate when compared to those grown in low saline garden soil (<200 µS/cm). These results have demonstrated that raising mangrove nursery for reforestation purposes is ideal on a low saline substrate with amendments especially at its young age in other to achieve maximum growth and development.

Key words: Mangrove, Total dry biomass, above ground biomass, relative growth rate.

Introduction

Mangrove forests are unique plant communities that are mostly restricted to intertidal areas of lagoons, estuaries and sheltered bays in tropical and sub-tropical areas worldwide, [1] [2]. As a form of their physiological traits, they have adapted to growing under extreme environmental conditions such as unstable water salinity, continuous tidal flow in addition to low oxygen status of sediment, low nutrient etc. Besides, the numerous ecological services and economic benefits derived from the mangrove ecosystems, its establishment and development have continued to decline alarmingly in the Niger delta region in particular and in several other regions on a global scale [3] [4]. The loss of mangrove forest is orchestrated by a number of factors and chief among it is anthropogenic activities which includes conversion of mangrove forests into urban housing development, industrial sites, shrimp farms, roads, pollution and dumping sites [5]. Other key factors affecting mangrove development is nutrient deficiency in mangrove habitat and salinity stress just to mention a few. The Niger Delta mangrove forest is one of the natural endowments in the region and is dominated mostly by the viviparous species of Rhizophora racemosa R. harrosonii, R. mangle etc among other plant species [6] Nutrient deficiency and high salinity in mangrove habitat are serious factors restraining mangrove survival, growth and development, [7] [8]. Waterlogging in the mangrove habitat is a common denominator which usually creates anaerobic condition within the soil thus preventing nitrification process and as a consequence, bioavailability of nutrients in the soil is greatly reduced [9]. Similarly salinity on the other hand has been reported to affect and determine the survival and growth of planted mangrove seedlings by upsetting nutrient availability to plants and as well its uptake and/or absorption by the root system [10] [11]. According to [12] nutrient addition to soils promotes substantially shoot elongation of Rhizophora mangle, enhances leaf and branch growths of Avicennia germinans and has outstandingly broaden the leaf area of Ceriops tagal. Besides, other studies have suggested that nutrient addition might enhance water supply to leaves by increasing hydraulic conductivity through the stimulation of root growth and/or improving some aspects of the water conducting pathway [13]. Therefore the main aim of the current work was to ascertain the responses and productivity during early growth stage of the mangrove species Rhizophora racemosa a predominant mangrove species in the Niger Delta region under two soil types with contrasting characteristics as nutrient levels and salinity. This will further elucidate on the viability of raising vigorous mangrove seedlings on such media for reforestation purposes.

MATERIALS AND METHOD

Site description

The study was carried out at the Botanical Garden of the University of Port Harcourt, (Latitude 4°43 N and Longitude 7°05 E). The area lies within the tropical rain forest ecological zone in Southern region of Nigeria popularly referred to as the Niger Delta. Meteorological characteristics of the study area as reported by [14] revealed that the monthly temperature during the dry season (November – February) ranged between 31.13 – 33.08°C with a mean of 31.97°C while during the rainy season (March – October), the temperature ranges from 25.71 – 32.48°C with a mean of 29.095°C. The area records a 203.03 mm mean annual rainfall [15] which peaks during the months of July and September.
Experimental design

The experiment consists of two treatments [garden soil (GS) and mangrove soil (MS)] and each was subdivided into five subsets. The five subsets received different amendments and were numbered 1 to 5 for each treatment. Subset number 1 had no amendment and served as control GS or MS, number 2 was amended with saw dust ash (SD), number 3 was amended with rice husk ash (RH), number 4 was amended with Nitrogen Phosphorus Potassium fertilizer (NPK 10:10:10) and lastly number 5 was amended with a combination of SD+RH+NPK. Each subset of a particular treatment was replicated six times and was made by filling 1.5kg of mangrove and garden soil respectively in a polyethylene bag (28cm x 20cm). Mangrove soil were collected from the intertidal zone of Ogbogoro estuarine waters (535525.548N, 270244.003E and 535498.008N, 270306.874E) where R. racemosa grows using hand trowel while the garden soil was collected from the Botanical Garden of the University of Port Harcourt at approximately 5cm deep. Debris and partially decomposed materials were carefully removed with rake before soil collection. The soils were homogenized separately and potted into garden and mangrove soil respectively. Each of the polythene bags containing the prepared soil was amended with its assigned amendment. This was done by weighing 15g of the relevant amendment in a BL20001 digital balance and subsequently mixed in the first 10 cm of the top soil of the prepared soil prepared soil types while in the combination amendment, 5g each of SD, RH and NPK was first weighed in a balance and mixed together first before applying in the soil. The method of [16] with modification for raising mangroves in the nursery was adopted. The polythene bags containing the amended soil were laid out in a partially shaded plot allowing for natural sunlight and rain to reach it and were left for four days to allow for decomposition and thorough mixing with the soil material. Matured propagules were assessed visually (i.e. colouration) as described by [17] and by sense of touch described by [18]. Soil samples for physicochemical analysis were collected to a 5cm depth from each polythene bag using a spartula. The samples were air-dried and passed through a 2-mm sieve. Soil pH, Salinity and electrical conductivity (EC) were measured in a soil-water suspension (1:1 and 1:5 soil to distill water ratio, respectively electrometrically) using OAKTON pH/Conductivity/TDS/Salinity/Temperature Multi parameter Model testr35 35425-00. Total Organic Matter was determined by loss on ignition method while Total organic carbon (TOC) was determined by calculation using total organic matter result applying the ‘Van Bemmelen’ factor [19] Total Nitrogen was measured by the Kjeldahl method as described by [20]. On day five (5) post soil amendment, propagules of R. racemosa of the same length and weight were planted directly into each of the prepared soil at approximately 5cm depth and exposed to natural sunlight and rainfall. The soil in each bag with the planted propagule was watered with 250ml fresh tap water once every two days ensuring the soil remains wet for a period of 12weeks (First phase). At the end of the 12weeks the plants were carefully harvested, ensuring no part was damaged especially the roots. The roots were washed carefully with fresh water to remove any soil debris and was subsequently transferred into plastic containers measuring about 18cm x 7cm and filled with 500ml of saline water arranged according to five subsets previously described above. The setup was housed in a prototype green house with exposure to natural light but without allowing rainfall to reach it (Second phase). The saline water in each container was replaced once every week to avoid the water being stale. The saline water was collected from the same spot in Ogbogoro estuarine waters. After 8weeks of exposure of test plant to saline water, the mangrove plants were harvested, washed and separated into leaves, stems and roots for further analysis.

Measurement of biomass characteristics

Fresh weight of each of the plant component parts roots, stem and leaves were immediately weighed to determine their fresh weight using the BL20001 digital balance (Labtech). To determine the dry weights of the leaves, stem and roots of each plant, the parts were dried in Mermet oven at 75 ºC for 48 hours until constant weight. Values for the above-ground biomass dry weight was obtained by the summation of the oven dry weight of the stem and leaves together while the value for below-ground biomass was obtained from the oven dry weight of the roots. Total plant biomass was obtained by the summation of the below and above ground biomass. Absolute Growth Rate (AGR) gives absolute values of biomass between two intervals. AGR was calculated using formula according to [21].

\[
AGR = \frac{h_2 - h_1}{t_2 - t_1}
\]

Where, \(h_1\) and \(h_2\) are the plant height at \(t_1\) and \(t_2\) times respectively

The difference between fresh and dry weight of the individual plants was taken as the water content and whereas the percentage water content was calculated as follows:

\[
\text{Percentage water content} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Fresh weight}} \times 100
\]

Propagule fresh weight and height was determined using a digital balance and a meter rule respectively. Ultimately the cumulative mean total dry biomass, above ground biomass and mean percentage water content of seedlings previously grown under different levels of soil salinity and nutrient regimes and later exposed to saline water were compared.

Statistical analysis

The data were analyzed using standard statistical tests. The effect of different substrates on the survival and growth of the seedlings was evaluated using a 1 One Way Analysis of Variance (ANOVA) followed by Duncan’s test for comparisons of all treatments against the control. The data are presented as means ± standard error, while differences between treatments were considered significant at the (p < 0.05) level.
RESULTS

The propagules had a mean fresh weight of 25.884±1.42g and a height of 33.345±1.48cm.

Above ground dry biomass (AGDB) and below ground dry biomass (BGDB) of Rhizophora racemosa grown in amended mangrove and garden soil and exposed to saline water.

During the first phase of the study, the AGDB of R. racemosa raised in the amended garden soil recorded its highest value of 14.36 ± 0.79g in plot 5 while the lowest value of 9.52 ± 0.39 of the same soil treatment was recorded in plot 4, Figure 1A. Whereas in the amended mangrove soil the highest AGB value of 11.88 ± 0.72g was recorded in the plot 5 while the lowest values of 8.21 ± 0.47 was recorded in plot 1. It was observed that in the mangrove soil treatment, the value of AGDB of all the amended plots were higher relative to the control; however in the garden soil treatment AGDB values were higher than the control plot except in plot 4 which had AGDB value lower than plot 1. On exposure to the test plant to saline water (the second phase), AGDB recorded its highest values of 7.67 ± 0.30g and its lowest value of 5.62 ± 0.41g in plots 5 and 1 respectively of the post amended GS treatment soil. Likewise in the post amended mangrove treatment, highest and lowest AGB values of 9.48 ± 0.76g and 7.39 ± 0.48g respectively in plots 5 and plot 4. The result further showed that there was a reduction in the AGDB of test plant on exposure to shoreline saline water relative to the soil treatment phase, Figure 1. The result of the Above Ground Biomass (AGDB) of Rhizophora racemosa on exposure to saline water is presented in Figure 1. During the first phase of the study, it was observed that the test plant that was raised in the garden soil plot 5 (amended with the three combination treatment) had the highest value of 14.36 ± 0.79g while the highest AGDB value in the amended mangrove was 11.88 ± 0.72g recorded in plot 5 (combination treatment). On exposure to saline water; the second phase, highest AGDB value of 9.48 ± 0.76g and 7.67 ± 0.30g were recorded in plot 5 for test plants that was raised previously in mangrove and garden soil respectively Figure 1. There was significant difference at p<0.05 in the AGDB of test plants between phase 1 (amended soil types) and phase 2 (saline water).

Below Ground Dry Biomass

In phase 1 of the study, the below ground dry biomass of Rhizophora racemosa recorded its highest value of 3.23 ± 0.16g and 2.62 ± 0.10g in plot 5 for garden and mangrove soil respectively while the lowest BGDB value (2.06 ±0.23g and 1.37 ± 0.12g) was recorded in control (plot 1), Figure 2A. In the second phase of the study, BGB highest values of 2.29 ± 0.27g and 2.34 ± 0.21g were recorded in 5 and plot 2 respectively, Figure 2B; while the lowest BGDB values of 0.77 ± 0.04g and 1.14 ± 0.05g was recorded in plot 1 and plot 3 respectively, Figure 2B.
R. racemosa exposed to saline water

**Total Dry Biomass (TDB)**
The highest value for Total Dry Biomass of test plant in both soil types during the first phase of the study was 17.22 ± 0.82g and 14.50 ± 0.72g recorded at plot 5 of the amended garden and mangrove soil respectively while the lowest TDB value of 11.70 ± 0.52g and 8.69 ± 0.70g was recorded in plot 3 of the garden soil and plot 1 (control) of the mangrove soil respectively, Figure 3A. During the second phase, the highest TDB of test plant (R. racemosa) was 9.96 ± 0.82g and 11.81 ± 0.78g at plot 5 respectively. While the lowest value of 6.39 ± 0.49g and 7.50 ± 0.55g respectively was recorded for the test plant in the control plot, Figure 3B. There was significant difference p<0.05 in the TDB of test plant between the treatment in phase one as well as in the phase two of study.

<table>
<thead>
<tr>
<th>Soil Treatment</th>
<th>GS*</th>
<th>S + SD</th>
<th>S + RH</th>
<th>S + NPK</th>
<th>S + SD + RH + NPK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garden soil</td>
<td>68.84 ± 1.24</td>
<td>66.64 ± 1.13</td>
<td>64.63 ± 1.12</td>
<td>65.02 ± 0.93</td>
<td>64.28 ± 0.89</td>
</tr>
<tr>
<td>Man grove soil</td>
<td>70.22 ± 1.12</td>
<td>67.53 ± 1.23</td>
<td>67.29 ± 1.18</td>
<td>70.00 ± 0.90</td>
<td>64.91 ± 0.80</td>
</tr>
</tbody>
</table>

* Significant difference at p<0.05 in the percentage water content of test plant within each treatment group.

**Table 2.1: Percentage Water Content (%) of R. racemosa in phases one and two of the study.**

<table>
<thead>
<tr>
<th>Soil Treatment</th>
<th>GS*</th>
<th>S + SD</th>
<th>S + RH</th>
<th>S + NPK</th>
<th>S + SD + RH + NPK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + SD</td>
<td>0.046 ± 0.005</td>
<td>0.071 ± 0.012</td>
<td>0.076 ± 0.005</td>
<td>0.062 ± 0.006</td>
<td>0.128 ± 0.010</td>
</tr>
<tr>
<td>S + RH</td>
<td>0.056 ± 0.026</td>
<td>0.064 ± 0.010</td>
<td>0.055 ± 0.006</td>
<td>0.041 ± 0.005</td>
<td>0.096 ± 0.009</td>
</tr>
<tr>
<td>S + NPK</td>
<td>0.008 ± 0.020</td>
<td>0.034 ± 0.004</td>
<td>0.025 ± 0.003</td>
<td>0.033 ± 0.002</td>
<td>0.045 ± 0.001</td>
</tr>
<tr>
<td>S + SD + RH + NPK</td>
<td>0.002</td>
<td>0.041</td>
<td>0.038 ± 0.004</td>
<td>0.001</td>
<td>0.067 ± 0.001</td>
</tr>
</tbody>
</table>

The highest percentage water content of 68.84 ± 1.24% and 70.22 ± 1.12% for test plant in phase one of the study was recorded in the control plot of both the amended garden and mangrove soil respectively. Also the lowest percentage water content value of 64.28 ± 0.89% and 64.91 ± 0.80% for test plant was recorded in plot 5 of both amended soil types too. In the second phase of the study, highest percentage water content value of 70.8 ± 0.9 and 72.1 ± 0.8 was recorded in plot 4 and plot 5 respectively. raised previously in the garden soil treatment was recorded in Plot 4 (amended with NPK) while the highest value of 71.9 ± 0.8% raised previously in the mangrove soil treatment was recorded in plot 5 (amended with the combination treatment). There is significant difference at p<0.05 in the percentage water content of test plant within each treatment group.

**Table 2.2: Absolute growth rate of R. racemosa previously raised in two different amended soils and exposed to saline water**

<table>
<thead>
<tr>
<th>Soil Treatment</th>
<th>GS*</th>
<th>S + SD</th>
<th>S + RH</th>
<th>S + NPK</th>
<th>S + SD + RH + NPK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S + SD</td>
<td>0.046 ± 0.005</td>
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<td>S + NPK</td>
<td>0.008 ± 0.020</td>
<td>0.034 ± 0.004</td>
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<td>0.033 ± 0.002</td>
<td>0.045 ± 0.001</td>
</tr>
<tr>
<td>S + SD + RH + NPK</td>
<td>0.002</td>
<td>0.041</td>
<td>0.038 ± 0.004</td>
<td>0.001</td>
<td>0.067 ± 0.001</td>
</tr>
</tbody>
</table>
The highest absolute growth rate of 0.045 ± 0.001 cm/day for the test plant in the previously amended garden soil treatment was recorded in plot 5 (amended with combination amendment) while in the previously amended mangrove soil, the highest absolute growth rate of 0.067 ± 0.001 cm/day was recorded in plot 5 (amended with combination amendment). The result revealed significant differences at p<0.05 within each treatment groups relative to the control.

Discussion
The research study examined the responses of mangrove seedlings that were initially raised under two soil types contrasted by salinity and amended with different soil conditioners for 12 weeks and the seedlings were subsequently exposed to saline water for 8 weeks. The findings of the study revealed that there was an improvement in growth performances such as Absolute Growth Rate, Total Dry Biomass, Percentage Water Content, Above Ground Dry Biomass of the mangrove seedlings when raised in the low saline amended garden and mangrove soil relative to their performance on exposure to high shoreline saline water. This is in agreement with previous studies of [22] [23] [24] who have reported the negative effects of high salinity on mangrove plants development and growth. Total dry biomass of R. racemosa was maximal when grown in the amended mangrove and garden soils compared to when exposed to high saline shoreline water, figure 2. This is consistent with the report of [25] who has reported significant decrease in biomass accumulation and relative growth rate leading to modification in biomass partitioning sequence. Also [26] have reported that high salinity causes stunting of seedling which may have been a consequence of reduced transpiration rates and photosynthesis of mangrove seedlings. Absolute growth rate of test plant declined on exposure to saline water when compared to the rate when grown in amended garden and mangrove soil. This is consistent with the findings of [27] who have reported significant reduction in the growth and RGR of H. fomes in Bangladesh grown in high saline media. Reports of [28] [29] have suggested that mangroves tends to store water under low saline conditions, this finding is consistent with our result as mean percentage water content of test plant grown in the amended garden and mangrove soil where higher compared to when exposed to shoreline saline water as presented in, Table 2.0. The improved water absorption by mangrove as suggested by [30] could be as a result of low osmotic potential under hypersaline condition. In conformity with the works of [31] that nutrient enrichment promotes investment in the shoot, test plant had higher above ground biomass in the amended garden and mangrove soil relative to when exposed to saline water. Figure 1. This growth is accomplished by other physiological process as increased hydraulic conductance and photosynthetic rates which are known to be significantly influenced by high salinity. Also high salinity has been reported to inhibit nutrient uptake and use even in other wetland plants like the salt marshes. [32] Furthermore, (Wahome, 2001) have reported that salinity affects nutrient availability to plants through modification of binding sites, retention and transformation of nutrients in the soil thereby affecting the uptake and/or absorption of nutrients by the root system.

Conclusion
Salinity is assumed to be the primary hindrance to mangrove growth, development as well as nutrient partitioning in mangrove plant parts especially in early stages of establishment in the study. The report is of the view that salinity is the main hindrance to mangrove natural regeneration within the Niger Delta area where salinity due to rising sea level is very obvious. However, nutrient amendment was observed to not only greatly enhance plant growth, but also alleviate salt-induced damage to plant physiology. Therefore, amending the growth medium could be very helpful in promoting the establishment and survival of mangrove seedlings especially Rhizophora racemosa for reforestation purposes in areas with relatively high salinity as is the case in the Niger Delta region of Nigeria.

Reference


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