Effect of Salinity on Buoyancy of Mangrove (*Rhizophora racemosa*) and Nypa Palm (*Nypa fruticans*) Seedlings in the Niger Delta, Nigeria

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ABSTRACT

Seed dispersal is a major factor of species distribution and propagation. It was hypothesized that Nypa palm seed will float more than mangrove seeds in water due to its outer fiber coat. An experiment was conducted with 30 seeds each of both mangrove (*Rhizophora racemosa*) and Nypa palm (*Nypa fruticans*). Buoyancy experiment was conducted in the laboratory. The weights of all the seeds were recorded. A small basin full of water was placed in an empty bigger basin. The seeds of each species were sequentially placed inside the inner container that was full of aqueous media. The amount of water spilled was collected and measured in milliliter (ml). The weight of the seed and the weight of the water spilled were then used to calculate the floatability of each seed. If the weight of the seed is greater than the mass of water spilled the seed floats while if the weight of the seed is less than the mass of water spilled the seed sinks. The result indicates that there was no significant difference in the amount of spill between tap and river water ($F_{1,119}$=3.76, p>0.05). But there was a significant difference in the amount of spill between mangrove and Nypa palm seeds ($F_{1,119}$=163.2, p<0.0001). Five Nypa palm seeds floated in tap water while one floated in river water, as for mangrove none of the seeds floated in both water types. Nypa palms seeds were heavier (0.13 ± 0.01 kg) than mangrove seeds (0.026 ± 0.001 kg). This implies that Nypa palm seed has higher buoyancy than mangrove seeds. Similarly, salinity influenced seed floatation, as the tap water (control) had higher floatation than river (saline) water.

INTRODUCTION

Mangroves are one of the most productive plants in the world because of the ecosystem services they render [1]. They are habitat specialist and mainly found at the interface between the land and the sea. Their position near the sea predisposes them to serious stress and environmental challenges such as high salinity [2], oil pollution [3], waste disposal [4], deforestation, tidal flushing, erosion, dredging, invasive species and urbanization [5]. Mangroves of the Niger Delta face serious competition with Nypa palm in terms of species distribution and abundance. The seeds of a most aquatic organism are dispersed and travel thousands of kilometers by tidal current from one region to another. The dispersal and colonization of the seed of new territory determine the population dynamics of the species. Dispersal ability is critical to the demographic and evolutionary persistence of a species in fragmented landscapes as it allows the exchange of individuals and genes among fragments, the re-colonization of empty habitat, and even local adaptation [6]. Seed dispersal distances vary with many environmental factors [7], as well as with plant traits for which there is genetic variation both between and within populations [8]. Traits influencing seed dispersal ability can evolve quickly in response to change in selection pressures [9]. Theoretical models predict that the evolution of dispersal traits in a changing landscape could rescue a meta-population from extinction [10] or, by contrast, accelerate its collapse [11]. In river corridors, water-mediated spread (hydrochory) is considered to be the most important dispersal mechanism of aquatic plants [12]. Seeds and vegetative plant parts of most aquatic and riparian plants display the ability to float for extended periods of time while remaining viable, thus potentially contributing to their downstream dispersal.

Mangrove and Nypa palm trees dwell in an aquatic environment, where the buoyancy of their seedling is a key factor in their survival and dispersal. The seedlings of these two species are under selection pressure to survive and pass on their genes to the next generation. This depends on the ability of the seed to remain afloat for a longer time in the harsh watery saline environment, and spread faster and colonize more areas. Seeds are subjected to tidal pressure of low and high tides, which carries them deep into the ocean where they drown or are deposited on dry land where they dry up, shrink and die. They are also faced with differences in the physical chemistry of the environment as a result of the introduction of pollutants and other organic waste in the aquatic environment. This can lead to the contamination of the seeds. Biotic factors like mangrove crabs also feed on seedlings to derive nutrients. Mangrove and Nypa palm are always in a competitive state in the environment especially in the Niger Delta, where the later has gained an upper hand [13]. This has to do with the survival of the fittest. Apart from the tidal pressure, physical, chemical and biotic factors that affect survival there is the problem of anthropogenic activities that lead to the degradation of the environment such as oil spillage, deforestation, disposal of waste, sand dredging, etc. Human activities had resulted in the destruction of a large cache of mangrove and Nypa seedlings. The more humans discover the utility of the seeds the more endangered the seeds become. The seeds are used as food for livestock and humans, manure in agriculture, bio-energy production, ornamental production and medicinal herbs [1].

Seeds that rely on water for their dispersal face additional challenges in their quest to be dispersed. Problems like how to stay afloat and prevent the valuable food supply from rotting need to be addressed. If the seed is destined to cross the ocean it has the added requirement to be resilient to salt water and not corroded by the very element assisting in its dispersal. One of the side effects of water dispersal of the seed occurs after flooding has taken place. Seeds are left on the forest floor as the water level recedes and saplings grow up in rows. Some of the seedlings especially red mangroves are unable to grow because while lying horizontally on the forest floor they cannot grow since their roots cannot embed in the soil in that position.

Seed Dispersal Mechanism (Hydrochory)

Hydrochory is the movement of seeds by water, either floating, submerged in flowing water, or with the help of floating vessels. Wetland species can be dispersed by several different mechanisms; however, dispersal by water is the primary vector for wetland systems [14]. Merritt et al. [15] provide evidence that water dispersal of seeds influences the dynamics of colonization and can be important for the long-term development of communities in floodplain areas. They also concluded that hydrochory contributes to variability among sites, enhances species richness over time, and can play an important role in meta-population dynamics of plant communities [16] found that hydrochory increased the number of colonizing species by 40%-200% per year and resulted in more diverse plant communities after three years of succession. [17] found that 94% of water-dispersed seeds caught in their traps fell and were dispersed only 0.5 meters from the mother plant, whereas [15] reported that hydrochores (and seed mimics) were dispersed anywhere from 6 km up to 152 km [18] conducted experiments in floodplain areas of the Amazon River and concluded that seed dispersal was greatest when water depth was greatest.

Impact of Floatation Characteristics

One feature of seed dispersal compared with the well-studied sediment dispersal is buoyancy. Seeds can be subdivided into two classes, non-buoyant seeds, and buoyant seeds. Seeds are organic matter and will absorb water; hence non-buoyant seeds which are dispersed in the water will absorb a certain amount of water that will change their density. Among the buoyant class, the phenomena of absorbance are the same; some are wettable and will sink after being water-logged and some are unwettable and will remain buoyant. The potential duration of buoyancy relative to the actual time spent in water might be critical for successful dispersal for several reasons. First, seeds can absorb so much water that they can become water-logged and sink or their germinating power is destroyed by the infiltration of water [19]. Thus, the viability of seeds is directly linked with the time spent in the water and the time spent will have an influence on the probability of active growth and establishment after transport and deposition. Second, the patterns of transport and deposition between buoyant seeds and non-buoyant seeds will be considerably different. The floating characteristic is usually due to a low specific weight of the seed. This is achieved by two mechanisms which are a low tissue density and some air trapped between the cotyledons [20]. Nevertheless, another possibility for floating is that small seeds take advantage of surface tension to remain buoyant. The potential duration of buoyancy is correlated with the permeability

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and the thickness of the seed coat [21]. Seeds which are too heavy to float in water and sink soon after they fall in can be dispersed as well [22]. Collected seeds of 55 freshwater wetland species and related degree of buoyancy to the distribution of species. Their results showed that seed buoyancy enhances aquatic seed dispersal [23] also addressed this hypothesis. In studies of Swedish rivers, distribution of downstream plants and floating capacity of seed were measured. No relationship appeared in their data between floating ability and distribution of species along the river. This result can be explained by the fact that floating ability is only one aspect of seed dispersal.

In other to determine the stress caused by salinity and its impact on floatation on mangrove and Nypa palm seeds the following objectives were outlined: (1) To determine the floatation of mangrove and Nypa palm seedlings in river water, (2) to determine the floatation of mangrove and Nypa palm seedlings in tap water, and (3) to compare the relationship between mangrove and Nypa palm in tap (control) and river (saline) water.

MATERIALS AND METHODS

Description of Study Area

The study and sample collection were carried out in Okirika (4 °43" N 7°05' E; Elev. 6 m). It is a port town in Rivers State, Nigeria (Figure 1) and situated on a small island south of Port Harcourt. It is one of the few coastal settlements in the region that is accessible by road. The town is made of brackish water environment, with a lot of oil exploration activities going on in the region. The vegetation of this area includes trees, shrubs, herbs, and grasses. The river has organisms such as fishes, crabs prawns, etc. Three major species of mangrove plants include red (*Rhizophora racemosa*), black (*Avicennia germinans*) and white (*Laguncularia racemosa*) mangrove. They occur in zonations of different species that tolerate a more different level of salinity. The species occurring in a zone depends on the depth, duration, and frequency of the tidal inundation, soil salinity, etc.

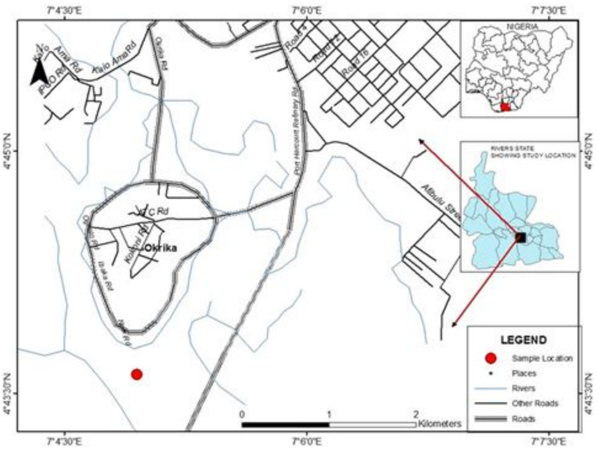

Figure 1. Map of study area showing the area of seed collection at Okrika, rivers state, Nigeria.

Sample Collection

In the mangrove forest at Okrika 80 seedlings each of mangroves and Nypa palms seedlings (n=160) were picked or plucked from the parent plant and placed in a cellophane bag (Figure 2a-2d). Adjacent to the mangrove forest in nearby river water was collected in-situ using as a 20 liter container. Both the seeds and the container of water were taken to the laboratory. The salinity and temperature of the river was tested *in-situ* at different points using a dual sensor salinity meter (OAKTON SALT 6 Acorn Series) (Table 1) and while the tap water, which was used as a control was tested for salt at the laboratory (0 ppt).

Figure 2. Experimental setup showing (a) Mangrove seeds used for floatation experiment, (b) Nypa seeds used for the floatation experiment (c) Electronic weighing balance, (d) Buoyancy experiment showing seeds of mangrove and Nypa floating in the water.

Table 1. Mean salinity and temperature readings at three transects in the study location.

Site	Salinity (%) ± SE	Temperature (°C) ± SE
T1	1.55 ± 0.003	29.44 ± 0.13
T2	1.47 ± 0.02	29.44 ± 0.25
T3	1.18 ± 0.04	32.48 ± 0.77

RESULTS

Influence of Seed and Water Salinity on Water Displacement (Spill)

The result indicates that there was no significant difference in the amount of spill between tap and river water ($F_{1, 119}=3.76$, $p>0.05$) when the seeds of both plants were introduced in the aqueous medium. However, there was a significant difference in the amount of spill between mangrove and Nypa palm seed ($F_{1, 119}=163.2$, $p<0.0001$) during the floatation experiment. Five Nypa palm seeds floated in tap water while one floated in river water, as for mangrove none of the seeds floated in both water types **(Table 2)**. The result shows that Nypa palms seeds (0.13 ± 0.01 kg) are heavier in than mangrove seeds (0.026 ± 0.001 kg) **(Table 2)** and spilled more river water **(Figure 2)** when placed in the two watery media. This means Nypa palm seeds have higher buoyancy than mangrove seeds **(Figure 3)**. The result also indicates that tap water also relatively conferred higher floatation ability to Nypa palm seeds. None of the mangrove seeds floated, which indicates their poor floatability in both river and tap water media.

Table 2. Mean weight of Nypa palm (*Nypa fruticans*) and mangrove (*Rhizophora racemosa*) seeds and the amount of tap and river water displaced in a floatation experiment (n=60).

Species	No. of seeds	Mean seed weight (kg)	Mass tap spill (m^3)	Mass river spill (m^3)	No of seeds that float in tap water	No. of seeds that float in river water
Nypa palm	30	0.13 ± 0.01	1.12×10^{-1}	7.40×10^{-2}	5	1
Mangrove	30	0.026 ± 0.001	1.03×10^{-3}	1.03×10^{-4}	0	0

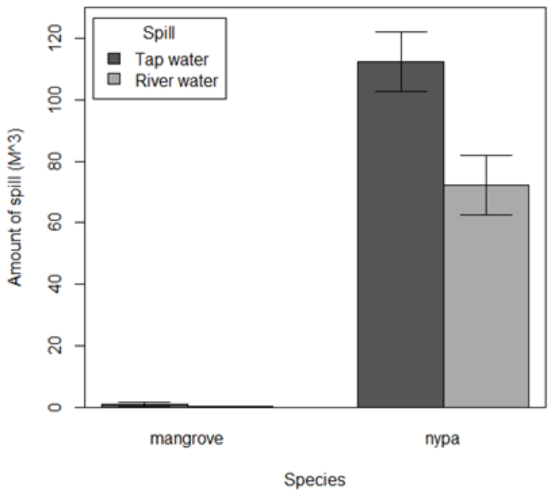

Figure 3. Amount of tap and river water spilled by mangrove and Nypa palm seeds during floatation experiment. The result indicates that Nypa palm spilled more tap water than river water. ± standard error of the mean.

The graph of correlation of the weight of seeds and the mass of water spill (Figure 4) shows a close cyclical relationship in Nypa palm seeds (Figure 4a and 4b), and a farther cyclical relationship in mangrove seeds (Figure 4c and 4d). For both the Nypa palm and mangrove seeds there was higher floatation ability in tap water than in river water. Similarly, the closer the red and blue lines to each other, the better the floatation of the species. Thus, Nypa palm had higher floatation than mangroves seeds.

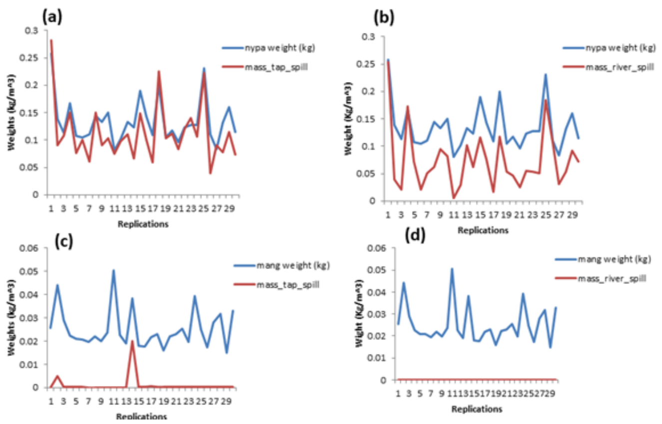

Figure 4. Line graph shows the weight-water spill relationship for (a): Nypa palm seed in tap water; (b): Nypa palm seed in river water; (c): mangrove seed in tap water and; (d): mangrove seed in river water in a floatation experiment. "Mang" refers to the mangrove.

DISCUSSION

Water salinity is a major stressor to aquatic plants [2], due to its impact on the osmotic pressure of the living cells. Internally mangroves avoid this stress by excreting saline crystals, undertaking litter fall of senescent leaves and controlling the excess intake of salt by slowing down salt absorption via their root. However, it is not clear as to whether the same principle is applied in evading salinity stress of its seeds when submerged in an aquatic medium. This study has shown that salinity might be one of the factors of poor buoyancy of mangrove and Nypa palm seeds in (saline) marine water based on the poor floatability as compared to tap water.

Nevertheless, high floatation ability of Nypa palm seed than mangrove seeds means that the palm seeds will have higher dispersal advantage over mangrove seeds during high tide or flooding. Higher dispersal means more colonization of empty lands by the palms. High dispersal advantage is what has contributed to the successful invasion and colonization of most areas formerly occupied by the mangroves around the Niger Delta [13]. The ability to float enables the Nypa palm seeds to be distributed far and wide around several wetland locations. The Mangroves are at a disadvantage because of their low ability to float. This means if they don't get stuck to the soil after they detach from the tree they may be washed ashore on hard land. As for the Nypa palms, they will have the capability of floating to a conducive environment where they settle and germinate.

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The reason for the high floatation ability of Nypa palm seeds can be attributed to the inherent qualities of their rounded seed that rotates on water and an outer coat that acts like life buoy [24]. The round nature of the seed enables an equal distribution of the weight around the seed, which increases their floatation ability despite their weight. These attributes enable them to disperse easily around wetlands and coasts. The poor flotation ability of mangrove seeds may be attributed to their elongate nature (torpedo-shaped) with the center of gravity distributed unequally along the length of the seed. Similarly, their low weight does not contribute to their floatation ability due to their elongate nature. The inability of the mangroves to float reduces their chances of dispersal and distribution around the coasts as compared to the palms. This means mangrove seeds that don't embed in the soil after detachment from the tree are either consumed by crabs or thrown offshore by tidal currents.

In contrast, Nypa palm seeds are easily dispersed as a result of their high floatation ability. Due to the low buoyancy of mangrove which limits their wide dispersal and distribution, it is important that their seeds should be preserved in seed banks to avoid extinction of mangrove species. Mangrove forest provides services by acting as a breeding ground for aquatic organisms (e.g. fish periwinkle, oysters, bivalves, etc.). Conservation of mangrove forest is necessary to stop the reduction of a species population in other to accelerate the proliferation of more seeds to counter the effect of seeds loss as a result of poor floating ability. Further studies will consider the conduction of a natural experiment in marine and freshwater system to test the influence of other factors that impede floatation ability of mangrove and Nypa palm seeds apart from salinity.

CONCLUSION

Mangroves are plants of great economic importance that can be found occurring in all wetlands and coastal areas partly because they serve a great deal to the aquatic organism. Nypa palm occurs more frequently in these areas. The high occurrence of Nypa palm can be attributed to their high floating ability. This ability confers an advantage to species in terms of distribution and dispersal. The Nypa seeds have ability to float more than the mangrove seeds hence; they are widely distributed around coast and wetlands and colonize different areas. Therefore, this study is of great importance because we are able to understand why the palms are quickly colonizing the mangrove forest in the Niger Delta.

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