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Mangrove plantation experiments for controlling coastal erosion at Gazi Bay

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Introduction

Mangrove forests provide goods and services that are of economic, ecological and environmental values to the people. Environmentally, mangroves offer coastal protection against erosion, storm damage, prevent siltation of adjacent seagrass beds and control floods (FAO 1994). The value of mangroves in coastal protection was demonstrated during the 2004 Indian Ocean tsunami in which areas with degraded coastal mangroves were more affected than areas with intact forests (Dahdouh-Guebas *et al.* 2005). However, around the world mangroves are being degraded at an alarming rate due to human induced activities (Spalding *et al*. 1997). Losses of mangroves in many nations exceed 2-5% of forest area per year (Wilkie & Fortuna 2003).

In Kenya, the main threats to mangroves are overexploitation of wood resources, conversion of mangrove areas for other land uses and oil pollution. Losses of mangroves have affected the local economy as witnessed by shortages of firewood and building poles, reduction in fishery, and increased coastal erosion (Abuodha & Kairo 2001; Bosire *et al*. 2003).

For most coastal areas in Kenya, coastal erosion has become of major social, economic and environmental concern (Kairu & Nyandwi 2000; Abuodha 2003).

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The problem is severe in a number of sandy beach areas at Vanga, Gazi, Malindi, Mambrui and Ngomeni. Considerable amounts of money have been invested in shoreline stabilization throughout the Western Indian Ocean region, including use of rock revetments and seawalls (Kairu & Nyandwi 2000). Mangrove reforestation can provide a long-term and cost-effective solution while at the same time providing aesthetically and ecologically functioning habitats. Mangrove reforestation as a means to control coastal erosion has been used in Hawaii (Walsh 1976); Florida (Teas 1977); China (Lin & Xin-Meng 1983); Bangladesh (Saenger & Siddique 1993); Vietnam (Hong 1996) and Cuba (Padron 1996). In Florida, use of encasement piping to protect propagules led to improved performance of the saplings (Kent & Lin 1999; Riley & Kent 1999).

No information exists on the use of mangroves to control coastal erosion in the Western Indian Ocean region, thus the purpose of this study was to test growth performance of mangrove saplings grown in a high erosion zone. We tested the effectiveness of locally available bamboo encasements in protecting replanted propagules.

Study site

The study was carried out at Gazi Bay, located 55 km south of Mombasa (Map 6.1, p.100). The Bay supports coral reefs, seagrass beds and mangroves. All the nine mangrove species recorded in Kenya occur in Gazi, the dominant species being *Rhizophora mucronata* and *Ceriops tagal* (Dahdouh-Guebas *et al*. 2004).

The experimental site was located on the landward side of a fringing *Sonneratia alba* zone. Mangrove deforestation in the 1970's for industrial fuelwood left a huge contiguous bare area with no natural regeneration to date (Dahdouh-Guebas *et al*. 2004). Inside the fringing stand of *S. alba*, scattered individuals of adult *R. mucronata* were found. It is the presence of adult *R. mucronata* that prompted us to use the species in the reforestation. In addition, Rhizophororacea is the easiest mangrove family to use in reforestation programs (Kairo *et al*. 2001).

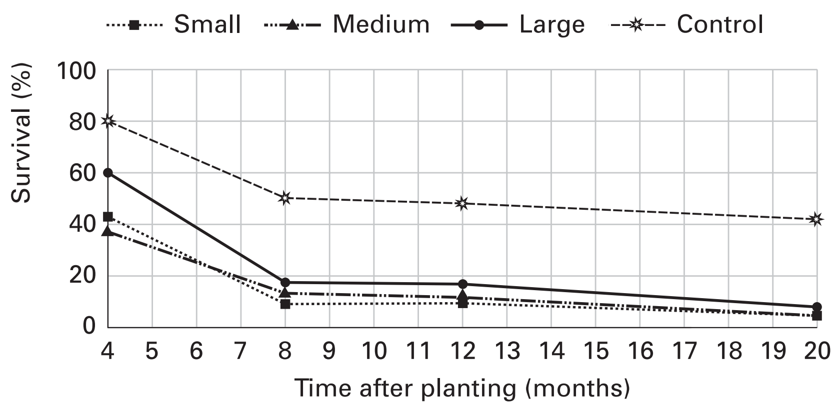
Method

Mature *R. mucronata* propagules were collected from the forest floor in a nearby natural stand. After collection, the propagules were sorted out to remove the predated, premature and partly dry ones before putting them in a moist gunny bag for transportation and storage. Planting was carried out in March 2005.

Three blocks (A, B and C) each measuring 10x10m lying side by side with a path of 2 m in between were marked. Within each block, bamboo encasements of three size classes, large (6.0 cm), medium (5.0 cm) and small (4.0 cm) in diameter resepectively, were firmly installed at spacing of 1.0 m within each row, leaving 15 cm above the ground. These were then filled with sediment to the brim, pressure applied and the propagules planted. Propagules were planted in a spacing of 0.5 m by 1 m. with the directly planted propagules put in between every two bamboo embedded lines to serve as controls. Each plot had, at the beginning of experiment, a total of 221 propagules, 100 directly planted and 121 bamboo-embedded. Enhancement planting was done for the first three months in order to remove any human error likely to have risen.

Mortality/survival rate of the saplings was monitored monthly for 13 months and a final assessment was carried out in the 20th month. Growth performance of the survivors was assessed every two months for the study period. The following growth parameters were recorded; shoot height (cm), diameter at the second internode (mm), and number of leaves. Data collection was done in two phases; 1) pre-establishment (the first 3 months) and 2) post-establishment (after 3 months).

Figure 9.1 Post-establishment survival of *Rhizophora* propagules planted in an eroding beach at Gazi Bay.



Results

Survival

Pre-establishment mortality was higher for bamboo embedded propagules than for the direct planted propagules. During the post-establishment phase saplings survival for all treatments declined, but stabilized in the 8th month after planting (Figure 9.1). In the 12th month of growing, the direct planted saplings (control) had the highest survival of 48.48±13.12%; while the small bamboo encasement had the lowest survival (9.85±8.18%; means±s.d.). Since there was no significant difference (p=0.20) between the treatments, the data was pooled together under one parameter (bamboo encasement) and compared with the control. At 20 months after planting the bamboo encased seedlings had a significantly lower % survival (6.9±6.3%) than the directly planted ones (33.03±8.6%) (p=0.01).

The causes of sapling mortality were attributed to washing away by tidal waves, crab attack and scorching by the sun. The most pronounced loss was due to seedlings being washed away. Quite unexpected, most washing away was experienced in the bamboo-embedded propagules, pointing at the possibility of human error while setting up the experiment rather than natural causes.

Table 9.1 Growth performance of *Rhizophora* saplings at Gazi, 13 months after planting (values are means - s.d.).

Treatment	Total height (cm)	Shoot height (cm)	Diameter (mm)	Leaf number
Bamboo	61.4 (8.9)	38.2 (8.6)	5.8 (1.1)	8.9 (3.2)
Control	82.1 (12.0)	45.6 (10.1)	6.6 (0.9)	16.1 (7.8)

Growth rate

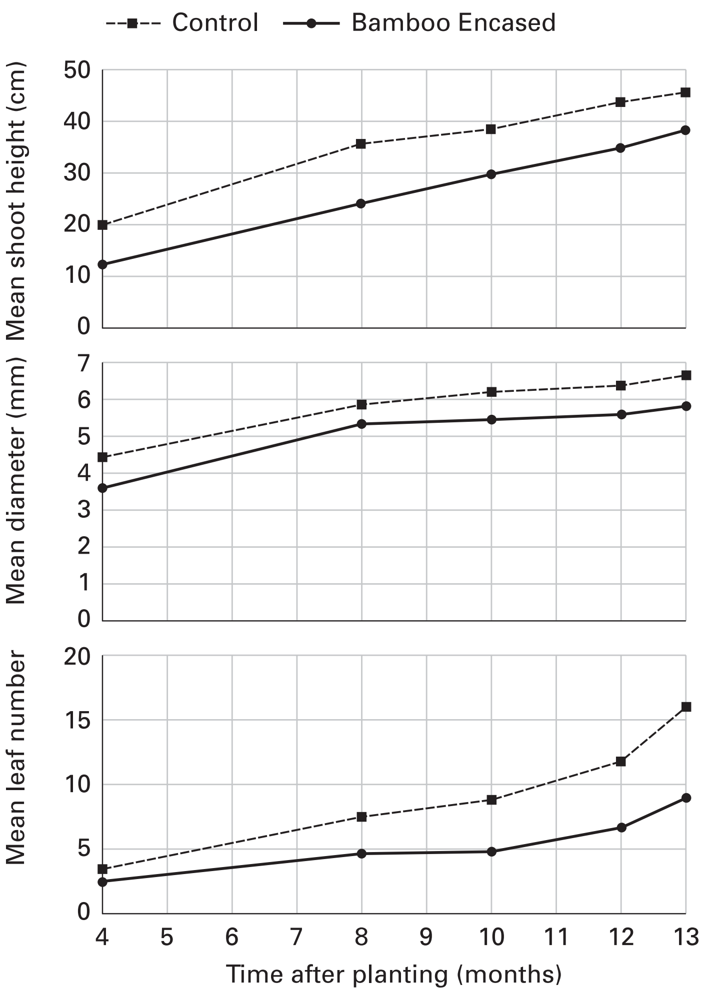
The growth variables in April 2006, 13 months after planting are given in Table 9.1. For all growth variables, the encased saplings performed significantly poorer than the directly planted saplings (p<0.01 in all cases).

Figure 9.2 shows the trend in growth performance of the bamboo encased versus the directly planted propagules, 13 months after planting. The mean annual shoot and diameter increment for directly planted saplings were 42.1 cm/yr and 6.1 mm/yr while those for encased saplings were 35.2 cm/yr and 5.4 mm/yr respectively.

Discussion

The experimental site is subjected to high wave energy due to past deforestation. Even though mortality in all cases was greater than 60% at 20 months after planting the saplings in bamboo encasements were hardest hit. The causes of mortality could partly be attributed to experimental error whereby the bamboo encasements were shallowly installed causing them to be easily washed away by tidal waves. Other factors contributing to high mortality of the replanted propagules included predation by crabs, washing by tides, as well as natural deaths. In the encased saplings, the incoming waves scooped out sediment from the bamboo tubes exposing the saplings. The tubes also provided ample hiding places for predatory crabs that ended up feeding on the propagules and saplings.

Figure 9.2 Growth performance of *Rhizophora* saplings at Gazi Bay



Earlier studies by Kairo (1995) in the same area provided suitable planting heights for different mangrove species in Gazi. The seaward zone is mostly suitable for *S. alba,* whereas *R. mucronata* prefer muddy substrate in sites receiving water at least twice every week; in the inundation class 3 of Watson (1928). Elsewhere in the world, saplings of *Rhizophora stylosa* have been reported to show reduced growth in low intertidal elevations (Smith 1987).

Although *R. mucronata* saplings in the present study were able to attain greater height increments they produced relatively few leaves per plant at 13 months as compared to *R. mucronata* planted in its natural site after 10 months (16.1 vs. 26.9; Kairo 1995). The leaves in the present experiment were also narrow and concentrated at the tip of the sapling; compared to saplings growing in ideal conditions whose leaves are uniformly distributed along the lead stem (Kairo

1995). Physiological explanations for observed condition could be that *R. mucronata* growing at low inundation tend to develop elongated shoots to enable the leaves to escape submersion.

Conclusion

This study aimed at testing whether we could use the easily cultivable mangrove species, *R. mucronata*, to control soil erosion. The inherent root architecture in *R. mucronata* (Tomlinson 1986) makes the species ideal for use in coastal protection. Under natural settings, the intertwined rooting complex of *Rhizophora* species stabilizes sediment by reducing erosive capacity of water passing through the root system (Wolanski *et al.* 1992). In fact, countries like Bangladesh have introduced large scale mangrove afforestation programs to minimize damage to coastal village and agricultural land from frequent cyclones (Saenger & Siddique 1993). The high mortality observed in encased saplings may be partly associated with poor installation of the bamboo tubing rather than natural causes. In the future we plan to experiment with different encasement types and installing saplings deeper into the sediment to reduce the probability of washing away.

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Summary

Horizontal distribution of mangrove species is a common phenomenon in mangrove ecosystems. In Kenya, where 9 species of mangroves occur, the seaward zone is normally occupied by *Sonneratia alba* and occasionally by *Rhizophora mucronata*. The present study was conducted in a low lying site previously dominated by *S. alba*. Our study aimed at testing the suitability of replanting *R. mucronata* propagules in low elevation site to control soil erosion and stabilize sediments. The experiment was set up in March 2005 with three treatments and a control group. *R. mucronata* propagules were planted directly into the sediment or inside bamboo encasements of various diameters. Field measurements included percentage mortality, shoot height increment (cm), diameter at second internode (mm), and leaf number. The results showed that the directly planted saplings had a significantly high % survival ($p=0.01$) as well as better growth performance ($p<0.01$) than the encased saplings. There was no significant difference between the bamboo treatments in both survival and growth performance.