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CHEMICAL COMPOSITION OF MANGROVE LEAVES (*AVICENNIA MARINA* AND *RHIZOPHORA MUCRONATA*) AND THEIR CORRELATION WITH SOME SOIL VARIABLES AT THE EGYPTIAN RED SEA COAST

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Abstract: Due to the importance of mangrove forests to the ecological system, environment, climate change adaptation, mitigation, and ecosystem services, it is necessary to understand the mangrove forests status in Egypt (ecology and physiology), therefore, the aim of the present study was to obtain the basic information needed to evaluate the chemical composition of leaves of the mangrove trees (*Avicennia marina* and *Rhizophora mucronata*) and their correlation with some soil variables with the ambient Salinity. The results showed variations between the two mangrove species in the mineral composition of leaves at different study locations. In all the locations, Na^+ and Cl^+ ions were more dominant in leaves than K^+, Ca^{++}, and Mg^{++} ions. For *A. marina*, a higher value for Na^+ (8.22%), Cl^- (7.9%), and K^+ (1.4 %) was recorded at 0.81% and 0.33% for Ca^{++} and Mg^{++} respectively. Where, *R. mucronata*, a higher value for Na^+ was recorded (6.7%) and (7.23%) for Cl^-. and the mean values for K^+, Ca^{++}, and Mg^{++} ions were noted 0.64%, 2.13%, and 0.31 % respectively. The results showed that both ordination techniques clearly indicated that soil contents (*fine sand, silt, and clay*), *pH* gradient, CaCO3, K^+, Ca^{++}, Cl^-, Na^+, and electric conductivity were the most important soil parameters showed variations between the mineral compositions of the two mangrove species leaves at different study locations. The results showed that there is a similarity between the soil samples in different locations as a whole area. The variability of ecosystem structure and function is generally a product of interactions between its different components. In the extreme arid environmental conditions of arid lands these interactions are of high significance, so that slight irregularities in one component of the ecosystem are likely to lead to substantial variations in others, creating distinct microhabitats.

Keywords: mangrove, Red Sea, *Avicennia marina*, *Rhizophora mucronata*, soil, eco-physiological.

INTRODUCTION

Plant ecophysiology is an experimental science that seeks to describe the physiological mechanisms that underlie ecological observations. Mangroves possess morphological, physiological, and dynamic characteristics that make them unique: Tidal dispersal of propagules, fast turnover of foliage, and very effective nutrient-retaining mechanism (Alongi, 2002). Mangrove forests cover approximately 137,760 km^2 worldwide (Giri *et al.,* 2011) and are unique ecosystems – highly productive forests built by a small group of trees and shrubs that have adapted to survive in the harsh interface between land and sea (Spalding *et al.,* 2010). Mangroves grow under extreme environmental and climatic conditions such as high salinity, temperature, and radiation (Moorthy and Kathiresan, 1999). Mangroves are typical brackish water vegetation of the tropics where the mixing of freshwater and seawater occurs (Karsten, 1891). They are facultative halophytes (Krauss and Ball, 2013), with the capability of tolerating salt stress (Ali *et al.,* 2010). Mangroves can grow in a broad range of salt concentrations including freshwater. Saltwater is needed for the proper development of typical mangrove vegetation. Mangrove trees growing in the swamps having freshwater substratum are of small size and poorly developed (Bowman, 1917).

Mangrove forests are a characteristic feature of the shorelines of the tropical and subtropical seas and oceans, however, their optimum density, diversity, and cover are in the wet tropics. Some mangrove swamps occur in the coastlines of arid areas like those of the Red Sea and Arabian Peninsula's coastal belts (Zahran, 2007). The plant life in the coastal shoreline, desert wadis, and mountains of the Eastern Desert is rather rich and interesting, where considerations of the exploitation and conservation of wild plants must take ecological principles into account (Afefe, 2021). *A. marina* usually grows in pure stands, *R. mucronata* may be mixed with *A. marina* as a co-dominant or as an abundant associate, or it may form pure stands. Where both species grow together *R. mucronata* forms an open layer higher than the thick and almost continuous bushy canopy of A. marina (Zahran and Willis, 2009).

The mangroves in Egypt occupy about 525 hectares distributed in 28 different locations along Egyptian Red Sea coasts. One large discontinuous stand along the Gulf of Aqaba in the Nabq Protected Area and one small stand at the most southern part of the Gulf of Suez at Ras Mohammed National Park (Zahran and Willis, 2009). From a geographical point of view, the Egyptian mangroves can be divided into the Sinai mangroves, and mangroves growing on the Egyptian-African Red Sea coast (PERSGA, 2004). *A. marina* is

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relatively more tolerant and adapted to salinity, low rainfall, and extreme temperature conditions than *R. mucronata* and this explains the larger local distribution (in Egypt) of *A. marina* than *R. mucronata* (Afefe *et al*., 2021). Mangrove formations along the Egyptian shoreline are formed mainly of *A.marina*, a salt-excreting species (Afefe *et al.*, 2019) except for a few locations near the Egyptian-Sudanese border area, where *Rhizophora mucronata* (loop-root mangrove; Rhizophoraceae) coexists along with *A. marina* (PERSGA, 2004). Afefe *et al*., (2020) reported that the average biomass per hectare of Egypt mangroves recorded 74997.1 and 22536.8 kg for *A. marina* and *R. mucronata*, respectively. Moreover, for Egypt mangroves (525 ha), the total organic carbon content recorded 17.73 Gg C for biomass and 5.97 Gg C year^{-1} for soil, with a total of 23.7 Gg C of organic carbon content storage in the mangroves ecosystem in Egypt.

Many studies were examined to understand the adaptations, ecophysiological processes, morphological characteristics, and conservation of *A. marina* and *R.* mucronata trees growing in a per-arid area on the Red Sea coast of Egypt (Teraminami *et al.*, 2013; Matsuo *et al*., 2016; Afefe *et al*., 2019; Afefe *et al*., 2020; Afefe, 2021a).

The aim of the present study was to obtain the basic information needed to evaluate the chemical composition of leaves of the mangrove trees (*Avicennia marina* and *Rhizophora mucronata*) and their correlation with some soil variables with the ambient Salinity in Elba Protected Area along the Egyptian-African Red Sea Coast.

MATERIALS AND METHODS

Study area

Gebel Elba Protected Area is located between the longitudes 22°00'N - 23°50'N, and the latitudes 35°00'E - 37°00'E, with a total area of about 35,600 km². It is the largest declared protected area in Egypt. Gebel Elba is a part of the Egyptian desert that is considered one of the most extremely arid areas of the world. The recorded mean minimum temperature is 11.4C° during January, while, the recorded maximum temperature is 38.7C° in July. The area is almost rainless, with a mean annual precipitation of 27.8 mm. The relative humidity shows that the atmosphere is dry throughout the year (RH=47.2% to 60%) (GEPA, 2008). Field sites were located in the south of Shalateen city to the north of Abu Ramad village. Sampling was carried out in three main mangrove locations to represent the mangrove forests along the Egyptian Red Sea Coast (Figure 1). Sharm El Madfaa (9.2km^2), MarsaSha'ab (15.8 km^2) and Marsa Abu Fassi (0.7km^2) (ITTO, 2006). Mangrove species composition at each location was determined (either *A. marina*or *R. mucronata*).

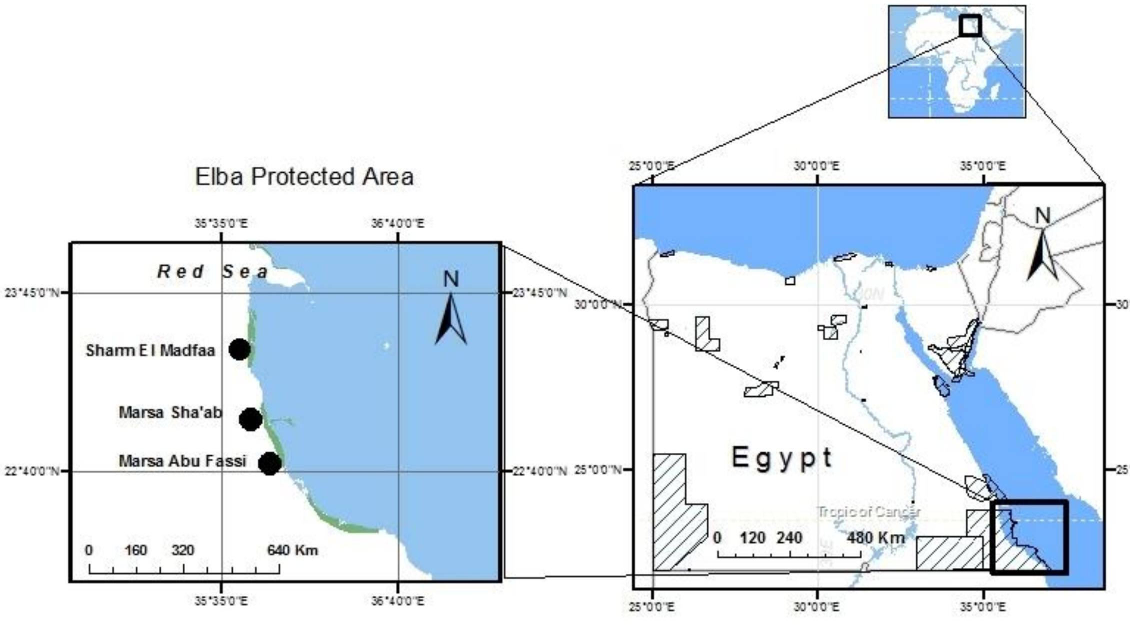

Fig. 1. Map of Egypt focusing on Elba Protected Area and the study locations.

Mangrove minerals contents

Mangrove stands were observed at these sites during June 2016 to June 2017. Sampling was carried out in three main locations (Sharm EL Madfaa, Marsa Sha'ab, and Marsa Abu Fassi) including 24 study sites in the Elba Protected Area to represent the mangrove forests along the Egyptian-African Red Sea Coast. The sampled stations were classified as mangrove *A. marina* and *R. mucronata*.

In each stand, three random plots (10×10 m) were selected for each mangrove type. A plot location was arranged randomly within each stratum, plots were picked at random to increase the likelihood of capturing the true variation within and across forest strata (terrestrial side/ middle/seaside) (Howard *et al.*, 2014). In each plot, species density, frequency, and canopy cover were calculated according to Muller-Dombois and Ellenberg (1974). The main lateral branches per tree, tree circumference (at d.b.h), and leaf area are measured (Crisp and Lange, 1976).

Plant tissue samples were collected and the minerals contents (Na, Mg, Ca, K, N, Cl, and P) were analyzed to estimate their values in tissues of *Avicennia marina* and *Rhizophora mucronata* for physiological study (AOAC, 1984; 1996; 2000). Three independent replicates were performed for each sample and were measured in parallel washed thoroughly with tap water to remove any attached particles, and then rinsed three times with deionized water. The sample was put in an oven and air-dried at 70° C and then grounded. The fine ground was prepared as half a gram of dry matter was wet digested by using a mixture of sulphuric and perchloric acids (HClO4+H2SO4) acids according to the procedure of Benton (2001). Total K and Na in the plant were determined by flame photometer; Total N in the plant was determined using Automatic micro Kjeldahl Vapodest 30S according to AOAC (1990). P and Ca were determined in the digestion extracts by Inductively Coupled Plasma Spectrometry (ICP) (Ultima 2 JY Plasma), According to EPA (1991).

Soil samples and analysis

The soil samples were collected during the work from all the plots of the study. From each plot, three soil samples were collected and mixed to form a composite sample for the determination of their physical and chemical characteristics. The surface samples (excluding the surface crust) were taken to a depth of 25 cm.

Physical analysis: soil texture was determined using a series of sieves. Soil samples were air-dried and passed manually through a 2-mm sieve to evaluate gravel percent. Particle size analysis was accomplished according to Piper (1950) to calculate the percentages of sand, silt, and clay and the classification of the soil texture type was accomplished according to the USDA soil texture triangle (USDA, 1993).

Chemical analysis: Calcium carbonate was measured by titration against 1.0 N HCl following Allen *et al*. (1976). Oxidizable organic carbon (as an indication of the total organic matter content) was measured according to (Black, 1965). Soil reaction (pH value), electrical conductivity, sulfates, and chlorides were measured according to Jackson (1967). Bicarbonate was determined by titration using 0.1 N HCl (Allen *et al*., 1976). Extractable cations (Ca^{++} and Mg^{++}) were determined (meq/L) by titration following Richard (1954); while sodium and potassium ions (meq/L) were measured from air-dried soil using ammonium acetate solution at pH=7 (Allen *et al*., 1976).

STATISTICAL ANALYSIS

One-way analysis of variance (ANOVA-1) was used to identify statistically significant differences between the soil samples using the least significant difference (LSD) test at $P < 0.05$. Statistical analyses were performed using SPSS 15.0 software (SPSS, 2006).

Canoco analysis, Vegetation, and related environmental factors were analyzed using classification and ordination techniques. Classification (e.g. Siebert *et al*., 2002) or ordination (e.g. Pavlůet *et al.*, 2003) are two possible means to obtain results from multivariate data analysis. The present study preferred a direct ordination method to enable us to test environmental variables collected for each relevé (statement). All ordinations were performed in the Canoco program (Version 4.5) (Ter Braak and Milauer, 2002; Hejcmanovā-Neźerková and Hejcman, 2006). Detrended Correspondence Analysis (DCA) was used to detect the length of the environmental gradient (Lepŝ and Milauer, 2003). Where the DCA analysis reveals information about the range of variation among the stands at the Gebel Elba coastal area mangrove.

RESULTS AND DISCUSSION

Mangroves showed variations between the mangrove species in mineral composition at different study locations with F-value= 4.54 and $p < 0.050$. In all the locations Na^+ and Cl^- ions were more dominant than K^+, $Ca^{++,}$ and Mg^{++} ions. For *Avicennia marina*, a higher value for Na^+ (8.22%) and Cl^- (7.9%) were recorded at stands of Sharm EL Madfaa, and Marsa Sha'ab respectively, where, the minimum values were recorded at 5.2% and 5.01 in Marsa Abu Fassi respectively.

While K^+ recorded a higher value recorded (1.4 %) in Marsa Abu Fassi and a minimum value recorded (1.09%) in Sharm EL Madfaa. A higher value of Ca^{++} and Mg^{++} was recorded at 0.81% and 0.33% respectively, while the minimum values were recorded at 0.79% and 0.26% respectively. (Table s 1, 2)

For *Rhizophora mucronata*, a higher value for Na^+ was recorded (6.7%) at Marsa Sha'ab, and a higher value for Cl^- was recorded (7.23%) at Marsa Abu Fassi. While the minimum values for Na^+ and Cl^- were recorded as 4.98 % and 6.39 % respectively. However, the mean values for K^+, $Ca^{++,}$ and Mg^{++} ions noted 0.64%, 2.13%, and 0.31 % respectively. (Tables 1, 3).

Table 1.

The mean values of mineral composition in the two species

Character (%)	*A. marina*	*R. mucronata*	LSD (P-value =0.05)
Na^+	7.31	5.84	0.05
Cl^-	6.22	6.81	0.17
Ca^{++}	0.78	2.13	0.01
K^+	1.23	0.64	0.02
Mg^{++}	0.3	0.31	0.53
N^{---}	0.26	0.11	0.11

Table 2.

Values of mineral composition for *Avicennia marina*

Character (%)	Sharm EL Madfaa	Marsa Sha'ab	Marsa Abu Fassi	Mean	LSD (P-value =0.05)
Na^+	8.22	7.9	5.2	7.31	0.409
Cl^-	7.46	6.21	5.01	6.22	0.479
Ca^{++}	0.79	0.81	0.71	0.78	0.416
K^+	1.09	1.21	1.4	1.23	0.446
Mg^{++}	0.26	0.3	0.33	0.30	0.499
N^{---}	0.08	0.09	0.8	0.26	0.407

Table 3.

Values of mineral composition for *Rhizophora mucronata*

Character (%)	Marsa Sha'ab	Marsa Abu Fassi	Mean	LSD (P-value =0.05)
Na^+	6.7	4.98	5.84	0.912
Cl^-	6.39	7.23	6.81	0.807
Ca^{++}	2.02	2.23	2.13	0.316
K^+	0.6	0.67	0.64	0.436
Mg^{++}	0.26	0.36	0.31	0.901
N^{---}	0.13	0.09	0.11	0.709

The current results of soil factors are in accordance with those of Afefe *et al*. (2019). The results of soil particles sand, silt, and clay of all the study sites are given in Table 4. Where the textural study revealed that sand and clay were the predominant fractions at all the sites. Results clearly show that the saturation percentage (SP) of soil in the studied areas ranged between 42% (Sharm EL Madfaa) for *A.marina* to 55% (Marsa Abu Fassi) for *R. mucronata* and 52% (Marsa Abu Fassi) for *A. marina* / *R. mucronata* mix stands.

The analyses of the chemical properties of the soil showed that it was slightly alkaline (ranging between 7.7 "Marsa Abu Fassi" for A. *marina* / R. *mucronata* mix stands to 7.93 "Marsa Sha'ab" for *R. mucronata*). The EC values of soil extract showed variation ranging between 27.9 ds/m (Sharm EL Madfaa) for *A.marina* to 51.5 ds/m (Marsa Sha'ab) for *A.marina* (Table 4). The organic carbon content ranges from 5.2 % for *A. marina* (Sharm EL Madfaa) to 2.9% for *A.marina /R. mucronata* mix stands (Marsa Sha'ab).

Soil carbonate content ($CaCO_3$) showed variation among the studied stands and ranged between 8.91 % (Sharm EL Madfaa) for *A.marina* to 30.3 % (Marsa Abu Fassi) for *R. mucronata*. Soil calcium contents ranged between 70.1 meq/L (Sharm EL Madfaa) for *A.marina* to 130.5 meq/L (Marsa Sha'ab) for A. *marina*. Soil magnesium contents showed a range from 63.5 meq/L (Sharm EL Madfaa) for *A.marina* to 116.5 meq/L (Marsa Sha'ab) for A. *marina*. Soil sodium contents ranged between 142.5 meq/L (Sharm EL Madfaa) for *A.marina* to 264.6 meq/L (Marsa Sha'ab) for A. *marina*. Soil potassium contents ranged between 1.9 meq/L (Sharm EL Madfaa) for *A.marina* to 3 meq/L (Marsa Abu Fassi) for R. *mucronata*, with the mean value was 2.66 meq/L.

The data indicate that Marsa Sha'ab stands for *A. marina* recorded the highest value of bicarbonate content (3 meq/L), but the lowest values were recorded for soil of Sharm EL Madfaa stands for *A.marina* (1.9 meq/L). The soil collected from Marsa Sha'ab stands for

A. marina recorded the highest value of chloride content (492.1 meq/L) while the lowest values were recorded in the soil of Sharm EL Madfaa stands (256.4 meq/L). Soil sulfate contents showed that the highest value was recorded in the soil of (Marsa Abu Fassi) which stands for *A. marina* (52.3 meq/L) and the lowest value was recorded in the soil of Marsa Sha'ab stands for *A. marina* (18.9 meq/L).

Vegetation and related environmental factors were analyzed using classification and ordination techniques. *A. marina* showed a high correlation along the gradient of organic carbon in the soil. The opposite trend was observed for *R. mucronata* which is highly correlated along the gradient of salinity-related factors in the soil (EC, Na, Cl,...). The first gradient is by far the longest one, explaining about 100 % of the total species variability, whereas the second and higher axes explain much less (Figure 2, 4). The first axis is very well correlated with the environmental data (r=1), and the correlation for the other axis is considerably lower. All this suggests that the whole data set is governed by a single dominant gradient. The sum of all canonical eigenvalues in the printout corresponds to the sum of all canonical eigenvalues in the corresponding canonical analysis. The percentage variance of the species-environment relationship values represents percentages of this value. The number of axis scores calculated for a species–environmental variable biplot is restricted in a DCA, by default, to one. This is why they explained variability for the second, third, and fourth axes is shown as 0.

Table 4.

Descriptive statistics for Chemical and physical prosperities

Character	Sharm EL Madfaa	Marsa Sha'ab			Marsa Abu Fassi		
	A. marina	***A. marina***	***R. mucronata***	**Mixed stands**	***A. marina***	***R. mucronata***	**Mixed stands**
	Pure	Pure	Pure	Mixed	Pure	Pure	Mixed
Coarse Sand (%)	11.5	11.5	18	16	15	12	12.5
Fine Sand (%)	38	38	34	35	37	38	36.5
Silt (%)	14.5	14.5	9	11.5	10.5	13.1	10.8
Clay (%)	36	36	39	37.5	37.5	36.9	36.2
pH	7.89	7.88	7.93	7.91	7.9	7.83	7.7
EC (ds/m)	27.9	51.5	40.3	38.2	36.6	44.5	39.5
Na (meq/L)	142.5	264.6	206.6	194.5	185.8	229	205
K (meq/L)	1.9	2.7	2.8	2.5	2.8	3	2.9
Ca (meq/L)	70.1	130.5	102.2	97.2	92.2	113.5	103
Mg (meq/L)	63.5	116.2	88.4	85.8	84.2	98.5	92
Cl (meq/L)	256.4	492.1	375.4	341.2	310.1	403.1	357
SO4 (meq/L)	19.7	18.9	22.3	36.8	52.3	38.1	45.2
HCO3 (meq/L)	1.9	3	2.3	2	2.6	2.8	2.6
CaCO3 (%)	8.91	22.1	23.7	16.3	29.7	30.3	29.8
Organic carbon (%)	5.2	4.8	4.4	2.9	3.2	3.1	3.1
SP (%)	42	45	49	48	48	55	52

The results showed that both ordination techniques clearly indicated that soil contents (*fine sand, silt, and clay*), *pH* gradient, $CaCO_3$, K^+, Ca^{++}, Cl^-, $Na^{+,}$ and electric conductivity were the most important soil parameters showed variations between the mineral compositions of the two mangrove species leaves at different study locations. A closer inspection of the correlation matrix in the CANOCO Log View showed that the variables are indeed correlated, but in some cases, the correlation is not very great. The correlation matrix also confirms that the correlation of all the measured variables with the second axis is rather weak (Figure 2, 4). The Electrical Conductivity (EC) of soil extracts ranges from 27.9 ds/m (Sharm El Madfaa) for *A. marina* to 51.5 ds/m (Marsa Sha'ab) for *A.marina*, the mean value was 39.79. However, the total mean of EC for *A. marina* was 38.74 ds/m and 40.62 ds/m for *R. mucronata*. In the present study, the Gebel Elba Area is considered a hyper-arid area, with sea water salinity ranging from 41.04 to 43.95 ppt (EEAA, 2018). Modeling species response curves is used to describe the relationship between the mineral compositions of the two mangrove species leaves and the environmental gradients at different study locations as shown in Figures 3, and 4. Moreover, Ecological models can be used to establish trajectories of mangrove response to a variety of initial site conditions at spatially explicit locations that can improve engineering designs, and future project operations, and more clearly define monitoring programs and natural resource valuation. Modeling techniques can be us.

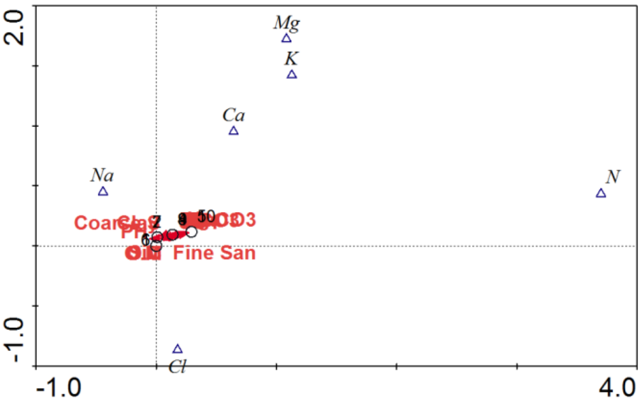

Fig. 2. The species-environment biplot of the DCCA for the leaves mineral compositions of *A. marina* species and the environmental variables (soil).

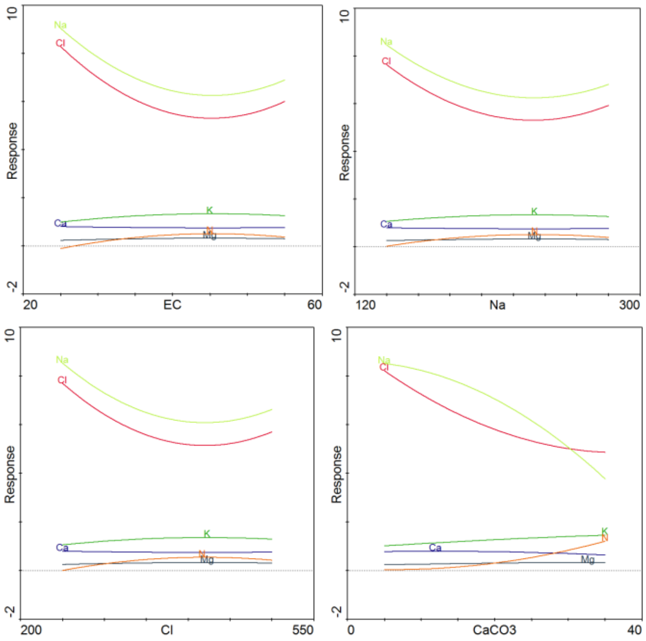

Fig. 3. Important value index of the leaves mineral composition for *A. marina* species against soil EC, Na^+, Cl^-, and $CaCO_3$.

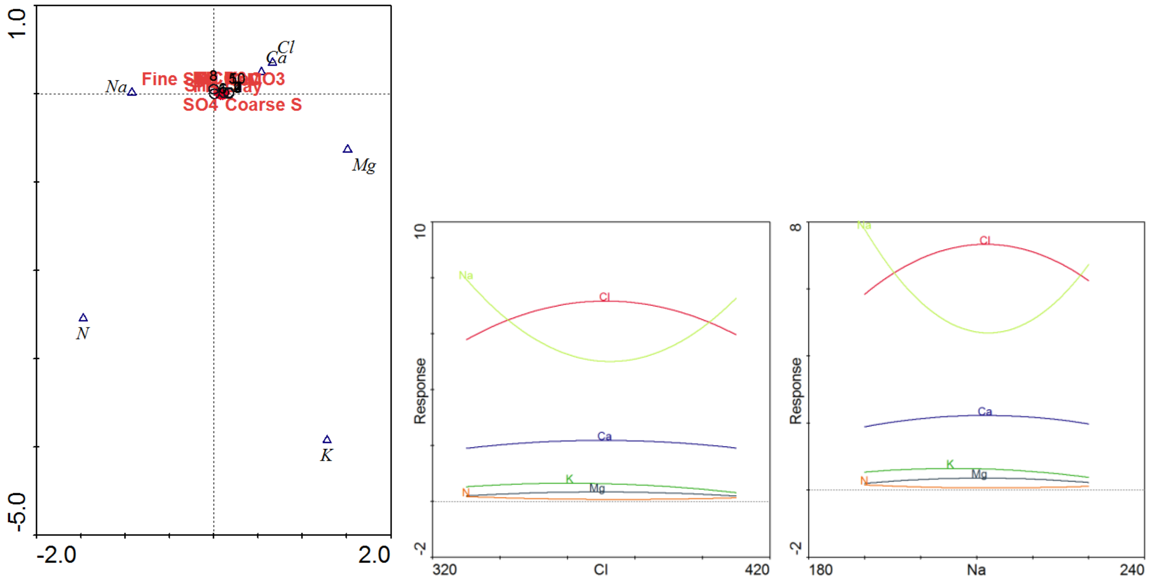

Figure 4. Important value index of the leaf's mineral composition for *R. mucronata* species against soil Na^+ and Cl^-.

DISCUSSION

In comparison with the previous studies, the current results agree with Afefe *et al.* (2019) that the soil factors electric conductivity, CaCO3, K^+, Ca^{++}, Cl^-, $Na^{+,}$ and Mg^{++} were the most important parameters determining the current distribution of mangrove pattern in the Egyptian Red Sea coast, and there is a similarity between the soil samples in different of the study locations as the whole area is coastal. The soil of mangrove sites was made up of silt and clay particles. This type of soil shows high water-holding capacity, soil aeration, and supply of available nutrients (Sheela, 2007).

Additionally, the current results are in accordance with those of Afefe *et al.* (2019) and Zahran & Willis (2009) they reported that the variability of ecosystem structure and function is generally a product of interactions between its different components, and in the extreme arid environmental conditions of arid lands, these interactions are of high significance, so that slight irregularities in one component of the ecosystem are likely to lead to substantial variations in others, so creating distinct microhabitats.

The mono-specific stands of *A. marina* are found on the Red Sea coast where fresh water is less supplied from inland areas with extremely low rainfall (<70 mm/yr^1) for this reason the *A. marina* trees in this area have short stems, and lateral branches with attached adventitious roots. This unique morphology is likely related to the water-use habits of leaves in per-arid areas (Yoshikawa *et al.*, 2011). The soil of *A. marina* mangrove contains 4.5–19.5% calcium carbonate whereas that of *R. mucronata* is highly calcareous, containing up to 80% of its weight of calcium carbonate, and the tidal mud of the mangrove vegetation of the Red Sea coast is usually grey or black, and often foul-smelling (Kassas and Zahran, 1967). The total water-soluble salt content ranges from 1.2 to 4.3% and the pH ranges from 8.5 to 9.0m where a notable difference between the tidal mud colonized by *A. marina* and that by *R. mucronata* is the low content of calcium carbonate in the former (4.5–19.5%) as compared with the calcareous mud (80%) in the latter (Zahran and Willis, 2009).

The current results are in accordance with those of Waisel (1972) that the sodium accumulation in some halophyte species was found to be higher than in other cations. Moreover, Divate and Pandey (1979) noted that the sodium content of leaves increased with an increase in the concentration of salts in the soils. Joshi (1982) proved that halophytes are able to survive in high concentrations of salts and the salts are accumulated either in the plant until it dies or in the deciduous leaves that fall from the plants excessive salts are excreted through the glands. Additionally, Pollak and Waisel (1979) reported that the salt excretion exhibited an optimum type of curve when measured against external salt concentration, while the sodium content of the leaves increased linearly. Salt excretion by salt glands of halophytes is claimed to be among the fastest ion transport systems in plants. The efficiency of the salt excretion system, and the relative excretion values, were shown to be negatively correlated with the salt concentration of the habitat.

According to Waisel *et al.* (1986), salts are continuously absorbed by plant roots and transported into the shoots. Salt concentration in the xylem sap varied during the day. Al-Zahrani and Hajor (1998) reported that Na+ and Cl- concentrations in the root were much lower than in the shoot, the highest values were in the root of the plants grown in 510mM NaCl, and values decreased with the increase in salinity concentrations. Ungar (1996) proved that *Atriplex patula* accumulates Na$^+$ and Cl$^-$ ions in stems and leaves with an increase in media salinity, which is similar to the response of other halophytes in the family Chenopodiaceae. Joshi *et al.* (1993) reported that Na$^+$, Cl$^-$, K$^+$, Ca^{++}and Mg^{++} were the principal inorganic constituents of leaves and stems in *Salvadora persica* with reference to saline habitats. The ash content in the leaves varied from 21 to 31% of dry weight. Amongst the cations, Na$^+$ and Ca^{++} contributed to the major fractions of the ash followed by Mg^{++} and K$^+$ whereas Cl$^-$ balanced about half of the cationic content. According to Ramos *et al.* (2004), when NaCl was used to induce salt stress, the Na$^+$ and Cl$^-$ content in roots, stems and leaves increased with salinity. At the same time the K$^+$ content was low at 100 mM NaCl a relevant decrease in K$^+$ was observed in stems and leaves. Cherian *et al.* (1999) proved that the increase in NaCl concentration steadily increased Na$^+$ and Cl$^-$ in all plant parts and the accumulation was significantly higher in the leaf than in the shoot or root. Cl$^-$ concentration increased with external salinity in all plant parts. The salinity induced a decrease in K$^+$ concentration. In parallel with the Na$^+$ accumulation and decline in K$^+$ content, the Na$^+$/K$^+$ ratio increased at all levels of external salinity.

On the other hand, Rao *et al.* (2005) reported that the leaf and stem ions i.e., Na$^+$ and Cl$^-$ increased with an increase in salinity in *Eragrostis* sp. and *Aeluropus lagopoides*. According to Hossain (2006), in seedlings of *Bruguiera parviflora*, higher K$^+$ content was observed in leaves followed by roots and stems. Comparatively higher content of potassium was found in leaves, buds, branches, and roots during the intermediate seasons.

The tendency of leaves to retain high Potassium levels is common in monocotyledonous halophytes (Albert and Kinzel, 1973). The process of osmotic adjustment in the halophytes subjected to saline conditions is mainly achieved by the uptake and accumulation of inorganic ions such as Na+ and Cl- in their shoots (Flowers *et al.* 1977; Greenway and Munns, 1980). *Avicennia* leaves have fine hairs secreted from the lower surface while their upper surface is shiny with some salt glands (Yasseen and Abu-Al-Basal, 2008). The mechanism of reducing the accumulation of salt is by loading ions in the leaf hypoderm, then a dynamic elimination of salt through glands (Griffiths *et al*., 2008). A study by (Tan *et al.*, 2013) demonstrated that salt crystals were observed in the leaves after treating the shoot with 500mM NaCl and the X-ray microanalysis confirmed that these crystals were mostly sodium and chloride. These salt glands help them maintain mineral balance and water status under extreme salinity (Esteban *et al*., 2013).

Moreover, Halophytes have been defined as plants that survive to complete their life cycle at high salinities (Flowers *et al.*, 1977). Many halophytes depend on seasonal reductions in salinity to improve germination or enhance growth even though salinity may be high during the remainder of the year. Very little data support a physiological requirement for salt among surveyed halophytic taxa (Flowers *et al.*, 1977); halophytes simply tolerate salinity. This distinction has also historically been applied to mangroves (McMillan, 1974; Ball, 1988). Thus, salt secretion contributes to eliminating the excess of salt reaching the leaves (Lüttge, 1971; Sobrado, 2001). The activity of salt glands is highly selective, secreting mostly NaCl and thus contributing to maintaining a favorable K$^+$/Na$^+$ ratio in the leaf cells (Sobrado and Greaves, 2000). However, other ions such as K$^+$, Mg^{++}, Ca$^{++,}$ and SO4^{--} can be present in the secreted solution (Sobrado and Greaves, 2000).

According to Lugo (1980), a saline environment is required for stable mangrove ecosystems. Mangroves are facultative halophytes i.e., they can often survive though not necessarily thrive in non-saline habitats. It is reported that the growth of many halophytes is depressed without NaCl in the external environment (Greenway and Munns, 1980). Limited amounts of NaCl are required in the external medium for the maximum growth of the mangroves. Salinity and interstitial water salinity are important to the growth rate, survival rate, and zonation of mangrove species (Aksornkoae, 1993). Mangrove species continuously incorporate salts from the substrate and transport them to the leaves in the transpiration stream (Ball, 1988). Salt uptake helps to maintain positive pressure potential through their contribution to the osmotic adjustment of growing tissues (Suárez and Sobrado, 2000). However, under high salinity conditions, the survival of the plant depends on its ability to regulate the internal salt concentrations and prevent it from reaching toxic levels (Ball, 1988).

In general mangrove plants are long-day plants and require high intensity of full sunlight. Light also affects the flowering and germination of mangrove species. Temperature is of importance to physiological processes such as photosynthesis and respiration. Aksornkoae (1993) reported that periods of intense physiological stress may be experienced when high temperatures are combined with full sunlight and prevailing winds giving rise to high evapotranspiration and increased surface salinity due to capillary uptake. Moreover, the free proline content: Free proline accumulation is one of the most frequently reported metabolic modifications induced by different stresses in plants. Despite this, the precise role of proline in stress physiology, as well as the metabolic adjustments associated with its biosynthesis, remains a matter of controversy. Still today, there is no definitive evidence for the adaptive value of proline itself under adverse conditions (Gibon *et al.*, 2000).

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Mangrove species continuously incorporate salts from the substrate and transport them to the leaves in the transpiration stream (Ball, 1988). Salt uptake helps to maintain positive pressure potential through their contribution to the osmotic adjustment of growing tissues (Suárez and Sobrado, 2000). However, under high salinity conditions, the survival of the plant depends on its ability to regulate the internal salt concentrations and prevent it from reaching toxic levels (Ball, 1988). Afefe *et al.* (2021) reported that the mechanism of salt tolerance in mangroves in particular *Avicennia marina*, its adaptations for surviving in a saline habitat, and its physiological characteristics (Biochemical) are peculiar. The mangroves in the current study showed variations in proline content, the maximal value (23.56 mg/ g dry wt) was recorded in *R. mucronata* stands, while the minimum value (17 mg/ g dry wt) was recorded in *A. marina* stands, and there were highly significant differences among species mangroves from different locations and stands.

The present study agrees with Zahran & Willis (2009) that in arid lands, the interrelationships between soils, vegetation, and atmosphere are so interconnected that, from an ecological perspective, they can hardly be considered separate entities, and agrees with Afefe *et al.* (2019) reported, the mangrove is a tropical formation and its best growth occurs in high temperatures and the individual trees and shrubs, especially of the salt excreting species like A. marina, withstand to some extent dry and hot climate.

From the geomorphologic forms, the mangroves in Egypt growing in three main geomorphological forms (A mangrove community growing on an extensive inter-tidal flat; in an enclosed bay, protected by a coralline ridge; and growing in a channel) and four groups for environmental aspects: Climatic conditions; Geomorphological aspects of Red Sea lagoons, bays and islands; Water characteristics and Man-made modifications (Afefe, 2021a). For conservation of mangroves and flora: the sustainable management of the mangrove and floral biodiversity in the Red Sea coastal area requires stopping the severe human impacts that lead to eliminating certain plant populations and modifying the complex plant communities into simple fragile once (Afefe, 2020; Abbas *et al*., 2016; Afefe *et al*., 2016; Afefe, 2021b). The major threats to mangroves in Egypt are the exploitation of it for coastal development (as removal for constructing hotels, roads, and other infrastructures), firewood, camel feed, and timber. by human beings, this leads to a great loss of mangrove biodiversity (Afefe, 2021a).

CONCLUSION

The halophytic mode of life of mangroves is very interesting. The mechanism of salt tolerance in mangroves in particular *Avicennia marina*, its adaptations for surviving in a saline habitat, and its physiological characteristics are peculiar. As a result in the current study, the Soil factor: electric conductivity, $CaCO_3$, K^+, Ca^{++}, Cl^-, $Na^{+,}$ and Mg^{++} were the most important parameters determining the current distribution of mangrove pattern at the Egyptian Red Sea coast.

Moreover, the structure of the mangrove ecosystem is determined by the physical and chemical factors of the habitat. The limit of tolerance of each species is determined by its specific environmental requirements such as salinity, temperature, soil feature, pH, electrical conductivity, etc. Thus at the sea front *A. marina* and *R. mucronata* are the pioneers. The mangrove trees can grow in water ranging widely in salinity from marine to freshwater. No other trees can do it, and therefore when the environment becomes unsuitable for mangroves, the vegetation cannot be replaced.

Finally, giving an overview study some aspects of mangrove physiological and biochemical will help us to know more about the nature of mangrove vegetation. This will help us to suggest the remedial measures needed for the proper conservation of the mangrove ecosystem in Egypt and give the opportunity to transceiver this knowledge to other countries in the Red Sea and Arab region.

AUTHORS CONTRIBUTIONS

Conceptualization, A.A.A., A.M.S. and S.A.S.; methodology, A.M.S. and K.A.H.A..; data collection A.A.A.; data validation, S.A.S., A.M.S. and K.A.H.A.; data processing, A.A.A. and K.A.H.A.; writing—original draft preparation A.A.A.; writing—review and editing, A.A.A., S.A.S., A.M.S. and K.A.H.A.

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CONFLICT OF INTEREST

The authors do not have any competing financial, professional, or personal interests from other parties.

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