Scientific Research and Essays Vol. 5(18), pp. 2801-2805, 18 September, 2010
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 ©2010 Academic Journals

Full Length Research Paper

Early growth and survival of *Avicennia alba* seedlings under excessive sedimentation

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Accepted 9 September, 2010

A field study of growth and survival of *Avicennia alba* seedlings was conducted at a reforestation site where excessive sediment accretion resulted in seedling burial. A nearby natural habitat, where the sedimentation was not active, was also monitored as control plot. Seedlings height and number of leaves increments and survival rates have been measured monthly as indicators of the growth performance. Seedlings at both sites have similarly produced 2 leaves per month while seedlings at the reforestation site showed a significantly higher stem elongation compared to those in the natural habitat. Higher stem elongation rate in the reforestation site could be attributed to exposure to higher level of sunlight. There was a significant difference between seedlings survival in the natural habitat and the reforestation site ($P < 0.05$), with 91.66 and 6.82% of the original 314 transplanted and 80 natural seedlings remaining, respectively. We postulate that more than 7 cm sediment burial could significantly increase the mortality of *A. alba* seedlings ($P < 0.05$). The results suggest that *A. alba* may not be suitable for rehabilitation projects in areas subject to high sedimentation.

Key words: *Avicennia alba*, mangrove, survival, growth, excessive sedimentation.

INTRODUCTION

Mangroves are unique salt-tolerant species which grow in the intertidal zone between terrestrial and marine systems along tropical and subtropical shorelines of the world. Despite the wide range of ecological and socio-economic benefits provided by mangrove ecosystem (Lewis, 2005; Bosire et al., 2008; Stone et al., 2008), the area of the world's mangrove forests has decreased by 35% during the last two decades of the 20th century (Valiela et al., 2001). In recent years the true value of mangrove forests has increasingly emerged. Consequently, great efforts have been made to restore mangroves in tropical and subtropical coastal regions around the world. However, these efforts were not often successful (Lewis, 2005) mainly due to lack of knowledge necessary to plan rehabilitation projects, especially with regard to species and site selection (Elster, 2000; Primavera and Esteban, 2008; Samson and Rollon, 2008).

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Ellison (1998) discussed the impacts of sedimentation excess on mangrove survival. More information was provided by Thampanya et al. (2002). These studies revealed that sediment burial could cause death to mangroves. However, the severity of the impact varies form species to species. The main objective of this study was to investigate the effect of sedimentation on stem elongation, leaf production and survival of *Avicennia alba* seedlings.

MATERIALS AND METHODS

This study was carried out in Carey Island situated in the state of Selangor, on the west coast of Peninsular Malaysia (Figure 1). This island is located within the Klang Isle, which is one of the mangrove forest reserves in the Strait of Malacca. Klang Isle Mangrove Forest Reserve is composed of 8 small islets, and Carey Island is the largest island separated from the mainland by the Langat River. The total area of this island is 16,187.45 hectares where 65% of it is planted with oil palm. An earth dike was build along the coastlines of the island to prevent salt water intrusion during high tides.

Saraswathy et al. (2009) recorded 16 species from 5 families (*Rhizophoraceae*, *Avicenniaceae*, *Meliaceae* *Sonneratiaceae* and

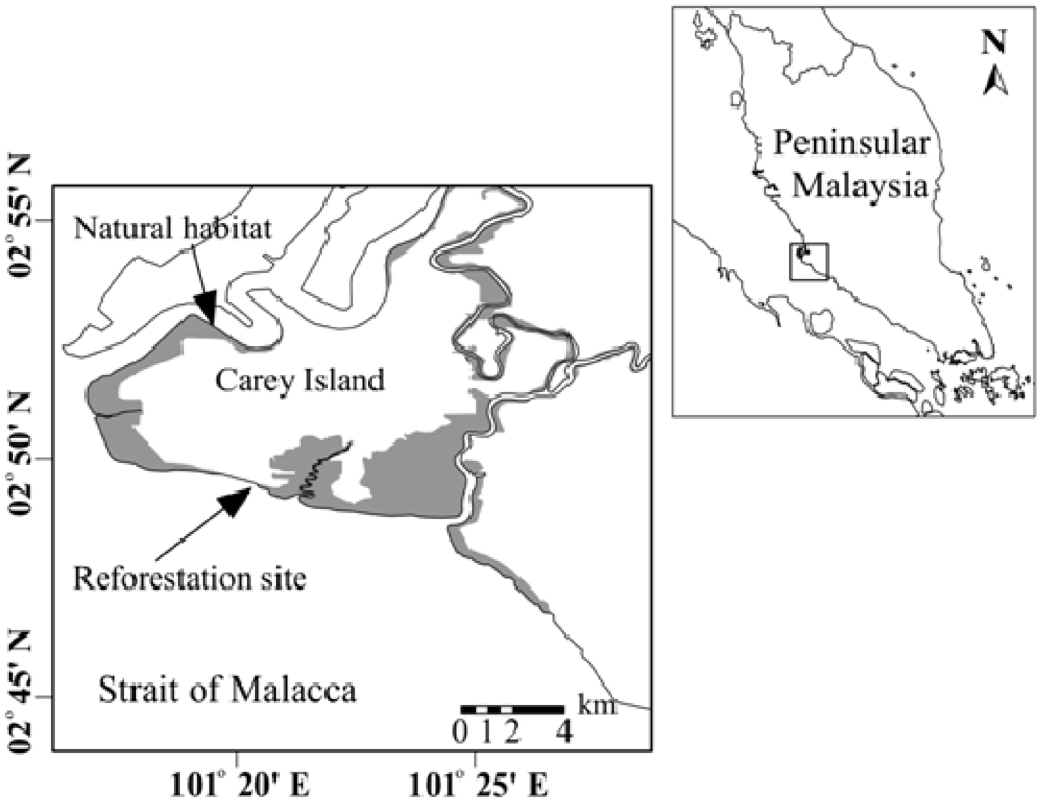

Figure 1. Map of the study area. Grey shade depicts the mangrove cover.

Rubiaceae) on Carey Island; *A. alba* was identified as the most dominant species in the area. They argue that the estimated biomass of mangrove trees on Carey Island is very low implying that the mangrove area is undergoing stress due to deforestation. The tropical climate of Peninsular Malaysia is mainly influenced by the Southwest monsoon (May – September) and the Northeast monsoon (November – March), with a period of change between the two monsoons that is often called transitional period which occurs in April and October. Heavy rainfalls often occur during these two transitional periods (Desa et al., 2001). Rainfall data for the study area was obtained from the West Estate Office, Sime Darby Plantation Berhad and Carey Island. In 2009, the total annual precipitation at the study site was 2220.51 mm; during this study the maximum and minimum monthly rainfalls were 372.30 mm in August and 112.20 mm in June, respectively. The tidal regime is semi-diurnal with an annual maximum range of 4.10 m.

The reforestation site is located in a barren area of intertidal zone (02°49'N and 101°20'E) that was previously occupied by a fringing mangrove forest (Figure 1). Old mangrove stumps were found in the area up to 300 m seaward of the current shoreline indicating the large-scale deforestation. The site receives daily tidal inundation (inundation class 2 of Watson (1928)); it is exposed frequently to waves from SW (during the Southwest monsoon) and W (during the Northeast monsoon). The subsoil at the site is stiff clay covered by a thin layer of silt loam. Muddy sediments were observed at the site during the Northeast monsoon that might be carried from the deep water to the shore by strong waves and currents of the Northeast monsoon.

The site is exposed to direct wave action which makes the environmental conditions very unfavorable for mangrove establishment. In order to provide suitable environmental conditions to transplant mangrove seedlings a low crested breakwater was introduced to the site. This structure shelters the site from wave action and storm attacks, replicating the same method introduced by Hashim et al. (2010). Breakwaters could reduce or dissipate the wave energy reaching the shore. Therefore, on the basis of a desk study, a breakwater was designed and constructed seaward the restoration area. This 80 m long rubble mound structure shelters an area of about 1700 m^2 (Figure 2).

The beach morphological changes have been monitored monthly. Measurements have been made at high resolution so that small-scale changes in the beach topography could be perceived. The survey was concentrated on the lee of the breakwater where the beach was more affected by the presence of the structure. The surveys have been conducted during low tides, using a high-end total station. An ecotechnological method was used in this study to grow the mangrove seedlings in coir logs. Coir logs are made of processed and loose coir pressed into polythene nets and tied at both ends. Two different sizes of coir logs were used; both were 3 m in length with different diameters of 200 and 300 mm. The seedlings of *A. alba* were collected from a natural mangrove habitat. Loose coconut coir was used to wrap round the seedlings roots and then tied with cotton strings to form plant plugs. To ensure that the roots are entwined with the coir, the plant plugs should be put in the brackish water for about a month before inserting into the coir logs (Hashim et al., 2010). One of the key advantages of planting the seedlings in the coir logs is to avoid damage to the roots during transplantation. Five plant plugs were planted in each coir log. Then the vegetated coir logs have been reared in the nursery for about 6 months (until the seedlings were hardened) at a light intensity of about 270 µmole m^{-2} s^{-1}; the seedlings were exposed gradually to direct sunlight before transplanting to the site. Light intensity ranged from 240 in the natural habitat (under the canopy) to 1432 µmole m^{-2} s^{-1} at the

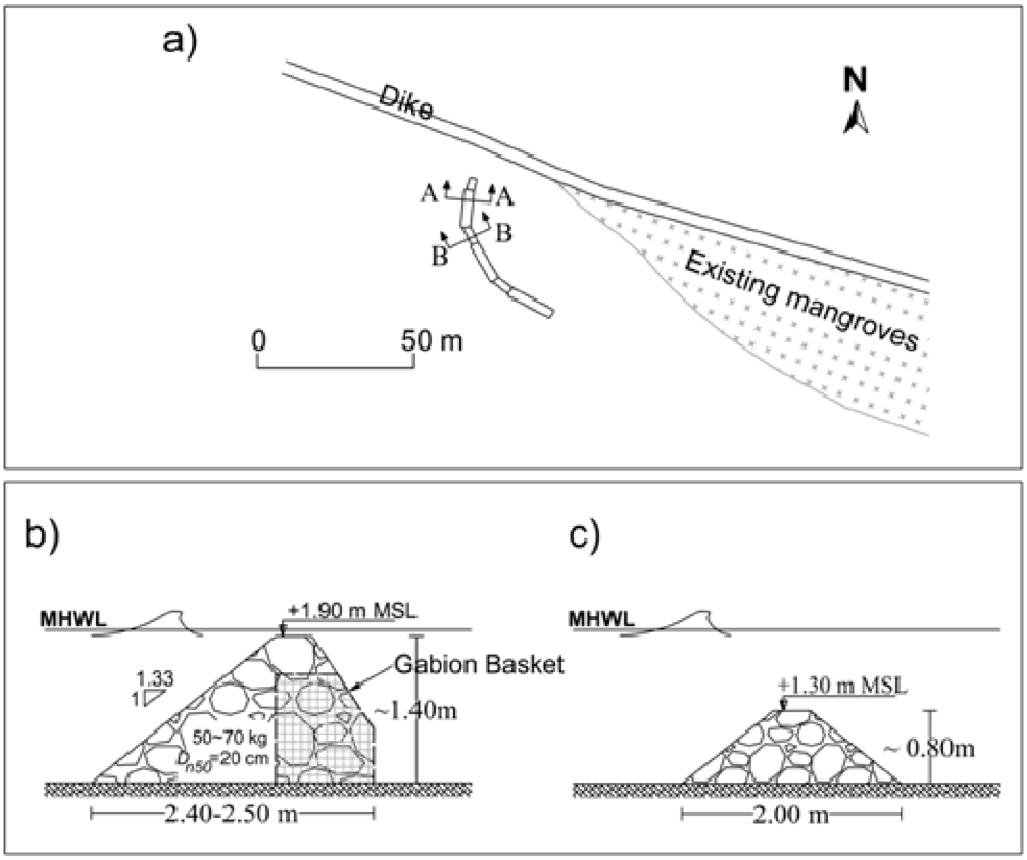

Figure 2. (a) plan view of the breakwater, (b) cross section of the breakwater A-A, (c) cross section of the breakwater at gaps B-B.

reforestation site (full sunlight). 73 pieces of coir logs carrying 314 *A. alba* seedlings were transplanted to the reforestation site on 23 April, 2009. The coir logs were installed between the shoreline and the breakwater in the form of grids divided into 7 plots as depicted in Figure 3.

A nearby mangrove natural habitat has been selected as a control plot for monitoring the performance of *A. alba* under natural conditions. This reference site is situated in an estuarine area (Figure 1), which is not exposed to the wave action. Being located at almost the same elevation as the reforestation site this natural habitat is flooded by daily tidal inundation (Watson inundation class 2). The substrate is sandy loam composed of 39% silt and 61% fine sand on average. Four subplots, each 25 m^2 were set up and 20 seedlings were picked randomly from each subplot to be monitored (monthly) for its growth.

Each seedling has been monitored monthly for its survival, height increment and number of new leaves produced. The rates of seedling height increment were translated into relative height increment rate because initial seedling sizes were slightly different. Survival rate was calculated from the number of seedlings survived divided by the total number of the original transplanted seedlings.

Salinity and pH in the soil water have been measured in each plot after low tides every month, with samples collected at depths of 10 and 20 cm from the soil surface. *In situ* measurements were conducted using IQ Scientific Multiparameter Probe. Sediment samples collected from the site by scraping the soil surface (~ 1 cm depth) have been taken to the laboratory for grain size analysis. Grain size distribution of granular soils (coarse sand) is often determined by sieving, and the sedimentation test using hydrometer is suit for finer soils (silt and clay).

RESULTS

The pH values in the soil water were almost similar in both sites, with a mean value of 7.23 ± 0.19 and 7.14 ± 0.21 in the reforestation site and the natural habitat, respectively. Salinity in the soil water was also very similar in both sites, ranging from 24.3 to 29.2 and 25.7 to 28.3 for the reforestation area and the natural habitat, respectively. Air temperature and relative humidity were almost the same in both sites. The study was carried out during the Southwest monsoon (May – September), by the end of September all the transplanted seedlings in the reforestation area died. Hence, the effect of seasonal variations could not be investigated in this study. The grain size distributions of the sediment samples collected from the reforestation area shows that the sediments deposited in the reforestation area were silt loam containing about 10% clay size particles (< 2 μm).

The survival rates of the seedlings at the reforestation site and in the natural habitat are shown in Figure 4. The

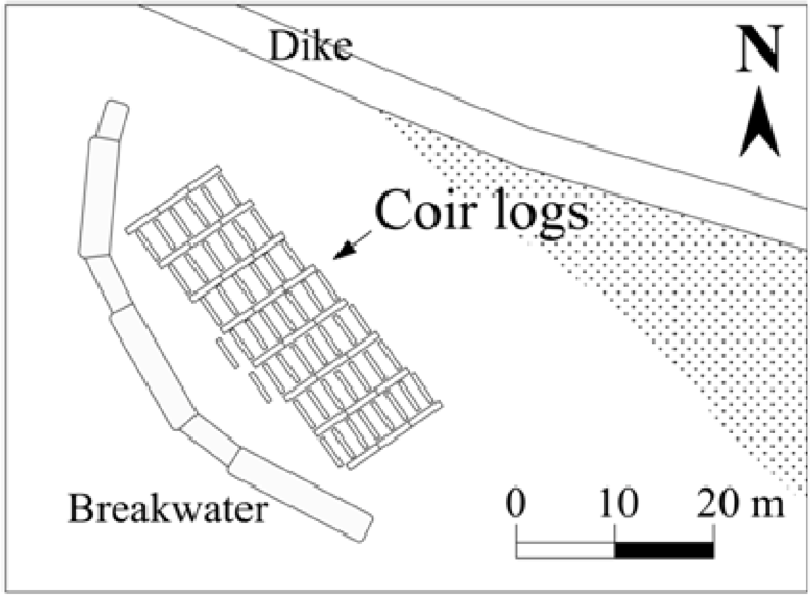

Figure 3. Vegetated coir logs in grid formation behind the breakwater at the reforestation site.

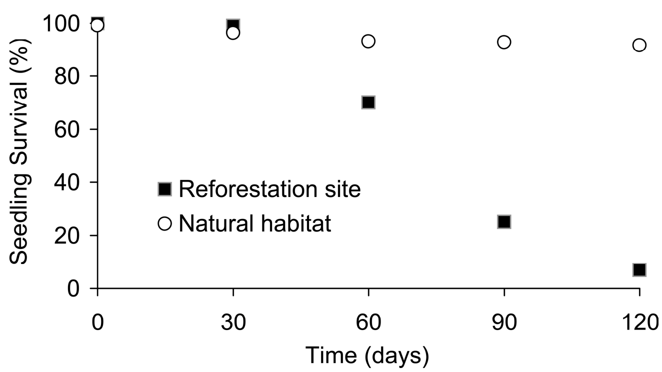

Figure 4. Survival rate of *Avicennia alba* seedlings at two different sites.

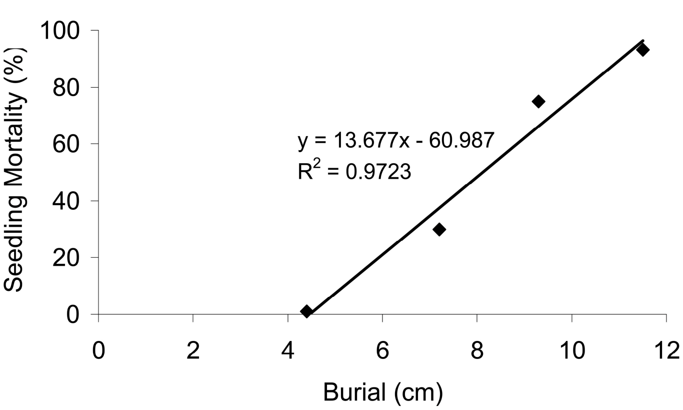

Figure 5. The relationship between sediment burial height and mortality of *Avicennia alba* seedlings at reforestation site.

seedlings in the natural habitat showed a significantly higher survival (91.66%) compared to those at the reforestation site with 6.82% survival at the end of the study period ($P < 0.05$). Sediment accretion rate in the vicinity of the breakwater was relatively high. The breakwater aimed at protecting the reforestation area by reducing the wave energy reaching the shoreline. Consequently, sediments carried by waves have been deposited in the sheltered area caused an excess of sedimentation. As depicted in Figure 5, there was a positive correlation between sediment burial height and mortality of *A. alba* seedlings.

Mortality was limited to about 30%, with 7.2 cm of sediment burial, 60 days after transplantation. However, the following month, an increase of about 2.1 cm in sediment height increased the mortality to 75%. Subsequently, a mortality of 93.18% was recorded after 4 months in the reforestation site that received 11.5 cm of sediments.

Relative height increments of surviving *A. alba* seedlings differs significantly ($P < 0.05$) between the reforestation site and the natural habitat (Figure 6). The monthly rates of relative increment in heights at the reforestation site and natural habitat were averaged at about 1.04 ± 0.06 (mean ± SE) mm cm^{-1} and 0.53 ± 0.04 mm cm^{-1}, respectively. The average number of leaves the seedlings produced was 2 leaves per month at both sites. The results suggest that sediment burial did not affect the growth rate of *A. alba* seedlings in our study site.

DISCUSSION

One of the physical factors known to affect the survival of

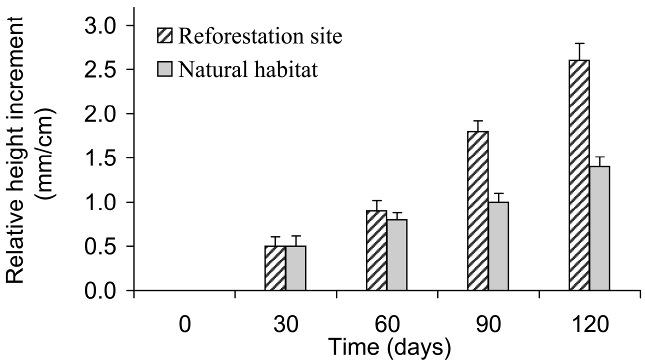

Figure 6. Relative height increment (mean + SD) of *Avicennia alba* seedlings at reforestation site and the reference site.

fringe mangrove seedlings is the wave action (Clarke and Myerscough, 1993; Kairo et al., 2001); the seedlings could be up-rooted and washed away or disturbed frequently by incident waves. The breakwater constructed seaward side of the reforestation site aimed to reduce the wave energy. However, the presence of this obstruction on the beach has resulted in sediment deposition in the sheltered area. Burial by sediments can result in mortality of mangrove trees and seedlings (Thampanya et al., 2002). For instance, burial beyond 10 cm could cause mortality to *Avicennia* trees as reported by Ellison (1998). Sediment burial can block aerial vents of the lenticels, declining the aeration process of the seedlings. The results of the present study proved that *A. alba* seedlings are sensitive to sediment burial beyond 7 cm. In addition, it was observed that about 9 cm burial significantly increased the mortality of the seedlings which is in agreement with observations made by Ellison (1998).

Contrary to the observations of Thampanya et al. (2002) on *A. officinalis*, smothering in sediments was found to have no significant effect on the growth rate of *A. alba* in our study. The lower height increment in the natural habitat could be due to shade condition caused by closure of canopy whereas exposure to direct sunlight could be contributed to higher stem elongation of *A. alba* seedlings in the reforestation site.

ACKNOWLEDGEMENTS

The support of University of Malaya and R and D Department, Sime Darby Plantation Berhad for funding this project is gratefully acknowledged by the authors. The support of Institute of Ocean and Earth Sciences and Institute of Biological Sciences, University of Malaya for providing the transportation and instruments is really appreciated.

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