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Potential of mangrove rehabilitation using different silvicultural treatments at Southeastern Coast of Egypt

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Key words: *Rhizophora mucronata,* Sea water salinity, Red sea mangrove, Silviculture, germination.

Abstract

Mangrove ecosystem has important ecological and socio-economic values in Egypt as it represents the primary natural forest on a country dominated by deserts. Large attentions have been paid for restoration and rehabilitation of mangrove communities in the last few decades. This study was carried out at the southeastern coast part of Egypt to provide baseline information of salinity tolerant and early growth of *Rhizophora mucronata* in addition; different silviculture treatments for mangrove regeneration were tested. Primary survey and results of this study indicated that the highest mangrove tree height of 2.97 m was noted at medium tides, while the lowest tree height of 2.5 m was recorded at the high tides. Overall, *Rhizophora mucronata* trees were growing better under low to medium tides comparing with high tides. The high level of salinity (80 % of sea water) had negativity affected growth of *Rhizophora mucronata* seedlings. Moreover, the highest values of blade length, blade width, leaf size, plant height, and number of nodes were achieved either with using 20 % or 40 % of sea water. Using wild seedling nursery transplanting technique was more suitable for establishment of mangrove seedlings and achieved the highest survival rate of 61 %. Wild seedling direct transplanting led to high mortality rate of 68 %. There was a significant difference among the propagation methods used in this study in dry shoot weight, dry root weight, total dry weight, number of leaves, and the survival rate; however, plant height was not affected by the silviculture treatments.

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Introduction

Egypt is predominantly a desert country and an important of timber and timber products, including those from the tropical forests. Along its Red Sea coast and islands it does however an important resource of natural mangrove forest has. Although small, this area contains significant biodiversity and is also an important source of income for the surrounding population. By virtue of their isolation, Egypt's mangroves are highly valuable internationally, as the unique genetic material they contain is part of a threatened global resource. Galal (2003) reported mangroves at 23 localities between latitudes 27° 40'N and 22° 33'N, most of which are only small patches or aggregations of stunted *Avicennia marina*. Generally, distribution and extent of the mangrove stands in Egypt are relatively small; they are dispersed along the Egyptian Red Sea coastline in sheltered bays and lagoons protected behind coral reefs (Gab-Alla *et al.*, 2010). Ecosystem services provided by mangrove communities include fuel wood, livestock grazing, traditional medicines, fisheries habitat, ecotourism, enhancing biodiversity, as well as protecting shoreline and controlling soil erosion.

Total area of mangrove stands in Egypt is about 550 ha and located mainly along the Gulf of Aqaba and the Red Sea coastlines and distributed over several small patches. Two plant species represent mangrove ecosystem in Egypt i.e. *Avicennia marina* and *Rhizophora mucronata* (Kassas and Zahran, 1967). The first mangrove species is the common type in Egypt, while *Rhizophora mucronata* exists in the southeastern coast of Red Sea (Galal, 1999). Avicennia marina is tolerant to relatively high salinity, low rainfall and temperature conditions. However, *Rhizophora mucronata* requires more humid conditions and is less tolerant to high salinity when comparing to *Avicennia marina*. Mangrove communities in this part of the world appear in patchy and scattered patterns and characterized by low biodiversity and harsh habitat of arid and highly saline conditions (Dahdouh-Guebas and Satyanarayana, 2012).

Little has been done with the Egyptian mangrove population. In part, this is because of limited national resources but also because of lack of information on both the constituents of the ecosystem and how to manage them sustainably. Overlying these issues is the dependency of the adjacent community on the resource for their livelihood. It is neither possible, nor acceptable, to simply prohibit use. The adjacent population is in reality part of the ecosystem and their needs must be incorporated fully into any recovery and sustainable management plans. Cutting of mangroves for a variety of purposes and land clearance for coastal development had led to significantly decreasing mangroves areas in Egypt. Therefore, there is a national need to frame, promote and implement policies and actions that ensure the conservation and sustainable utilization of the natural forest ecosystems of Egypt and to complement these with planted trees that enhance environmental and service values.

On the global scale, mangrove areas are becoming smaller or fragmented and their long-term survival is at great risk (Duke *et al.*, 2007). Cutting of mangroves for a variety of purposes and land clearance for coastal development had led to significantly decreasing mangroves areas in Egypt. Although destruction of mangrove communities is prohibited by law, they still suffer of the negative impact of human activities. Restoration of mangroves has received a lot of attention globally for many reasons including, the long ignored ecological and environmental values of mangrove forests have been documented for many mangrove areas in the world, there is a high subsistence dependence on natural resources from mangrove forests, and large losses of mangroves have occurred throughout the world leading to coastal erosion, decline of fishery resources and other environmental consequences, some of which in need of urgent attention (Kairo *et al.*, 2001).

Mangrove communities may recover without any active restoration efforts (Hamilton and Snedaker, 1984), however, due to harsh environmental conditions and negative human activities it is recommended to consider assisting the natural recovery of mangrove forests. There are several approaches for mangrove propagation such as direct planting of propagules collected from wild, outplanting of small seedling, direct planting of seedlings, and use of stem cuttings (Saenger, 2002).

There are some efforts for restoration mangrove forest in Egypt and research and experimental works were conducted to establish the baseline information of mangrove rehabilitation. But most of these researches focused on the common mangrove species i.e. *Avicennia marina*. However, little attention has given to *Rhizophora mucronata* as it has small area in southeastern coast of Egypt. Therefore, this study was conducted to examine Silviculture activities on *Rhizophora mucronata* rehabilitation including, direct re-transplantation of seedlings from the wild and from nurseries into selected areas, initiating new system by implementing the same activity in selecting sites void of mangrove plants but have potentialities for action, and rehabilitation of example of degraded mangroves stands applying additional needed measures. Salinity tolerance of *Rhizophora mucronata* was also examined at germination and early growth stages.

Materials and Methods

Study area

The study area is located at the southern part of the Egyptian coast of Red Sea and it belongs to the category of warm coastal desert. The annual mean temperature at the area is about 25.8 c. rainfall at the area is limited and it varies from year to year with an average of 17.8 mm/year. Soil characterizations in the study area are provided in Table (1).

Growth performance of Rhizophora mucronata

A pilot survey was carried out at the beginning of field work in spring of 2008 to describe the *Rhizophora mucronata* mangrove stands at the study area. Random belt transects were established perpendicular to the shoreline traversing the mangrove forest zone from the higher intertidal zone throughout lower intertidal till edge of mangrove stands on the back reef towards the seaward side. The number of transects sampled to study the mangrove stands were 4 transects distributed through the study area. Along each belt transect, five of 10 × 10 m quadrates were selected within the belt transect. At each quadrate, several tree parameters were recorded including tree height, trunk circumference, number of main branches, leaf area, number of aerial roots, number of seedlings, and size index.

Germination pots experiment

Seeds of *Rhizophora mucronata* were collected twice in spring of 2008 from naturally growing trees distributed along the Red Sea coast. Mature seeds were separated easily from the parent trees with a slight hand twist without the calyx according to Kairo (1995). After field collection, seeds were kept in moist plastic bags and protected from direct sunlight.

A preliminary germination pots experiment was conducted on the *Rhizophora mucronata* seeds under greenhouse conditions. Four salinity levels were used i.e. tap water, 20 % of sea water salinity, 40 % of sea water salinity, and 80 % of sea water salinity. Twenty seeds were used for each treatment and maintained for 6 months. Germination percentages were calculated for each treatment and continuous morphometric measurements were taken for seedlings grown in the different seawater concentrations over a period of six months. Growth parameters that were measured included, plant height (cm), stem diameter (cm), length of leaf blade (cm), average blade width (cm), leaf size (cm2), number of nodes, length of internodes (cm) and number of surviving leaves on shoots. Differences among the four salinity treatments were analyzed using the one-way ANOVA test. Statistically significant differences between treatments were assessed using Tukey's HSD significant difference (Lentner and Bishop, 1986; Zar, 1984).

Silviculture treatment experiment

Three different approaches were used for the *Rhizophora mucronata* mangrove propagation at the study area; these treatments were propagules nursery plantation, wild seedling direct transplanting, and wild seedling nursery transplanting. Propagules collection was carried out during summer of 2008, where collection was conducted by hand and only mature propagules were selected. Then, propagules raised in bags filled with sand inside intertidal nursery. During the same season, wild seedlings of *Rhizophora mucronata* were also collected, whereas seedling was removed by a metal core made of galvanized tube and then seedlings were placed directly into polyethylene bag and then placed at the shore line up to the collection time for the final plantation at the study area. Regarding, the wild seedling direct transplanting, the seedlings transported to the site in a low tide with sand shovel, and planted with density of 1 plant per square meter. For wild seedling nursery transplantations, seedling were transplanted temporary in intertidal nursery for 1.5 months then planted in the final plantation site (See Fig. below).

Results and discussion

Data in table 2 shows the growth performance of mangrove stand at Hamata area. Tree height and diameter were higher under low to medium tides compared with high tides areas. However, number of aerial roots and seedlings were higher under high tides in comparison with low and medium tides. The highest mangrove tree height of 2.97 m was noted at medium tides, while the lowest tree height of 2.5 m was recorded at the high tides. Overall, *Rhizophora mucronata* trees were growing better under low to medium tides comparing with high tides.

Table 1. Soil characteristics of the study area dominated by *Rhizophora mucronata* at Hamata, southeastern coast of Red Sea, Egypt.

Character	Value	Character	Value
Gravel %	0.70	Ca CO3 (meq/l)	26.70
Sand %	79.10	Na	327.80
Silt %	3.20	K	36.30
Clay %	17.10	Ca	23.70
Organic Carbon %	1.60	Mg	52.00
pH	6.70	Cl	294.00
EC (mS/cm)	136.70	SO4	0.90

Table 2. Growth performance of *Rhizophora mucronata* growing in pure population at low, medium, and high tides at southeastern coast of the Red Sea, Egypt.

Growth character	Low tides	Medium tides	High tides
Tree height (cm)	281.0	297.0	250.7
Length (cm)	187.7	210.0	162.7
Width (cm)	168.3	179.5	148.3
Size index (cm)	212.3	229.0	187.0
Trunk circumference (cm)	27.6	24.0	19.7
No. of main branches	19.3	21.0	17.0
No. of lateral branches	46.3	56.5	41.7
Leaf area (cm^2)	320.3	345.5	290.0
Leaves number	19.9	17.4	16.2
No. of aerial roots	296.0	287.0	422.0
No. of seedlings	159.0	311.0	386.0

Response of *Rhizophora mucronata* seeds and seedling to different salinity levels of sea water is presented in table 3. Overall results indicate that the high level of salinity (80 % of sea water) had negativity affected growth of *Rhizophora mucronata* seedlings. The highest values of blade length, blade width, leaf size, plant height, and number of nodes were achieved either with using 20 % or 40 % of sea water. Similar results were reported by Gab-Alla *et al.* (2003).

Table 3. Mean values of growth parameters recorded for *Rhizophora mucronata* plants grown for 6 months in different seawater dilutions. Mean values followed by different letters are significantly different at the $P < 0.05$ level.

Growth parameters	Sea water percent			
	0	20	40	80
Length of blade (cm)	5.23[a]	8.17[b]	7.25[b]	3.65[a]
Width of blade (cm)	1.63	2.15	2.01	1.54
Leaf petiole length (cm)	1.12	0.83	0.91	1.03
Leaf size (cm^2)	12.31[a]	15.71[b]	16.31[b]	9.2[a]
Plant height (cm)	24.35[a]	35.25[b]	33.78[b]	12.30[c]
Number of nodes	3.56	4.69	4.32	2.56
Internodal extension (cm)	10.41[a]	13.81[b]	12.11[a]	8.7[a]
Stem diameter (cm)	0.35	0.43	0.48	0.29
Surviving leaves on shoots	4.3	5.3	4.6	3.8

Table 4. Growth parameters of *Rhizophora mucronata* as influenced by three different silviculture treatments at southeastern coast of the Red Sea, Egypt.

Silviculture treatments	Dry shoot	Dry root	Total dry	Height (cm)	No. of leaves	No. of nodes	Root/shoot ratio	Survival (%)
Propagules nursery plantation	4.7a	1.9a	6.6a	51.3	8.5a	5.8a	0.40	47a
Wild seedling direct transplanting	9.2b	5.7b	14.9b	55.3	10.4b	8.6a	0.62	32b
Wild seedling nursery transplanting	7.8b	4.9b	12.7b	58.4	15.3c	11.2b	0.63	61c

Plant height was highly impacted with increasing salinity level, whereas the highest value (35.25 cm) of mangrove height was recorded under using 20 % of sea water and the lowest value (12.30 cm) was recorded at using 80 % of sea water. Vistro and de Soyza (2001) found that 50 % of sea water was more suitable for seedling emergence, growth and physiology of *Rhizophora mucronata* in comparison with higher sea water levels. Salinity has been reported as a limiting factor influencing mangrove growth (Price *et al.*, 1987). In general, the study shows that greenhouse production of *Rhizophora mucronata* plants is simple and successful; this has positive influence for in situ restoration and rehabilitation programs of mangrove ecosystem.

Results presented in table 4 show the effect of silviculture treatments of growth characteristics of *Rhizophora mucronata* at southeastern part of the Red Sea in Egypt.

Using wild seedling nursery transplanting technique was more suitable for establishment of mangrove seedlings and achieved the highest survival rate of 61 %. Wild seedling direct transplanting led to high mortality rate of 68 %. There was a significant difference among the propagation methods used in this study in dry shoot weight, dry root weight, total dry weight, number of leaves, number of nodes, and the survival rate; however, plant height was not affected by the silviculture treatments.

Fig. 1. Seedlings and intertidal nursery of *Rhizophora mucronata* grown at the study area at Hamata, southeastern coast of Red Sea, Egypt.

Fig. 2. Establishment of of *Rhizophora mucronata* seedlings at the study area at Hamata, southeastern coast of Red Sea, Egypt.

These results could provide valuable information regarding mangrove restoration in the coastal line in the Red Sea of Egypt. Similar results were reported by Al Sayed (2009) where he mentioned that propagation of *Avicennia marina* were very successful in Sinai, Egypt and the overall proportion of seedlings surviving to 16 months was 61 % for wild nursery transplanted seedling, 41 % for wild seedling direct transplantation, while results from direct propagules sowing was 53 %.

Conclusion

This study was carried out at Hamata area at the southeastern coast of the Red Sea, Egypt to investigate the potential of restoration of mangrove (*Rhizophora mucronata*) using different propagation methods. Survey of natural growing mangrove tree in the area was also conducted to evaluate the growth performance of *Rhizophora mucronata*. As this mangrove species sensitive to high levels of salinity comparing to other mangrove species, greenhouse experiment was also carried out to estimate the proper sea water level for seed germination and growth performance. Using 20 % to 40 % of sea water was giving the highest growth performance of *Rhizophora mucronata*.

Results indicate that there was a significant difference among the propagation methods used in this study in dry shoot weight, dry root weight, total dry weight, number of leaves, number of nodes, and the survival rate; however, plant height was not affected by the silviculture treatments. Overall results indicate that the high level of salinity (80 % of sea water) had negativity affected growth of *Rhizophora mucronata* seedlings. The highest values of blade length, blade width, leaf size, plant height, and number of nodes were achieved either with using 20 % or 40 % of sea water.

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