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Effect of salt habitat on the phytochemical composition of the halophyte *Arthrocnemum macrostachyum*

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Abstrct The current study investigates the effect of salt content on phytochemical composition of *Arthrocnemum macrostachyum* naturally growing in Deltaic coast, Egypt. The entire plant of *A. macrostachyum* in the flowering stage was collected from three sites in Deltaic Mediterranean coastal. Physical and chemical analyses of soil samples were determined by standard methods. The crude fiber, ash, ether extract, total nitrogen, protein and carbohydrates contents as well as mineral composition of selected halophyte was analyzed. The halophyte-supporting soil was sandy to sand-silty, with varying electrical conductivity, cations, and anions from one location to the next. In this work, we discovered that when salinity rises, the phytochemical content of a particular halophyte increase. *A. macrostachyum* attained the highest ash, total fiber, lipid, and total soluble sugars in site 3, with attained high electrical conductivity (mean value 7275 µmhos/cm). As a result, for the Egyptian desert, particularly the desert vegetation, prudent exploitation and long-term development are required.

keywords: Halophytes, Minerals, Phytochemical, Salt marshes, Coastal habitats.

1. Introduction

Halophytes contain 1%–2% of the flora in the world, and these are both monocots and dicots [1]. Halophytes show a diversity of growth responses to increasing salinity, ranging from inhibition up to dramatic stimulation. All halophytes display a common need to regulate cellular Na^+, Cl^- and K^+ concentrations as they adjust to the external water potential [2, 3].

The world's total area of salt-affected soils is 831 million hectares, with 397 million hectares of saline and 434 million hectares of sodic soils, respectively [4]. Due to population pressure, harsh environmental conditions, ever-increasing natural disasters, and global climate change, agricultural land is progressively diminishing [5, 6]. Salt affects more than 45 million hectares of irrigated land, accounting for 20% of total land, and 1.5 million ha of land is taken out of production each year due to high salinity levels [7]; if this trend continues, 50% of cultivable land will be lost by the middle of the twenty-first century [8].

The flora of Egypt contains about 2145 species and 220 intraspecific taxa of seed plants and vascular cryptogams belonging to 755 genera and 129 families [9]. The plant communities of the salinity habitat are organized into communities dominated or codominated by halophytes, such as *Arthrocnemum macrostachyum* (Moric.) K. koch., *Halocnemum strobilaceum* (pallas) M. Bieb., Inula crithmoides (L.) Dumort., *Juncus acutus* L., *J. rigidus* Desf., *Limoniastrum monopetalum* L. [10].

The family Chenopodiaceae is one of the largest families of the flowering plants. It consists of about 1500 species and about 102 genera distributed around the world. In Egypt, it is represented by 25 genera and 300 species [11]. The family consists primarily of succulent annual or perennial herbs, some are shrubs, and only a few are trees. They frequently inhabit dry, arid (xerophytic) and salt laden (halophytic) soils where they often become the dominant vegetation [12]. One of the species in this family is *Arthrocnemum macrostachyum*.

A. macrostachyum (glaucous glasswort) is a common succulent halophytic perennial shrub belonging to the family Chenopodiaceae. Its community is a prominent feature of the coastal strip vegetation, which can tolerate salt concentrations reaching up to 1.02 M [13]. It grows in patches covering the high sandy habitat amidst low areas where seeped water is accumulated [10]. The plant also plays a prominent role in traditional oriental and ancient medicine [14, 15], for example plant extracts are used as hypoglycemic agents [16]. This work mainly aims at the effect of salt content on phytochemical composition of *Arthrocnemum macrostachyum* naturally growing in Deltaic coast, Egypt.

2. Materials and Methods

2.1. Study area

The area chosen for the present study is located in the northern part of the Nile Delta region of Egypt which covers the north and middle borders of four Governorates namely, Port Said, El-Dakahlia, Damietta and Kafr El-Sheikh. Ecologically, the study area comprises four habitats: salt marshes, sand formations, reed swamps and fertile non-cultivated lands habitat (Figure 1).

2.2. Collection of plant material

The entire plant of *Arthrocnemum macrostachyum* in the flowering stage was collected in March 2020 from Deltaic Mediterranean coastal (**Plate 1**). The plant was identified by Dr. Yasser A. El-Ameir, Lecturer of Plant Ecology Botany Department, Faculty of Science, Mansoura University, Egypt, according to Boulos [17]. Healthy plants were gathered, handly cleaned and divided into two groups. 1) The first group is a fresh sample covered in foil and stored in the refrigerator, and 2) the second group is placed in zip-lock plastic bags, dry in an oven at 50 °C, ground to fine powder and preserved in a well stopped bottles which was directly used for different investigations. The experiment was repeated twice and the mean values were determined [18].

Plate 1. Close up view of *A. macrostachyum*

2.3. Soil Analysis

For each plant, soil samples were taken from 0-20 cm deep under the three populations investigated. The soil samples were dried, sieved, and kept until they could be examined further. For each soil sample, the physical and chemical analyses were determined by standard methods of Piper [19], Jackson [20], Allen, et al. [21], and Pierce, et al. [22]. The details were described in our previous work Abd-ElGawad et al., [23].

Figure 1: Map showing the different habitats and collection locations of the five halophytes.

2.4. Proximate Composition Analysis

AOAC [18] was used to determine the crude fiber, ether extract (lipid), and ash content of selected halophytes. The Kjeldahl technique [24] was used to estimate total nitrogen, and the protein content of the plant species was calculated by multiplying N content by 6.25 [18]. Hedge and Hosreiter's approach [25] was used to determine the carbohydrate content of the sample. A Flame Photometer (Model PHF 80 B Bi-ologie Spectrophotometer) was used to quantify sodium and potassium, while an atomic absorption spectrometer was used to estimate calcium and magnesium (A Perkin-Elmer, Model 2380. USA).

3. Results and Discussion

3.1. Soil analysis

3.1.1. Physical characteristics

The soil texture was assessed using the sieve method and found that the soil is sandy with very little silt and clay content. The fractions of sand, silt, and clay in the surface layer are 94.9, 4.4, and 0.7%, respectively, while the percentages in the subsurface layer are 97.6, 1.3, and 1.1%, with mean values of 96.25, 2.85, and 0.9%, respectively, in the soil samples supporting the growth of sample 1. The soil samples supporting the growth of sample 2, the fractions of sand, silt, and clay in the surface layer are 96.1, 2.7 and 1.2 %, respectively, while the percentages in the subsurface layer are 98.7, 0.9 and 0.4 %, with mean values of 97.4, 1.8 and 0.8 %, respectively On the other hand, the fractions of sand, silt, and clay in the surface layer of the soil samples supporting the growth of sample 3 are 82.7, 9.7, and 7.6%, respectively, while the percentages in the subsurface layer are 94.3, 4.7, and 1%, with mean values of 88.5, 7.2, and 4.3%, respectively.

The Hilgard Pan Box was used to analyze the WHC and discovered that there was some fluctuation in the various stands, with the surface layers being higher than the subsurface ones. The water– holding capacity of soil samples in the surface layer are 37.6, 32.4 and 30.5%, while the percentage of water- holding capacity in the subsurface layer are 35.0, 36.8 and 35.8% with a mean value of 36.6, 34.6 and 33.15% for sample 1, sample 2, and sample 3, respectively (Table 1). The porosity content showed slight variation in the different stands. The soil porosity of soil samples in the surface layer are 49.5, 42.7 and 49.9%, while the percentage of in the subsurface layer are 48.3, 42.1 and 43.2% with a mean value of 48.9, 42.4 and 46.55% for sample 1, sample 2 and sample 3, respectively (Table 1).

Table 1. Physical parameters of the represented habitats supporting the growth of the halophyte Arthrocnemum macrostachyum along the Deltaic Mediterranean coastal desert, Egypt.

A. macrostachyum	Depth (cm)	Physical characteristics					
		Sand (%)	Silt (%)	Clay (%)	Texture class	WHC %	Porosity %
Sample 1 (n=3)	0 – 20	94.9	4.4	0.7	Sand	37.6	49.5
	20-40	97.6	1.3	1.1	Sand	35	48.3
	Mean	96.25	2.85	0.9	Sand	36.3	48.9
Sample 2 (n=3)	0 - 20	96.1	2.7	1.2	Sand	36.8	42.7
	20-40	98.7	0.9	0.4	Sand	32.4	42.1
	Mean	97.4	1.8	0.8	Sand	34.6	42.4
Sample 3 (n=3)	0 - 20	82.7	9.7	7.6	Loamy Sand	35.8	49.9
	20-40	94.3	4.7	1	Sand	30.5	43.2
	Mean	88.5	7.2	4.3	Sand	33.15	46.55
Total mean		94.05	3.95	2.00		34.68	45.95

3.1.2. Soil chemical Properties

The calcium carbonate percentages in the surface layer are 2.68, 2.28, and 5.16%, respectively, while calcium carbonate percentages in the subsurface layer are 2.61, 3.08, and 4.59%, with mean values of 2.65, 2.68, and 4.88% for sample 1, sample 2, and sample 3, respectively. The organic carbon content showed slight variation in the different stands, usually higher in the subsurface layers than in the surface ones. The percentage of organic carbon are 0.57, 0.44 and 1.02% in the surface layer, while the percentage of organic carbon in the subsurface layer are 0.5, 0.6 and 0.83% with mean value of 0.54, 0.52 and 0.93% for sample 1, sample 2 and sample 3, respectively.

The soil pH values measured in all sites vary from slightly alkaline to alkaline in soil reaction, with a narrow range of variations from stand to other. The soil pH values are 10.37, 9.6 and 9.05 in the surface layer, while the soil pH values in the subsurface layer are 9.02, 9.57 and 9.45 with mean value of 9.7, 9.59 and 9.25 for sample 1, sample 2 and sample 3, respectively. The electrical conductivity (soil salinity) in the analyzed samples varied considerably in the different coastal sampled stands. Relatively higher values were determined in the subsurface layers than in surface one, except sample 3 contrast. The concentration of electrical conductivity (EC) are 120, 2230 and 8560 µmhos/cm in the surface layer, while the concentration of electrical conductivity (EC) are in the subsurface layer are 450, 3220 and 5990 µmhos/cm with mean value of 285, 2725 and 7275 µmhos/cm for sample 1, sample 2 and sample 3, respectively. The soluble chloride contents attained higher levels in sample 3, The percentage of chlorides are 0.01, 0.22 and 0.88% in the surface layer, while the percentage of chlorides in the subsurface layer are 0.04, 0.33 and 0.57% (mean value = 0.03, 0.28 and 0.73%) for sample 1, sample 2 and sample 3, respectively.

The percentage of sulphate content are 0.01, 0.13 and 0.47 % in the surface layer, while the percentage of sulphate content in the subsurface layer are 0.03, 0.17 and 0.4% (mean value of 0.02, 0.15 and 0.44%) for sample 1, sample 2 and sample 3, respectively. The soluble carbonate content is absent from all soil samples. On the other hand, the soluble bicarbonate content is determined in low amounts. The percentage of bicarbonates are 0.01, 0.16 and 0.56 % in the surface layer, while the percentage of bicarbonates in the subsurface layer are 0.04, 0.23 and 0.38% with mean value of 0.03, 0.195 and 0.47% for sample 1, sample 2 and sample 3, respectively.

The concentration of sodium markedly varied from stand to other and also varied from the surface to subsurface layers of the same profile. The concentration of sodium is 43.72, 163.3 and 656.88 mg/100g dry soil in the surface layer, while the percentage of sodium in the subsurface layer are 76.81, 241.73 and 434.47 mg/100g dry soil with mean value of 60.27, 202.52 and 545.68 mg/100g dry soil for sample 1, sample 2 and sample 3, respectively. The concentration of potassium is 7.83, 28.08 and 101.01 mg/100g dry soil in the surface layer, while The concentration of potassium in the subsurface layer are 27.34, 36.27 and 72.93 mg/100g dry soil with mean value of 17.59, 32.175 and 86.97 mg/100g dry soil for sample 1, sample 2 and sample 3, respectively. The calcium content shows the same trend of Na^+, The concentration of calcium is 13.06, 46.2 and 173.8 mg/100g dry soil in the surface layer, while The concentration of calcium in the subsurface layer are 48.26, 65 and 119.6 mg/100g dry soil with mean value of 30.66, 55.6 and 146.7 mg/100g dry soil for sample 1, sample 2 and sample 3, respectively. The concentration of magnesium is 4.20, 15.48 and 47.88 mg/100g dry soil in the surface layer, while The concentration of magnesium in the subsurface layer are 19.27, 21.6 and 47.16 mg/100g dry soil with mean value of 11.74, 18.54 and 47.52 mg/100g dry soil for sample 1, sample 2 and sample 3, respectively.The phytodiversity of natural communities can be influenced by soil texture, salinity, and organic carbon [26, 27]. In this study, soil texture, WHC, organic carbon, cations (Na^+, K^+, Ca^{++}, and Mg^{++}), and SAR were obviously the most influencing soil parameters with strong significant relationships with the first and second axis. This agrees more or less with the findings of Maswada and Elzaawely [28], El-Amier et al. [29] and Abd-ElGawad et al. [23] in the Mediterranean area of the Nile Delta.

Table 2. Chemical parameters of the represented habitats supporting the growth of the halophyte *Arthrocnemum macrostachyum* along the Deltaic Mediterranean coastal desert, Egypt.

Soil variables	***A. macrostachyum***								
	Sample 1 (n=3)			**Sample 2 (n=3)**			**Sample 3 (n=3)**		
	Depth (cm)		**Mean**	**Depth (cm)**		**Mean**	**Depth (cm)**		**Mean**
	0 – 20	20-40		0 - 20	20-40		0 - 20	20-40	
$CaCO_3$ (%)	2.68	2.61	2.65	2.28	3.08	2.68	5.16	4.59	4.88
Organic carbon (%)	0.57	0.5	0.54	0.44	0.6	0.52	1.02	0.83	0.93
pH	10.37	9.02	9.7	9.6	9.57	9.59	9.05	9.45	9.25
EC µmhos/cm	120	450	285	2230	3220	2725	8560	5990	7275
Cl^- (%)	0.01	0.04	0.03	0.22	0.33	0.28	0.88	0.57	0.73
SO_4^{--} (%)	0.01	0.03	0.02	0.13	0.17	0.15	0.47	0.4	0.44
CO_3^{--} (%)	0	0	0	0	0	0	0	0	0
HCO_3^- (%)	0.01	0.04	0.03	0.16	0.23	0.195	0.56	0.38	0.47
Cations (mg/100 g dry soil)									
Na^+	43.72	76.81	60.27	163.3	241.73	202.52	656.88	434.47	545.68
K^+	7.83	27.34	17.59	28.08	36.27	32.175	101.01	72.93	86.97
Ca^{++}	13.06	48.26	30.66	46.2	65	55.6	173.8	119.6	146.7
Mg^{++}	4.20	19.27	11.74	15.48	21.6	18.54	47.88	47.16	47.52

3.2. Proximate composition of the selected halophytes Smallholder populations and subsistence farming in underdeveloped nations rely on wild plants for food, fodder, and livelihoods. Plant species compositions provide essential ecological services and are critical in determining the nutritional relevance of plants for both humans and animals [30]. Table 3 shows a proximate study of the nutritional contents of *Arthrocnemum macrostachyum*.

1. Total ash: for sample 1, total ash is 6.55, 6.97, and 7.42 with a mean value of 6.98, while for sample 2, total ash is 7.88, 7.24, and 7.86 with a mean value of 7.66. On the other hand, total ash is 8.55, 8.97 and 9.42 with mean value of 8.98 for sample 3.
2. Crude fiber: for sample 1, crude fiber is 10.31, 10.77, 11.51 and with a mean value of 10.86, while for sample 2, crude fiber is 12.42, 13.07, and 12.33with a mean value of 12.61. On the other hand, crude fiber are13.96, 13.88 and 14.67with mean value of 14.17for sample 3.
3. Lipid %: for sample 1, lipid are1.44, 1.47 and 1.50 % with a mean value of1.47 %, while for sample 2, lipid is 0.91, 0.78, and 0.83% with a mean value of 0.84 %. On the other hand, lipid is 0.48, 0.51 and 0.53% with mean value of 0.51% for sample 3.
4. Total-nitrogen: for sample 1, total-nitrogen are 0.75, 0.78 and 0.74with a mean value of 0.76, while for sample 2, total -nitrogen are 0.89, 0.91 and 0.89 with a mean value of 0.90. On the other hand, total -nitrogen are1.22, 1.31and 1.43with mean value of 1.32 for sample 3.
5. Crude protein: for sample 1, crude protein is 4.69, 4.88 and 4.63 with a mean value of 4.73, while for sample 2, crude protein is 5.56, 5.69 and 5.56 with a mean value of 5.60. On the other hand, crude protein is 7.63, 8.19 and 8.94 with mean value of 8.25 for sample 3.
6. Total carbohydrates: for sample 1, total carbohydrates are 331.36, 328.47 and 322.71 mg g^{-1} DW with a mean value of 327.51 mg g^{-1} DW, while for sample 2, total carbohydrates are 324.18, 328.61 and 323.81 mg g^{-1} DW with a mean value of 325.53 mg g^{-1} DW. On the other hand, total carbohydrates are 319.22, 315.07and 309.38 mg g^{-1} DW with mean value of 314.56 mg g^{-1} DW for sample 3.

7 This study's findings are consistent with those of other wild species such as L. pyrotechnica, sunflower, date palm leaves, and rice straw [31, 32]. But it's greater than what Zahran and El-Amier [33] and El-Amier and Al-hadithy [34] stated. The variation in results might be explained by differences in origin, plant species, age, ecofactors, and meteorological circumstances [35].

Table 3. Salt-affected habitats on proximate composition of the halophyte *Arthrocnemum macrostachyum* along the Deltaic Mediterranean coastal desert of Egypt.

A.macrostachyum	**No. of samples**	**Parameters**					
		Total ash	**Crude fiber**	**Lipid**	**Total-nitrogen**	**Crude protein**	**Totalcarbohydrates**
		%					**mg g^{-1} DW**
Sample 1 (n=3)	1	6.55	10.31	1.44	0.75	4.69	331.36
	2	6.97	10.77	1.47	0.78	4.88	328.47
	3	7.42	11.51	1.50	0.74	4.63	322.71
	Mean	6.98	10.86	1.47	0.76	4.73	327.51
Sample 2 (n=3)	1	7.88	12.42	0.91	0.89	5.56	324.18
	2	7.24	13.07	0.78	0.91	5.69	328.61
	3	7.86	12.33	0.83	0.89	5.56	323.81
	Mean	7.66	12.61	0.84	0.90	5.60	325.53
Sample 3 (n=3)	1	8.55	13.96	0.48	1.22	7.63	319.22
	2	8.97	13.88	0.51	1.31	8.19	315.07
	3	9.42	14.67	0.53	1.43	8.94	309.38
	Mean	8.98	14.17	0.51	1.32	8.25	314.56

3.3. Effects of salinity on mineral (macro elements) composition

1. Sodium: for sample 1, sodium is 27.18, 25.61 and 23.71 mg g^{-1} DW with a mean value of 25.50 mg g^{-1} DW, while for sample 2, sodium is 64.36, 61.22 and 57.42 mg g^{-1} DW with a mean value of 61.00 mg g^{-1} DW. On the other hand, sodium are118.32, 120.94 and 125.86 mg g^{-1} DW with mean value of 121.71 mg g^{-1} DW for sample 3.
2. Potassium: for sample 1, potassium is 71.21, 76.29 and 73.57 mg g^{-1} DW with a mean value of 73.69 mg g^{-1} DW, while for sample 2, potassium is 60.11, 62.04 and 57.31 mg g^{-1} DW with a mean value of 59.82 mg g^{-1} DW. On the other hand, potassium is 48.07, 43.69 and 40.03 mg g^{-1} DW with mean value of 43.93 mg g^{-1} DW for sample 3.
3. Calcium: calcium values for sample 1 are 37.07, 40.10, and 41.87 mg g^{-1} DW, with a mean of 39.68 mg g^{-1} DW, while calcium values for sample 2 are 50.32, 49.61, and 55.09 mg g^{-1} DW, with a mean of 51.67 mg g^{-1} DW. on the other hand, calcium values are 64.14, 70.20, and 73.74 mg g^{-1} DW, with a mean of 69.36 mg g^{-1} DW in sample 3.
4. Magnesium: for sample 1, magnesium is 13.25, 15.69 and 15.07 mg g^{-1} DW with a mean value of 14.67 mg g^{-1} DW, while for sample 2, magnesium is 22.41, 20.85 and 25.05 mg g^{-1} DW with a mean value of 22.77 mg g^{-1} DW. On the other hand, magnesium is 27.69, 31.54 and 33.17 mg g^{-1} DW with mean value of 30.80 mg g^{-1} DW for sample 3.

5 When dietary calcium and phosphorus concentrations are low, a Mg^{2+} content of 0.04 percent in the diet should satisfy maintenance needs, according to Underwood and Suttle [36]. Our Mg^{2+} levels are greater than those seen in white clover [37] and wild grasslands [38]. Plants can be mineral-poor or mineral-rich depending on soil and environmental conditions (light, temperature, water, and humidity) [39]

Table 4. Salt-affected habitats on mineral (macro-elements) composition of the halophyte Arthrocnemum macrostachyum along the Deltaic Mediterranean coastal desert of Egypt.

A. macrostachyum	No. of samples	Macro-elements (mg g^{-1} DW)			
		Na^+	K^+	Ca^{2+}	Mg^{2+}
Sample 1 (n=3)	1	27.18	71.21	37.07	13.25
	2	25.61	76.29	40.10	15.69
	3	23.71	73.57	41.87	15.07
	Mean	25.50	73.69	39.68	14.67
Sample 2 (n=3)	1	64.36	60.11	50.32	22.41
	2	61.22	62.04	49.61	20.85
	3	57.42	57.31	55.09	25.05
	Mean	61.00	59.82	51.67	22.77
Sample 3 (n=3)	1	118.32	48.07	64.14	27.69
	2	120.94	43.69	70.20	31.54
	3	125.86	40.03	73.74	33.17
	Mean	121.71	43.93	69.36	30.80

4. Conclusion

The current study discovered that the investigated halophyte *A. macrostachyum* has a significant amount of nutritious components and minerals. The current findings suggest that the halophyte evaluated might be considered for pasture manufacture or as a green, environmentally friendly natural resource for bioactive chemicals. A more in-depth investigation of the examined halophyte as non-traditional feed for various species, as well as their safety and sustainability, is advised. As a result, for the Egyptian desert, particularly the wadi vegetation, prudent exploitation and long-term development are required.

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