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ECOPHYSIOLOGICAL RESPONSES OF *RHIZOPHORA MUCRONATA* L. PLANTED ON THE RED SEA COAST OF TRASACTIONS OF MINERAL FERTILIZATION AND PLANTING DISTANCES

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An experiment was conducted to assess the effect of NPK fertilizer (20: 20: 20), with control and two concentrations (250 mg/100 L and 500 mg/100 L), two distances (1 m and 2 m) in two different plantation sites, Hamata and Safaga at the shoreline of the Red sea. The average of growth parameters of *Rhizophora mucronata* seedlings (height, number of branches/plant, number of leaves/plant, fresh and dry weight/ plant) are determined, after three and six months of plantation. At the end of experiment, the photosynthetic pigments content (chlorophyll a, chlorophyll b and carotenoids) are determined in the seedlings in both the two sites and at different plantation distances. The data indicated that, most of growth parameters of *R. mucronata* seedlings were higher in Hamata locality compared with in Safaga locality. Fertilization by 500 mg/100 L NPK is essential for good and healthy growth of *R. mucronata* seedlings. Planting distance 2 × 2 m was more suitable for healthy growth of *R. mucronata* seedlings. The study showed successful propagation of *R. mucronata* in new sites about 500 km northward its natural distribution range on the Red Sea coast of Egypt.

Keywords: red mangrove, propagation, NPK fertilization, growth parameters, phytomass, pigments

INTRODUCTION

Mangroves are a dominant form of vegetation along tropical coasts. The distribution of mangrove in Egypt is limited by aridity and site topography. Regarding mangroves, as with other flora, only a small number of species can grow in such an arid and highly saline habitat. Therefore, almost all mangrove forests in the Red Sea area, including the Gulf of Aqaba, are pure forests of *Avicennia marina*, occasionally mixed with *Rhizophora mucronata* in the southern part of the Red Sea from Mersa El-Madfa (Lat. 23°N) till Mersa Halaib, on the Sudano-Egyptian border (Kassas and Zahran, 1967).

Mangroves as an ecosystem are capable of performing certain functions or environmental services. The *Rhizophora* is considered the most important of all mangrove genera across the Pacific tropical and subtropical region (Sharma et al., 2010). The bark, root, leaves, fruit, and flowers of *R. mucronata* have been used in traditional medicine in South Asian countries including India for treating diabetes, diarrhea, hepatitis, inflammation, wounds and ulcers, etc. *R. mucronata* is considered to have astringent, antidiarrhoea, antiemetic and haemostatic properties (Kokpol et al., 1990). Mangroves are among the most carbon-rich biomes, containing an average of 937 tC ha^{-1}, facilitating the accumulation of fine particles, and fostering rapid rates of sediment accretion (~5 mm year^{-1}) and carbon burial (174 gC m^{-2} year^{-1}). Mangroves account for only approximately 1% (13.5 Gt year^{-1}) of carbon sequestration by the world's forests, but as coastal habitats they account for 14% of carbon sequestration by the global ocean (Daniel, 2012).

El-Khouly and Khedr (2007) studied the variations in the distribution pattern and growth attributes of the two mangrove species *Avicennia marina* and *Rhizophora mucronata* as related to soil factors and tide levels were investigated along the Red Sea coast, Egypt. They found that the plant height, size index, trunk circumference, number main and lateral branches, leaf number and area and the number of seedlings of *R. mucronata* was high in pure patches than when grow mixed with *A. marina*. The variation in tide level showed no significant effects on the growth parameters of *R. mucronata* growing in pure community. The species belonging to the genera *Rhizophora* produce one propagule per fruit and the same is collected and used for planting. The characteristics of *R. mucronata* mature propagule are yellowish colored about 1.5 cm wide band (abscission collar) on the upper part of the propagule adjacent to pericarp develops on maturity. Mature propagules can be plucked with slight application of force. Fully mature propagules will also fall on shaking the tree or branches. When the collar reaches about 1.5 cm in length, the propagule leaves the pericarp.

Many previous studies showed that growth of mangroves is strongly affected by low nutrient availability (Reis et al, 2017). Also, some field fertilization studies are conducted by Boto and Wellington (1983), Feller (1995), Lovelock et al. (2007) and Naidoo (2009). In these experiments, they have demonstrated that mangrove plant growth and biomass production respond with great sensitivity to variations in nutrient concentrations. Miah et al. (2019) studied the effect of nitrogen, phosphorus and potassium (NPK) fertilizers on seedling growth and survival of five mangrove species in Bangladesh for nine months. They found that seedlings height growth of *Excoecaria agallocha* was enhanced significantly with the application of NPK fertilizers but it was shown negatively significant effect on height growth of *Xylocarpus mekongensis* after second time fertilizer application. Fertilization has not been practiced in Egypt mangrove forestry service. Susiana (2015) stated the fertility of mangroves in Indonesia is supported by the site and its planting media, high rainfall, as well as mud or coastal sediments that are suitable for mangrove to grow including mangrove species.

Mangrove ecosystem in Egypt facing the impact of tourism not only in the north of the Red Sea coast but also in the southern Red Sea, where growing tourism investment plans will potentially cause environmental impacts on a regional scale. Also, mangrove forests in Egypt subjects to encroachments represents in establishments of the tourist resorts; and pollution by the waste and oil ships. It is severely need to rehabilitation of the degraded sites of mangrove on the Red Sea coast and establishing new areas of mangrove seedlings along the coast.

This study aims to identifying the effect of different concentrations of NPK fertilizers and different planting distances on growth performance and the ecophysiological responses of *R. mucronata* planted on the Red Sea coast of Egypt in order to reach to the best practices for germination and cultivation of this plant.

MATERIALS AND METHODS

1. Study Area

Two sites are selected for cultivation of *R. mucronata* on the Red Sea Coast (Fig. 1), the first one 18 km south of Safaga (N: 26 61 54 160, E: 34 01 20 620), the second site, 1 km south Hamata, about 320 km south Safaga (N: 24 30 17 560, E: 35 3618200).

The climate of the Red Sea coastal land of Egypt is arid. The means of 30 years (1945-1975) from the climatic Normals of Egypt (Anonymous, 1979) showed that, the mean annual rainfall ranges from 25 mm in Suez, 4 mm in Hurghada to 3.4 mm in Qusseir. The main bulk of rain occurs in winter, i.e. Mediterranean affinity, and summer is, in general, rainless. Variability of annual rainfall is not unusual. Temperature is high and ranges between 14 and 21.7°C in winter and 23.1–46.1°C in summer. Relative humidity ranges from 43% in summer to 65% in winter. The Piche-evaporation is higher in summer (13.7–21.5 mm/day) than in winter (5.2–10.4 mm/day).

2. Plantation in Nursery

R. mucronata seeds (propagules) are collected in July, 2017. Two nurseries are established for propagation of *R. mucronata* seeds sites at the shoreline of the Red Sea, where sea water seeps to the nursery at the high tide and irrigate the seedlings. The first nursery established in Safaga and the second in Hamata, near the plantation sites. The propagation bags in each nursery fill with soil from mangrove sites near each nursery. The seeds of *R. mucronata* are soaked in sea water 24 hours before plantation. At the end of July, the seeds are planted in the bags.

After 3 months from seeds plantation in the nursery, the aerial parts of *R. mucronata* seedlings were sprayed by compound fertilizer containing equal percentages of NPK (20% N -20% P - 20% K). The fertilization is conducted in two levels, 250 mg / 100 L and 500 mg / 100 L and without fertilization as control. An amount of 12.5 g was added to 10 L of water and then sprayed on the plant leaves and vegetative plants and 25 g of fertilizer were added to 10 L of water and then sprayed on the leaves and vegetative mass. The leaves and vegetative mass were sprayed with 10 L of tap water for control.

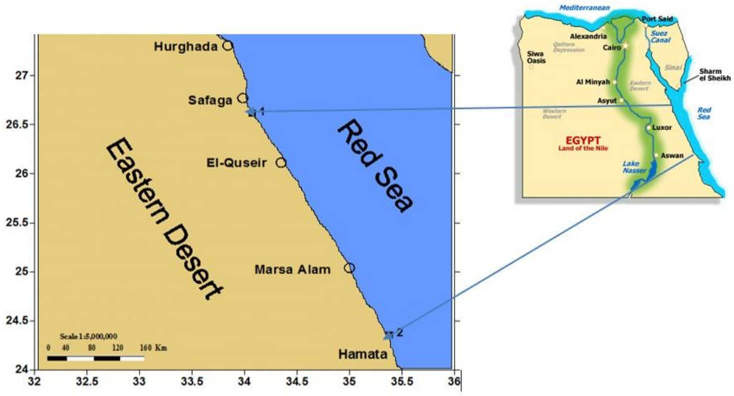


Fig. (1). Map of plantation sites of *Rhizophora mucronata* on the Red Sea coast of Egypt.

The seedlings of *R. mucronata* were sprayed three times during year before transplanting. After one year from plantation in nursery in August, 2018, ten random replicates from the seedlings in each treatment and in each nursery were investigated and the growth parameters were determined. The average of growth parameters in Safaga nursery of ten *R. mucronata* seedlings (height of seedling, number of branches/seedling and number of leaves/seedling) without fertilization (control) were 54.0 cm, 2.4 and 10.4, respectively. While, the seedlings treated with 250 mg/100 were 64.2 cm, 2.5 and 11.9, respectively, meanwhile, the average of growth parameters of seedlings planted treated with 500 mg / 100 L NPK were 62.5 cm, 2.8 and 14.1, respectively. The average of growth parameters of *R. mucronata* seedlings (height of seedling, number of branches/seedling and number of leaves/seedling) planted in Hamata nursery of seedlings without fertilization (control) were 54.0 cm, 1.3 and 6.4, respectively. While the seedlings treated with 250 mg / 100 L NPK were 61.6 cm, 1.4 and 8.2, respectively. Meanwhile, the seedlings treated with 500 mg / 100 L NPK were 68.0 cm, 1.4 and 9.0, respectively (Fig. 2).

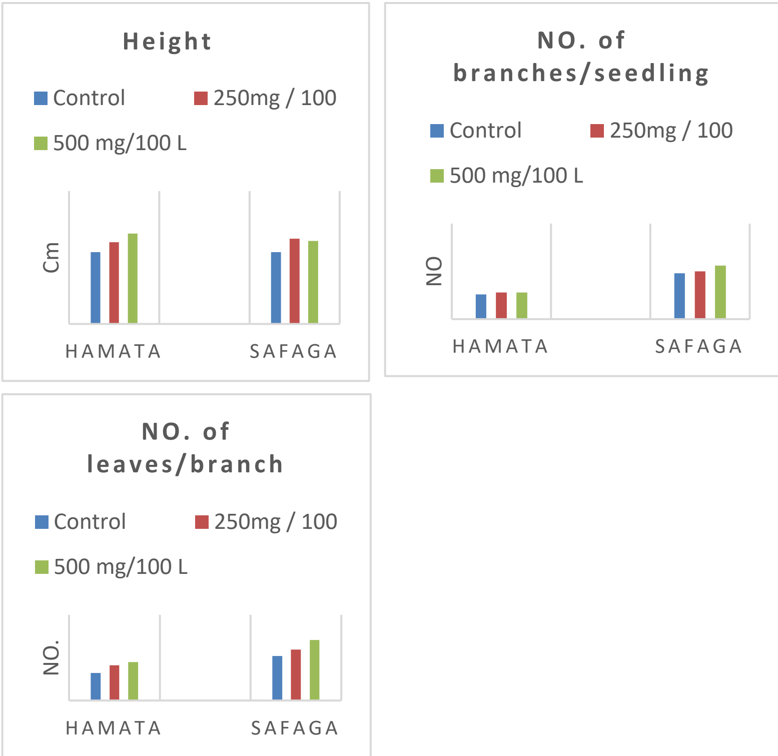


Fig. (2). The Effect of mineral fertilization on growth parameters of *R. mucronata* seedlings in nursery.

3. Plantation in the Field

R. mucronata seedlings that were treated with mineral fertilizers and those without fertilization as control were transplanted to the plantation sites in Safaga and Hamata in August, 2018. In each site, the seedlings of *R. mucronata* were planted in two distances (1× 1 m) and (2 × 2 m).

After plantation in the field, the seedlings were sprayed by compound fertilizer containing the percentages of NPK. The fertilization is conducted in two levels, 250 mg / 100 L and 500 mg / 100 L and without fertilization as control. The seedlings were sprayed two times in August and November, 2018 in both sites, Safaga and Hamata.

4. Soil Analysis of Plantation Sites

Three soil samples (0-20 cm depth) were collected randomly from each locality and were mixed together to form one composite sample. The samples were air dried and sieved through a 2 mm sieve to get rid of debris and coarse gravel. The samples were analyzed for the determination of soil texture, electrical conductivity (EC), cationic and anionic compositions according to Richards (1954) and Jackson (1963).

5. Water Analysis of Plantation Sites

A Sample of water was collected from the two plantation sites of *R. mucronata*. The water analyses for cationic and anionic compositions were carried out according to the methods adopted by ASTM (2002).

6. Determination of Growth Parameters

Ten random replicates from *R. mucronata* planted seedlings were treated with 250 mg / 100 L, 500 mg / 100 L NPK and the control in both of the two plantation sites were determined twice, 3 months after plantation in November, 2018 (R1) and six months after plantation in February, 2019 (R2). The average of growth parameters of *R. mucronata* seedlings (height of seedling, number of branches/seedling, number of leaves/seedling, and fresh and dry weight) treated with fertilizers and the control in both of the two plantation distances in both of plantation sites were determined.

7. Estimation of Photosynthetic Pigments

At the end of experiment after six months from plantation in the field, the photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) in the seedlings were determined in both of the two plantation distances in both of plantation sites were determined using the spectrophotometric method recommended by Metzner et al. (1965). A fresh weight of leaves was homogenized in 85% aqueous acetone for 5 minutes. The homogenate was centrifuged and the supernatant was made up to 100 ml with 85% acetone. The extraction was measured against a blank of pure 85% aqueous acetone at three wavelengths of 452.5, 644 and 663 nm using Spekol Spectrocolourimeter VEB Carl Zeiss. Taking into consideration the dilutions made of the pigment fractions, chlorophyll a, chlorophyll b and carotenoids were determined as µg/ ml using the following equations: Chlorophyll a (µg/ml) = 10.3 E663 - 0.918 E644, chlorophyll b (µg/ml) = 19.7 E644 - 3.87 E663 and carotenoids (µg/ml) = 4.2 E452.5 - (0.264 chlorophyll a + 0.426 chlorophyll b). Where E denotes absorbance. Then the fractions were calculated as mg/100g fresh weight of leaves.

8. Statistical Analysis

All data obtained from the experiment were subjected to the proper statistical analysis of variance of the complete plot design according to the procedure outlined by Snedecor and Cochran (1969). Mean values of treatments were differentiated by using L.S.D at 5% level as mentioned by Steel and Torri (1960).

RESULTS

1. Soil Characteristics of the Plantation Sites

Table (1) shows that, the percentages of coarse sands in the two selected sites for plantation are relatively similar, while the percentages of gravel, silt and clay were higher in Hamata site than in Safaga site; meanwhile, the percentage of fine sand was higher in Safaga site than in Hamata site. The soil in the two plantation sites is alkaline. The highest value of pH, soil salinity, TDS, Ca, Mg, Na, K, HCO_3^-, SO_4^{-2} and Cl^- are recorded in Safaga site than in Hamata Site (Table 2).

Table (1). Soil texture fractions percent (%) in the plantation sites of *Rhizophora mucronata* seedlings.

Site	Gravel	Coarse sand	Fine sand	Silt	Clay
Safaga	1.1	30.0	56.1	4.0	8.8
Hamata	2.2	32.0	43.0	11.4	11.4

Table (2). Chemical proprieties of soil in the plantation sites of *Rhizophora mucronata* seedlings.

Site	pH	EC	TDS	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	SO_4^{-2}	Cl^-
		mS/cm	g/L	g/L	g/L	g/L	g/L	g/L	g/L	g/L	g/L
Safaga	8.2	10.870	6.662	0.165	0.182	1.949	0.082	0	0.172	1.113	3.086
Hamata	7.7	7.440	4.336	0.099	0.117	1.251	0.073	0	0.066	0.789	1.973

2. Water Characteristics of the Plantation Sites

The water samples in the two sites are alkaline. Similar to soil properties, the highest value of water salinity, TDS, Ca, Mg, Na, K, CO_3^{-2}, HCO_3^-, and Cl^- are recorded in Safaga site than Hamata site, while SO_4^{-2} was relatively high in Hamata site (Table 3).

Table (3). Chemical characteristics of water in Safaga and Hamata sites planted by *Rhizophora mucronata* seedlings.

Site	pH	EC	TDS	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	SO_4^{--}	Cl^-
		(mS/cm)	(g/L)	(g/L)	(g/L)	(g/L)	(g/L)	(g/L)	(g/L)	(g/L)	(g/L)
Safaga	7.8	60.600	42.281	0.542	1.485	14.500	0.375	0.025	0.107	5.120	20.100
Hamata	8.0	59.700	42.271	0.523	1.463	14.350	0.355	0.023	0.104	5.585	19.920

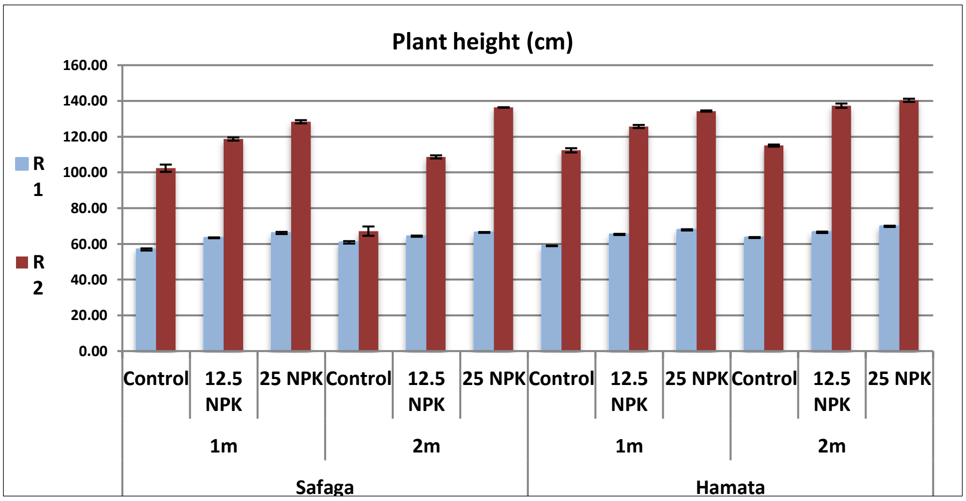
3. Effect of Planting Site on Growth Performance of *R. mucronata*

3.1. Effect of planting site on the growth parameters

Figs. (3 and 4) show that, after three months from plantation (R1), there is no significant differences between Safaga site and Hamata site in the average of all growth parameters of *R. mucronata* seedlings (height, number of branches and number of leaves/plant). After six months from plantation (R2), the average of all growth parameters of *R. mucronata* seedlings (height, number of branches and number of leaves/plant) showed highly significant variation in Hamata site (112.3 cm, 6.0 and 29.67/plant) compared with Safaga site (102.3 cm, 5.33 and 26.0/plant) respectively, regardless the fertilization treatments and the planting distances (Table 4). The above-mentioned results were supported by the interaction effect between the planting sites and all treatments concentration of fertilization used, where the average of all growth parameters of seedlings were high in Hamata than in Safaga, unless the plant height was not significant (Table 4). Analysis of data indicated that, after (R2), there were significant differences between both of the planting distances that were implemented 1×1 m and 2×2 m spacing in both of plantation localities for all growth parameters determined, where the values of all growth parameters measured in 2 × 2 m spacing at Hamata locality were higher than that in Safaga locality (Table 4).

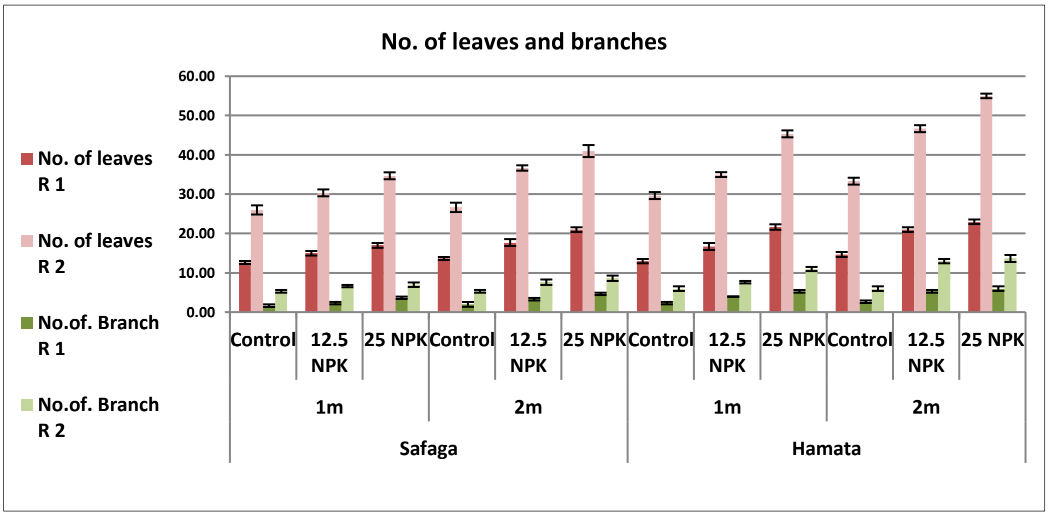
3.2. Effect of planting sites on the fresh weight and dry weight

The data in Fig. (5) show that, after six months from plantation of *R. mucronata* seedlings, the average values of fresh weight/plant and dry weight/plant (g) were high significant in Hamata site (92.77 g and 47.57 g/plant, respectively) more than in Safaga site (89.47 g and 41.37 g/plant, respectively) regardless the plantation density and the fertilization treatments. These data were supported by the interaction effect between the plantation sites and the two planting distances, where the values of fresh weight/plant and dry weight/plant (g) were high significant in Hamata site than in Safaga site among both of the implanted plantation distances (Table 4).



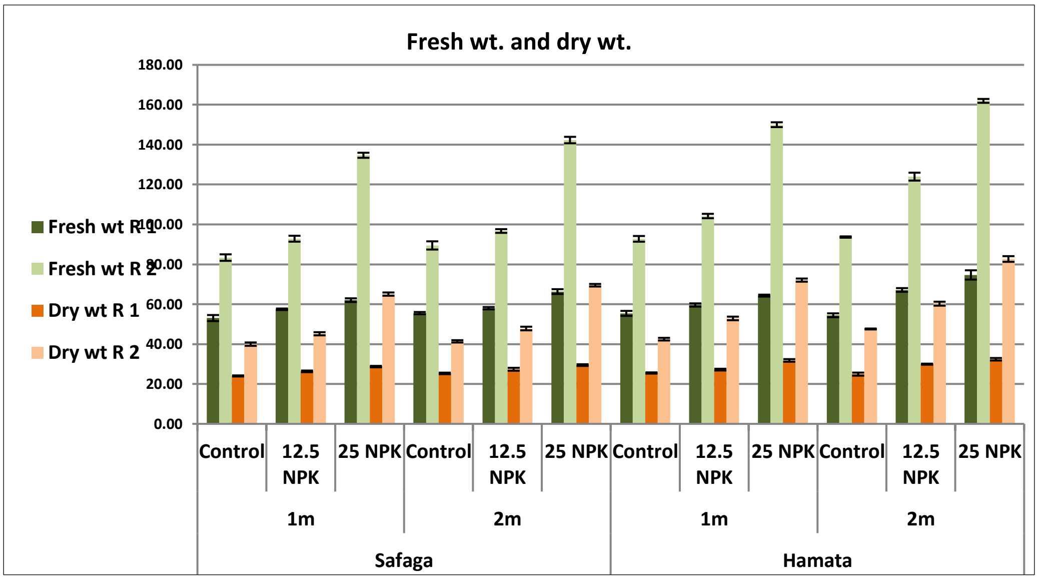
(R1= after 3 months, R2= after 6 months). Values are means SE.

Fig. (3). Effect of mineral fertilization on plant height of *Rhizophora mucronata* plants during six months after plantation in two sites at the Red Sea coast.



((R1= after 3 months, R2= after 6 months). Values are means ±SE.

Fig. (4). Effect of mineral fertilization on number of leaves and branches of *Rhizophora mucronata* during six months after plantation in two Sites at the Red Sea coast



(R1= after 3 months, R2= after 6 months). Values are means SE

Fig. (5). Effect of mineral fertilization on fresh weight and dry weight of *Rhizophora mucronata* planted during six months after plantation in two sites at the Red Sea coast.

Table (4). Three-way ANOVA showing the effect of site, distance and fertilizer on final growth parameters of *Rhizophora mucronata* planted along the Red Sea coast of Egypt.

		Growth parameters							
Source of variation	**DF**	**Plant height**	**No. of branches**	**No. of leaves**	**Fresh wt.**	**Dry wt.**	**Carotenoids**	**Chl. a**	**Chl. b**
Site (S)	1	90.16 ***	49.50***	37.43***	58.02***	121.29***	2.41***	10.76***	31.37***
Distance (D)	1	77.68***	16.84***	49.83***	64.73***	21.48***	26.43***	6.29***	144.04***
Fertilizer (F)	2	321.31***	70.73***	137.39***	76.18***	141.94***	20.01***	8.96***	16.05***
S*D	1	3.14***	0.00NS	0.02NS	25.61***	13.11***	4.72***	0.22NS	0.95***
S*F	2	0.44 NS	3.35***	4.95***	0.90***	0.38NS	6.42***	4.95***	8.94***
D*F	2	18.93***	1.63***	3.17***	4.77***	1.46***	3.46***	19.07***	6.96***
S*D*F	2	0.71**	0.26NS	3.42***	1.01***	4.50***	6.98***	2.41***	1.37***

n= 10, F-values are presented followed by level of significance NS= not significant; **= P<0.01; *** =P< 0.001

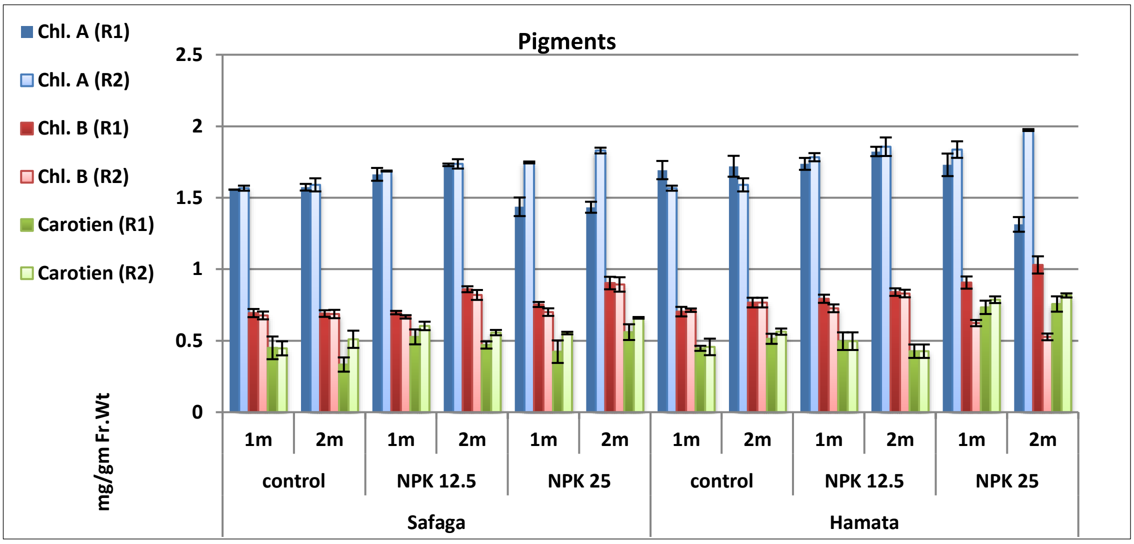
3.3. Effect of planting site on the photosynthetic pigments

Fig. (6) shows that the highest values of all photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) recorded in Hamata site (1.74, 0.80 and 0.62 mg/g F.wt, respectively) were higher than of Safaga site (1.58, 0.74 and 0.54 mg/g F.wt, respectively). There were significance differences between the two sites in the values, regardless the fertilization treatments and the planting distance (Table 4). The interaction effect between the plantation sites and the two planting distances showed that, after six months from plantation in the field, there was no significant differences in the values of chlorophyll a, while there were high significant variations in the values of chlorophyll b and carotenoids in Hamata site than in Safaga site. Also, the interaction effect between the plantation sites and fertilization concentrations showed significant effects on pigments (Table 4).

4. Effect of Mineral Fertilizers on Growth Performance of *R. mucronata*

4.1. Effect of mineral fertilizers on the growth parameters

The results in Figs. (3 and 4) show that, after three months (R1) and six months from plantation (R2), there were significant differences in the growth parameters of *R. mucronata* (height, number of branches/seedling, and number of leaves/plant) among the NPK concentrations used regardless of the planting sites and the planting distances, where the growth parameters of *R. mucronata* plants treated with NPK 500 mg / 100 L had the highest values (140.3 cm, 13.7 and 55.5/plant) followed by the seedlings that were treated with 250 mg / 100 L NPK (137.3 cm, 13.0 and 46.7/plant) compared with control (115.0 cm, 6.0 and 33.3/plant). The above-mentioned results were supported by the interaction effect between the fertilization treatments and the planting distances, where the highest values of *R. mucronata* plants in all growth parameters measured were attained in the seedlings treated with NPK 500 mg / 100 in 2 × 2 m spacing. As well as the interaction effect between the fertilization treatments and the planting sites, indicating that, the highest values of growth parameters were attained in the seedlings treated with NPK 500 mg / 100 L in Hamata locality (Table 4).



(R1= after 3 months, R2= after 6 months). Values are means -C 1 SE.

Fig. (6). Effect of mineral fertilization on pigments of *Rhizophora mucronata* planted during six months after plantation in two sites at the Red Sea coast.

4.2. Effect of mineral fertilizers on fresh weight and dry weight

Fig. (5) shows that there were significant differences in the values of fresh weight and dry weight/plant (g) of *R. mucronata* seedlings treated with 500 mg / 100 L NPK, which were significantly higher in both R1 (74.7, 32.4 g, respectively) and R2 (161.9 and 82.7 g, respectively) than that in control and that treated with 250 mg / 100 L NPK, regardless of the planting sites and the planting distances. These data were supported by the interaction between the NPK fertilization and the planting distance, indicating that, the values of fresh weight and dry weight/plant (g) of *R. mucronata* seedlings treated with 500 mg / 100 L NPK were significantly higher in both of 1 × 1 m spacing and 2 × 2 m spacing (Table 4). The interaction between the concentrations of fertilization and the plantation sites, showed that, the values of fresh weight of *R. mucronata* seedlings treated with 500 mg / 100 L NPK were significantly higher in both of planting sites (Safaga and Hamata) than that in the control and the concentration of 250 mg / 100 L NPK, regardless of the planting distances, while, there is no significant differences between the values of dry weight/plant in the two sites (Table 4).

4.3. Effect of mineral fertilizers on the photosynthetic pigments

The data summarized in Fig. (6) and Table (4) indicate that, there were significant differences between the values of all pigments determined in *R. mucronata* plants among all the concentration of NPK fertilization used regardless the planting sites and the planting distances of the seedlings**.** On the other hand, the value of chlorophyll b was significantly higher in the seedlings treated with 500 mg / 100 L NPK (0.89 mg/g F.wt) than that in the concentration of 250 mg / 100 L NPK (0.82 mg/g F.wt) and in control (0.69 mg/g F.wt), regardless of the planting sites and the planting distances. The interaction between fertilization concentrations and both of plantation sites and plantation distance support these results where, there were significant differences between the values of all pigments in both of plantation sites and plantation distances (Table 4).

4. Effect of Planting Distances on Growth Performance of *R. mucronata*

5.1. Effect of planting distances on growth parameter

The data in Figs. (3 and 4) and table (4) indicate that, the average of height, number of branches/seedlings, number of leaves/seedling of the seedling planted in 2×2 m spacing were highly significant (67.46 cm, 3.27 and 15.69) than in those were planted in 1×1 m spacing, regardless of the planting sites and fertilization treatments. These results were supported by the interaction effects between the planting distances with the fertilization concentrations.

On the other hand, the interaction between the planting distances and planting sites indicated that, there were significant differences in the plant height measured in the two planting distances among the two planting sites, while there was no significance between the two planting sites on the number of branches and number of leaves among the two planting distances conducted.

5.2. Effect of planting distances on fresh weigh and dry weight (g)

The results indicated that, the fresh weigh and dry weight (g) of the seedlings planted in 2×2 m spacing were significantly higher than those were planted in 1×1 m spacing, regardless of planting sites and fertilization treatments (Fig. 5). These results were supported by the effect of interactions between the planting distances and the planting sites, where the fresh weight and dry weight (g) in the 2×2 m spacing in Hamata site (92.77 and 42.47 g, respectively) were high significant than in Safaga site (89.47 and 41.73 g, respectively). Also, the fresh weight and dry weight (g) of the seedlings treated with the different concentrations of NPK were significantly higher in 2×2 m spacing than those planted in 1×1 m spacing.

5.3. Effect of planting distances on the photosynthetic pigments

The data in Fig. (6) and Table (4) indicate that, there is significant differences in the values of chlorophyll a, chlorophyll b and Carotenoids in the planting distances measured in *Rhizophora* plants, regardless the plantation sites and the fertilization treatments, where all the pigments values measured were higher in 2×2 m spacing than those in the 1×1 m spacing. The interaction effects of planting distances and fertilization treatments indicated that, pigments in *R. mucronata* seedlings treated with 500 mg / 100 NPK were significantly higher in both of the planting distances implemented than the seedlings treated with 250 mg/ 100 NPK. On the other hand, there were significant differences between planting distances with the planting sites in the values of chlorophyll b and carotenoids, while, there were no significant differences in the values of chlorophyll a, between Safaga site and Hamata.

The interaction between planting sites, planting distances and fertilization affected significantly the *R. mucronata* seedlings height, fresh and dry weight, number of leaves and pigments. On the other hand, the interaction between these three variables showed insignificant effects on the number of branches of the plant (Table 4).

DISCUSSION

Several studies have shown that environmental factors can influence the physicochemical properties of water present in mangrove forests. The growth of mangrove stands is influenced by parameters such as pH, salinity of the water in mangrove forests, which play a significant role in determining the species diversity and productivity of the mangroves (Cabañas-Mendoza et al., 2020 and Dookie et al, 2022). The data in this study indicated that, the average of all growth parameters of *R. mucronata* seedlings (height, number of branches and number of leaves/plant) were significantly higher in Hamata locality than in Safaga locality, due to the percentages of gravel, silt and clay that were higher in Hamata site than in Safaga site. On the other hand, the values of pH and soil salinity in Hamata site were lower than that of Safaga site. High salinity causes decrease in stomatal conductance and the transpiration rate in leaves, leading to a decrease in photosynthesis, as well as decrease in growth parameters of *R. mucronata*. These findings are in agreement with Cintrón et al. (1978), Lugo et al., (1981) and Boto and Wellington (1984), who found that the decreasing in tree height in mangrove forests has been correlated with increasing soil salinity. Also, Kathiresan and Bingham (2001) found that, soil properties have a major impact on mangrove nutrition and growth; nutrients availability may limit growth and production in many mangals. Soil texture, which is linked to soil porosity, controls water-holding capability, diffusion, and water movement, both of which influence the soil overall health (Upadhyay and Raghubanshi, 2020). Young mangrove seedlings, particularly those in the early growth stages, cannot withstand severe pH conditions (>5.16–7.72) since they prevent nutrients from reaching the plants. Under these conditions, nitrogen uptake is inhibited and nitrogen limitation is secondarily induced (Mendelssohn, 1979; Koch et al., 1990; Bradley and Morris, 1991 and 1992).

Susiana (2015) stated the fertility of mangroves is supported by the site and its planting media such as tropical climates, high rainfall, as well as mud or coastal sediments which are suitable for mangrove to grow including mangrove species. In this study, the growth parameters of *R. mucronata* plants which were treated with 500 mg / 100 L NPK had highest values in Hamata site. These findings agree with Naidoo (1987), Feller (1995), Lovelock et al. (2004 and Catherine et al. (2009), who stated that, NPK application enhances mortality and growth of mangrove species. The dwarf red mangrove trees recorded a large and rapid growth response to increased supplies of P and NPK fertilizers at Hidden Lake had after 1 yr of fertilization, the mean linear increase per shoot, including length of the original shoot and its sub shoots, were 0.47 m and 0.45 m for P- and NPK fertilized trees, respectively (Grimes, 1977). In this study, after six months of plantation, the average of growth parameters of *R. mucronata* (height, number of branches/plant, and number of leaves/plant) treated with 500 mg/ 100 L NPK were 140.3 cm, 13.7 and 55.5/plant, respectively, followed by that treated with 250 mg/ 100 L NPK (137.3 cm, 13.0 and 46.7/plant) and control (115.0 cm, 6.0 and 33.3/plant). The results of interaction effects between the planting distances with the fertilization concentrations indicated high significant differences in growth parameters, where the highest values of *R. mucronata* plants in all growth parameters measured were attained in the seedlings treated with 500 mg/ 100 NPK in 2×2 m spacing, this might be due to the fact that competition for nutrients is less in low planting density than at high planting density. These results agree with Sebai et al. (2022), they found that, there were positive significant effects for increasing nitrogen fertilization up to 30 kg N/faddan as well as nutrient foliar application on number of branches/ plants, number of leaves/plants, plant fresh weight, leaves fresh and dry weights/plant of Stevia plant.

The results of multivariate analysis showed that the effect of interaction between the concentrations of fertilization and the plantation sites on the values of fresh weight and dry weight/plant (g) of *R. mucronata* seedlings treated with 500 mg/ 100 L NPK were significantly higher in both planting sites (Safaga and Hamata) comparing with control and concentration of 250 mg / 100 L NPK. Also, the values of fresh weight and dry weight/plant (g) of *R. mucronata* seedlings treated with 500 mg/ 100 L NPK were significantly higher in both of 1×1 m spacing and 2×2 m spacing. The nutrients are known to be involved in mitigating the stress posed by high salinity (Gritcan, 2018). These findings agree with Feller (1995), who found that, P enrichment produced nearly a 7-fold increase in stem elongation rates with *Rhizophora* mangle seedlings and a 3-fold increase in leaf area in mesocosm and field experiments. He stated that, low P availability similarly limits growth of dwarf *R. mangle* and promotes development of hard, long-lived leaves called sclerophylls.

The interaction between planting sites, planting distances and fertilization concentrations showed significant effects on the plant height, No. of leaves and fresh weight, and insignificant variations on the No. of branches. Similar results have been achieved by Amare et al. (2020), they found, the highest seedling vigour index was observed from the interaction of wider spacing 20 x 30 x 50 cm double row spacing and 115 P2O5 and 114 N kg ha-1 NP fertilizers. Whereas, the lowest was observed from the interaction of control and closer 10 x 20 x 40 cm double row spacing and control.

The average values of fresh and dry weight of *R. mucronata* seedlings treated with NPK concentrations (control, 250 mg / 100 L and 500 mg / 100 L) increased from 54.43 to 67.13 and 74.67, respectively in Hamata site, after three months from plantation and from 93.67 to 123.97 and 161.93 g/ plant, respectively, after six months from plantation. These results agree with Sebai et al. (2022), which they found, the vegetative growth parameters of stevia plants as well as total leaves yield/faddan were increased as nitrogen fertilizer increased from 15 up to 30 kg N/faddan. Such finding might be attributed to the effective role of N as essential constituent of protein, amino acids, co-enzymes, and certain hormones as well as chlorophyll. Phosphorus fertilization increased leaves fresh yield/faddan by 14.3%, 53.1%, 52.1%, 31.3% and 31.2% in the three cuts of the 1st season and the two cuts in the 2^{nd} season, respectively. On the other hand, Phosphorus fertilization had exerted a profound significant improving impact on values of fresh and dry weights of leaves/plant and per faddan in stevia plant. The nutrients are known to be involved in mitigating the stress posed by high salinity (Gritcan, 2018).

After six months from plantation, the data indicated that, there were significant differences between both of the planting distances that were implemented and both of plantation sites for all growth parameters determined where the values of all growth parameters measured in 2×2 m spacing in Hamata site were higher than that in Safaga site. Similar results have been achieved by FAO (1994), they found that, for adequate natural regeneration a minimum of 2500 well distributed seedlings per hectare, equivalent to a spacing of 4 m^2/ seedling is required for multiple-use Rhizophora plantations. The planting spacing is 1.8 x 1.8 m beside the waterways for *Rhizophora mucronata*.

The interaction between planting sites and planting distances showed insignificant effects on the values of chlorophyll a as well as, between planting localities and fertilization concentrations, also, between planting distances and fertilization concentrations, while, there are significant differences in the values of chlorophyll b and carotenoids, where these values were higher in Hamata site than in Safaga site in both of planting distances implemented. The increase of chlorophyll b content in Hamata site may be as decrease of water and soil salinity. Zhao et al (2019) stated that, as salt concentration increased, the response time and chlorophyll fluorescence indices decreased, indicating that low NaCl concentrations can promote photosynthesis, these findings achieved by (El-Dakak, et al, 2022), where they found that, salinity reduced chlorophyll a and chlorophyll b content in the chilled *Vicia faba* plants by 35.5, 27.7, respectively after 16 h exposure to 120 mM NaCl. On the other hand, (Zhao et al, 2019), found that, chlorophyll a and Carotene contents in *Ginkgo biloba* plants were affected by lower concentrations of salinity, while chlorophyll b was more stable under salt stress. Also, they found that, no significant differences in Carotene were observed between the salinity levels and control groups at 64 days after *Ginkgo biloba* plantation. This finding suggests that carotene is relatively stable and exhibits some tolerance to salt stress, which may help in scavenging active oxygen and protecting the photosynthetic membrane. Our results supported by the multivariate analysis between the three variables (planting sites × planting distances × fertilization concentrations), where there were insignificant variations for chlorophyll a contents in *R. mucronata*, while a highly significant variations for chlorophyll b and carotenoid content in the seedlings treated with 500 mg/ 100 L NPK in Hamata site at 2×2 m spacing.

CONCLUSION

Salinity of soil and water in plantation site plays an important role in the establishment and growth of *R. mucronata* seedlings as well as in chlorophyll content of the plant at the Red Sea coast of Egypt. Most of growth parameters of *R. mucronata* seedlings were higher in Hamata site than in Safaga site. Fertilization by 500 mg/ 100 L NPK is essential for good and healthy growth of *R. mucronata* seedlings, where the plant height, number of branches, number of leaves, F.wt and D.wt increased by 54.7%, 56.2%, 40%, 42.8% and 48.6%, respectively, comparing with non-treated seedlings (control) in Hamata site, while increased in Safaga site by 55.4%, 38.5%, 29.2%, 41.4% and 42.5%, respectively, comparing with control. Planting distance 2×2 m spacing was more suitable for the propagation and healthy growth of *R. mucronata* seedlings than 1×1 m spacing. The best practices for the propagation and cultivation of *R. mucronata* on the Red Sea coast of Egypt were established when the seedlings localities characteristic were low soil and water salinity in planting distance 2×2 m, using fertilization of 500 mg/ 100 L NPK in the early stage of seedling propagation, about four times/ year. The success of *R. mucronata* plantation in site about 700 km (Lat. 26°N) north the natural distribution (Lat. 23°N) on the Red Sea coast of Egypt, enhances the efforts of combating desertification and mitigation of climate change impact as well as increases the income of the local people inhabiting these sites.

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الاستجابات الفيسيولوجية البيئية لنبات القندل المزروعة على ساحل البحر الأحمر لمعاملات التسميد المعدنى ومسافات الزراعة

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تم إجراء تجربة لتقييم تأثير السماد المركب المحتوى على نسب ٢٠٪ -٢٠٪ -٢٠٪ من النيتروجين والفوسفور والبوتاسيوم بتركيزين ٢٥٠ مجم/ ١٠٠ لتر و٥٠٠ مجم/ ١٠٠ لتر وبدون تسميد (كونترول) على شتلات نبات القندل، حيث تم رش الشتلات المزروعة بالأسمدة على مسافتين (١ × ١ م و ٢ × ٢ م)، في منطقتين مختلفتين هما حماطة وسفاجا على ساحل البحر الأحمر. تم تقدير متوسط معدلات نمو شتلات القندل (الارتفاع، عدد الأفرع/ النبات، عدد الأوراق/ النبات، الوزن الرطب والجاف/ النبات) المعالجة بالأسمدة وكذلك الكونترول في كل من مسافتى الزراعة في كل من موقعى الزراعة، بعد ٣ أشهر من الزراعة وستة أشهر بعد الزراعة. فى نهاية التجربة، بعد ستة أشهر من الزراعة، تم تقدير محتوى أصباغ التمثيل الضوئى (الكلوروفيل أ، والكلوروفيل ب والكاروتينات) فى الشتلات فى كل من مسافتى الزراعة فى كلا المنطقتين المزروعتين. أشارت النتائج إلى أن معظم معدلات النمو لشتلات القندل كانت أعلى فى منطقة حماطة عنها فى منطقة سفاجا. التسميد بمقدار ٥٠٠ ملجم/ ١٠٠ لتر من النيتروجين والفوسفور والبوتاسيوم ضرورى للنمو الجيد والصحى لشتلات القندل. كانت مسافة الزراعة ٢× ٢ م أكثر ملاءمة للإكثار والنمو الصحى لشتلات القندل. نجحت هذه الدراسة في استزراع نبات القندل في مواقع تبعد حوالى ٥٠٠ كم شمال اتجاه التوزيع الطبيعى لهذا النبات على ساحل البحر الأحمر فى مصر.