MANSOURA JOURNAL OF BIOLOGY
Official Journal of Faculty of Science, Mansoura University, Egypt
E-mail: scimag@mans.edu.eg ISSN: 2974-492X

Ecology of four halophytes along the Egyptian Middle Mediterranean coast

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Received:27/6/2023
Accepted: 18/7/2023

Abstract To achieve sustainable development, it is critical to conserve biodiversity and address the main drivers for distribution and abundance of plant species. In this study, the floristic and ecological features of four halophytes (*Atriplex halimus* L., *Arthrocnemum macrostachyum* (Moric.) K.Koch , *Limbarda crithmoides* (L.) Dumort. and *Tamarix nilotica* (Ehrenb.) Bunge) along the middle Mediterranean coast of Egypt were addressed in 55 stands. A total of 52 plant-species, 45-genera, 21-families were surveyed. After Two-Way Indicator Species Analysis (TWINSPAN), three groups were segregated: A: *Tamarix nilotica-A. macrostachyum*, B: *Atriplex halimus-Carthamus tenuis*, and C: *Avena fatua-A. macrostachyum*. The following soil factors: pH, Clay, SO4, total nitrogen (TN), SO4, water holding-capacity (WHC), electric conductivity (EC) were the main factors affecting the distribution of the vegetation in the sampled stands.

Keywords: Halophytes, *Atriplex*, *Arthrocnemum*, *Limbarda*, *Tamarix*, Ordination.

1.Introduction

Medicinal plants have long played important roles in the treatment of diseases all over the world **[1]**. They are a source for a wide variety of natural antioxidants and are used for the treatment of diseases throughout the world **[2]**. Some of these properties are antimicrobial **[3]**, anti-cancer **[4]**, anti-diabetic **[5]**, anti-atherosclerosis **[6]**, immunomodulatory **[7]**, and even reno-protection or hepatoprotective effects **[8]**. Recently, due to beneficial effects of antioxidants, particularly natural antioxidants, in the treatment and prevention of diseases, there has been a considerable interest in finding natural antioxidants from plant sources. The studies on medicinal plants show that most of them possess significant antioxidant activity **[2]**. Leaves, fruits and seeds of species of halophytic families like Amaranthaceae, Asteraceae, Chenopodiaceae, Apiaceae, Brassicaceae, Capparaceae, Plantaginaceae, Portulacaceae and Zygophyllaceae are the most important families among more than 50 plant families with medicinal properties **[9]**. These plants are mostly for the treatment of urinary system and internal diseases, as well as skin and respiratory conditions **[10]**. Inland salt marshes in the desert region and coastal salt marshes in Egypt are home to halophytes (along the Mediterranean and Red Sea coasts). The 2300 species of the Egyptian flora under consideration include over 80 terrestrial halophytic species that belong to 31 genera and 17 families.

Primary metabolites of halophytes, such as carbohydrates and lipids, are regarded with interest as supplements or nutraceutics. Secondary metabolites, such as terpenes and phenols, have antioxidant and anti-inflammatory antitumoral and antimicrobial activities **[11]** and underlie many of the applications of halophytes in traditional medicine **[12]**. Some compounds modulate and stimulate the immune system, lower the risk of heart diseases, control body weight and blood sugar levels, and can even act as antiaging agents **[13]**. Additionally, only a few studies have researched the bioactive phytocompounds of some of these plants **[14]**.

Atriplex halimus a perennial natural shrub belongs Chenopodiaceae family grows across the Mediterranean basin and is frequently utilized as feed due to its drought and salt tolerance, as well as its high protein content **[15-17]**. *Arthrocnemum macrostachyum* is a halophyte of in Chenopodiaceae family. It is abundantly growing in the coastal zones of the Mediterranean basin, Red sea, Middle East and Asia **[18-19]**. *Limbarda crithmoides* is a perennial coastal halophyte belonging to the family Asteraceae. It is a succulent plant natively distributed along the wetland's marsh areas, and sea cliffs throughout western and southern Europe and the Mediterranean basin **[20-21].** *Tamarix nilotica* is a species belonging to the Tamaricaceae family. It is a perennial halophyte growing naturally at the Mediterranean coastal salt marshes. It usually grows on saline soils **[22-24]**. The present work was conducted to (i) address the floristic associated with the selected halophytes, and (ii) detect the soil factors the distribution of the recognized plant groups.

2. Materials and methods

2.1. Study area

The sampled stands were distributed along the middle Mediterranean coastal region of Egypt where four studied halophytes are growing **(Fig 1)**.

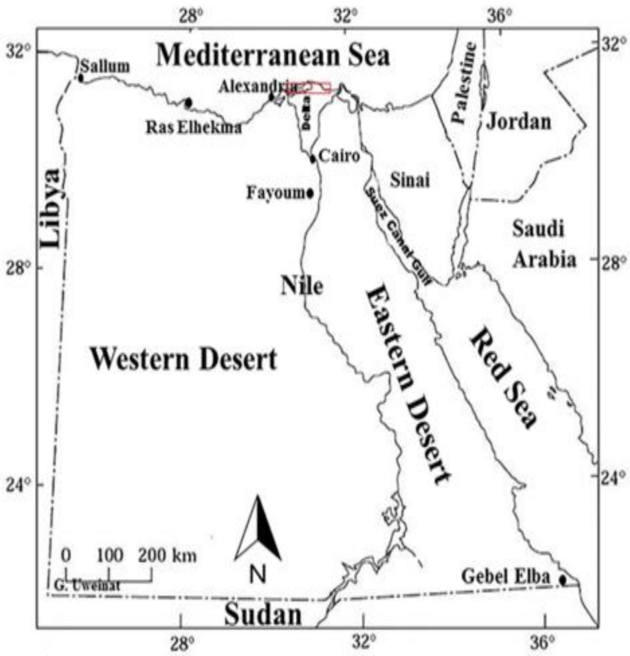

Fig (1): Map of Egypt shows the study area. The study area is highlighted in red colour

2.2. Vegetation analysis

Fifty-five stands of 20 m^2 each were selected across the middle coastal region. In each stand, all plants were listed. The importance-value was estimated by the sum of relative-density and relative cover **[25]**. The plant species were named after Tackholm **[26]** Boulos **[27].** According to Raeunkiaer **[28]**, life-form was recognized. The chorotypes were regarded Zohary **[29]** and Feinbrun--Dothan **[30]**.

TWINSPAN was categorized the flora of 52 species in 55 stands **[31-33],** while DCA was distributed the stands. CCA to connect the leading characteristic species with the soil factors **[34]**.

2.3. Soil- analysis

Three soil samples were collected at 50 cm depth and pooled as a composite. All of physical and chemical analyses were approved according to AOAC **[35]**.

3. Results

3.1. Floristic features

The floristic associates within the four studied halophytes are displayed in **Table (1)**. 52 plant-species, 45-genera, 21-families in 55 stands. The largest, most species-rich families were Asteraceae (11), Poaceae = Chenopodiaceae (6 each), Polygonaceae (5). Out of 52 species, 26 perennials, 25 annuals, and only one species was biennial.

As displayed in **Table (1)**, the life-forms of 52 species contained 24 therophytes, 8 chamaephyte, 9 hemicryptophyt, 6 phanerophyte and 5 cryptophyte.

The floristic classes of recorded-species are presented in Table (1). Bi-regional had the highest contribution by 34.6% (18 species), mono-regional (13 species= 25%), and pluri-regional (11 species = 15.74%).

3.2. Vegetation data

Based on the importance value of the 52 species and 55 stands by TWINSPAN three groups labelled A, B and C **(Fig. 2)**. Group A: *T. nilotica-A. macrostachyum*, Group B: *Atriplex halimus-Carthamus tinctorius*, Group C: *Avena fatua-A. macrostachyum*.

Vegetation group A included 40 species in 33 stands **(Table 2)**. The most important associated species were *L. crithmoides* (IV= 22.96) and *Halocnemum strobilaceum* (IV= 14.71). Group B consisted of 33 plant species distributed in 12 stands, the most dominant species were *A. halimus* (IV= 60.32) and *C. tenuis* (IV= 16.95). The most important associate was *C. murale* (IV= 12.83) and *T. nilotica* (IV= 12.27). Group C included 27 plant species distributed in 10 stands. The dominant species were *Avena fatua* (IV= 51.29) and *A. macrostachyum* (IV= 35.02). The most important species were *Reichardia tingitana* (IV= 29.03) and *A. halimus* (IV= 16.77).

Table (1): Species composition found in the study areas including family, life span, life form and floristic category. Life span is indicated by A: annual, B: biennial, P: perennial; life form includes Th: therophyte; Ch: chamaephyte; H: hemicryptophytes; Ph: phanerophytes; Cr: cryptophytes; and floristic category includes ME: Mediterranean; SA-SI: Saharo-Sindian; IR-TR: Irano-Turanian; S-Z: Sudano-Zambezian; ER-SR: Euro-Siberian; PAL: Palaeotropical, COSM: Cosmopolitan; NEO: Neotropical

Species	Family	Life span	Life form	Floristic category
Aegilops bicornis Jaub. & Spach	Poaceae	Ann	Th	ME+IR-TR+SA-SI
Alhagi grocoreum Boiss.	Fabaceae	Per	H	PAL
Arthrocnemum macrostachyum (Moric.) K.Koch	Chenopodiaceae	Per	Ch	ME+SA-SI
Asparagus stipularis Forssk.	Asparagaceae	Per	Cr	ME
Atriplex halimus L.	Chenopodiaceae	Per	Ch	ME+SA-SI
Avena fatua L.	Poaceae	Ann	Th	PAL
Brassica nigra (L.) Koch	Brassicaceae	Ann	Th	COSM
Brassica tournefortii Gouan	Brassicaceae	Ann	Th	ME+IR-TR+SA-SI
Bromus diandrus (Roth.)	Poaceae	Ann	Th	ME
Cakile maritima Scop.	Brassicaceae	Ann	Th	ME+SA-SI
Calligonum polygnoidues L.	Polygonaceae	Per	Ph	SA-SI+IR-TR
Carthamus tenuis (Boiss. & C.I. Blanche) Bornm.	Asteraceae	Ann	Th	ME
Carthamus tenuis L.	Asteraceae	Ann	H	COSM
Chenopodium album L.	Chenopodiaceae	Ann	Th	COSM
Chenopodium murale L.	Chenopodiaceae	Ann	Th	COSM
Conyza aegyptiaca (L.) Aiton	Asteraceae	Bi	Th	ME
Cynanchum acutum L.	Asclepiadaceae	Per	H	ME+IR-TR
Cyperus capitatus Vand.	Cyperaceae	Per	Cr	ME
Echinops spinosissimus Turra.	Asteraceae	Per	H	ME+SA-SI
Emex spinosa (L.) Campd.	Polygonaceae	Ann	Th	ME+SA-SI
Erodium laciniatium (Cav.) Wild	Geraniaceae	Ann	Th	ME
Halocnemum strobilaceum (Pall.) M.	Chenopodiaceae	Per	Ch	SA-SI+IR-TR
Heliotropium curassavicum L.	Boraginaceae	Per	Ch	SA-SI+S-Z
Hordeum murinum Huds.	Poaceae	Per	H	ME+IR-TR+ER-SR
Juncus acutus L.	Juncaceae	Per	H	ME+IR-TR+ER-SR
Juncus rigidus Desf.	Juncaceae	Per	H	ME+IR-TR+SA-SI
Lactuca serriola L.	Asteraceae	Ann	Th	ME+IR-TR+ER-SR
Launaea resedifolia (L.) Kuntz	Asteraceae	Ann	H	ME+SA-SI
Limbarda crithmoides (L.) Dumort	Asteraceae	Per	Ch	ME+ER-SR+AS-SI
Limoniastrum monopetalum (L.) Boiss.	Plumbaginaceae	Per	Ch	ME
Lycium europaeum L.	Solanaceae	Per	Ph	ME+IR-TR
Lycium schweinfurthii Dammer	Solanaceae	Per	Ph	ME
Malva parviflora L.	Malvaceae	Ann	Th	ME+IR-TR
Melilotus indicus (L.) All.	Fabaceae	Ann	Th	PAL
Mesembryanthemum crystallinum L.	Aizoaceae	Ann	Th	ME+ER-SR
Nicotiana glauca Graham	Solanaceae	Per	Ph	COSM
Pancratium maritimum L.	Amaryllidaceae	Per	Cr	ME
Phragmites australis (Cav.) Trin. ex Steud.	Poaceae	Per	H	COSM
Polygonum equisetiforme sibthi & Sm.	Polygonaceae	Per	Cr	ME+IR-TR
Reichardia tingitana (L.) Roth	Asteraceae	Ann	Th	ME+IR-TR+SA-SI
Retama raetam (Forssk.) Webb. & Berthel.	Fabaceae	Per	Ph	ME+IR-TR+SA-SI
Ricinus communis L.	Euphorbiaceae	Per	Ch	PAN
Rumex Pictus Forssk.	Polygonaceae	Ann	Th	ME+SA-SI
Rumex vesicarius L.	Polygonaceae	Ann	Th	ME+SA-SI+S-Z
Salsola kali L.	Chenopodiaceae	Ann	Th	COSM
Senecio glaucus L.	Asteraceae	Ann	Th	ME+IR-TR+SA-SI
Sonchus oleracus L.	Asteraceae	Ann	Th	ME
Stipagrostis lanata (Frossk.) De winter.	Poaceae	Per	Cr	SA-SI
Tamarix nilotica (Ehreb.) Bunge.	Tamaricaceae	Per	Ph	SA-SI+S-Z
Urospermum picroides (L.) F. W.	Asteraceae	Ann	Th	ME+IR-TR
Zygophyllum aegyptium Hosny.	Zygophyllaceae	Per	Ch	ME
Zygophyllum simplex L.	Zygophyllaceae	Ann	Th	SA-SI+S-Z

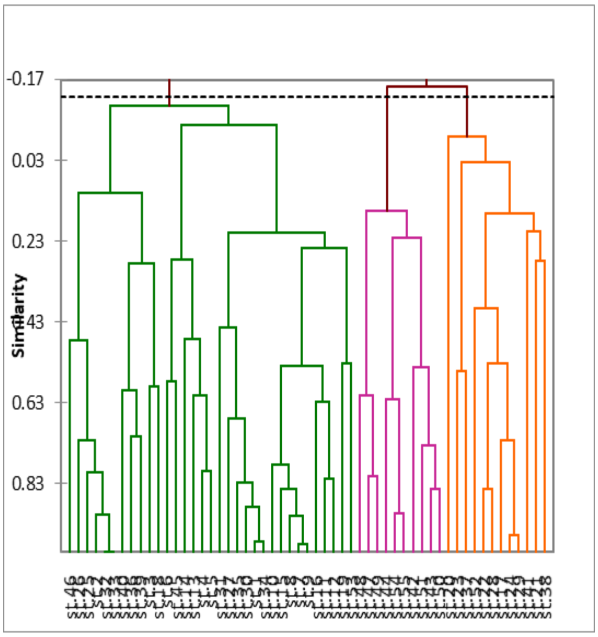

Fig. (2): TWINSPAN showing the three groups (A, B, C). The dashed line represents the level of classification.

The DCA of 55 sampled-stands is explained in **Fig. (3)**. It is obvious; the clusters (A, B and C) were clearly variable and had a specific form of segregation.

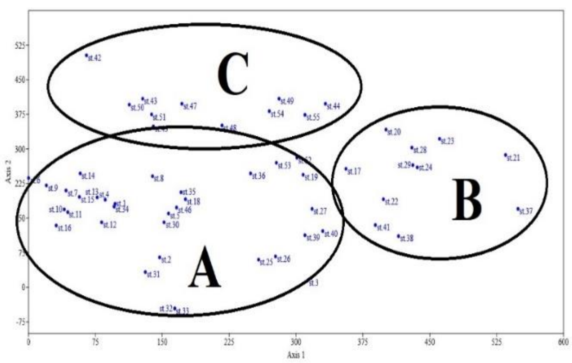

Fig. (3): DCA of three vegetation groups (55 sampled stands) in the study area

3.3. Vegetation- soil correlation

Results of the CCA of characteristic species and soil factors are displayed in **Fig. 4**. The following soil factors: pH, Clay, SO4, TN, SO4, WHC, EC were the main factors affecting the distribution of the vegetation in the sampled stands. On the other hand, *Carthamus tenuis* a co-dominant member of group B were parted at the right upper part of the CCA and were positively correlated with EC, Mg and K. *T. nilotica* and *L. crithmoides* are the leading members of group A were parted at right lower quarter of the CCA and positively correlated with sand fraction, bicarbonate, Cl- and OC. *A. macrostachyum* a co-dominant species of group A and C, *Halocnemum strobilaceum*, an important species of group A were parted at the lower left side of the CCA were positively correlated with clay, porosity, calcium, sulphate, pH and TDP, *Avena fatua* and *Reichardia tingitana* the leading members of group C were parted at the upper left quarter of the CCA were positively correlated with TN, Na, WHC, slit and calcium carbonate.

Table (2): Characteristic features of three vegetation groups with their first, second and important species with their importance values (IV)

. Group	No. of stands	No. of species	Dominant species	Important-species
A	**33**	**40**	***Tamarix nilotica*** **(IV = 54.9) and** ***Arthrocnemum macrostachyum*** **(IV = 25.69)**	***Limbarda crithmoides*** **(IV = 22.96) and** ***Halocnemum strobilaceum*** **(IV = 14.71).**
B	**12**	**33**	***Atriplex halimus*** **(IV = 60.32) and** ***Carthamus tenuis*** **(IV = 16.95).**	***Chenopodium murale*** **(IV = 12.83) and** ***Tamarix nilotica*** **(IV = 12.27).**
C	**10**	**27**	***Avena fatua*** **(IV = 51.29) and** ***Arthrocnemum macrostachyum*** **(IV = 35.02).**	***Reichardia tingitana*** **(IV = 29.03) and** ***Atriplex halimus*** **(IV = 16.77).**

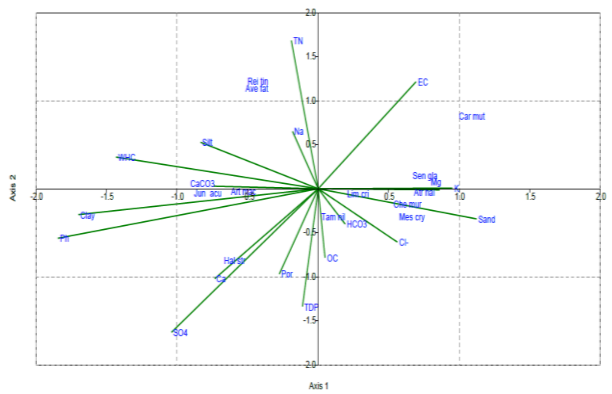

Fig. (4): CCA-ordination of species in each group (A, B and C) and soil variables

4. Discussion

A total of 52 plant species of 45 genera and 21 families were recorded as associates within the community of the studied four halophytes. As agreed with the Egyptian flora, five taxonomic families (Asteraceae, Poaceae, Chenopodiaceae, Polygonaceae, Brassicaceae and Solanaceae were the key families in the study area for the recorded species **[19, 27]**. The richness of a specific family proves that, its members able to persist under severe conditions, prevail in coastal deserts with high salinity.

The predominance of therophytes, Sahara-Sindian with Mediterranean-species was clear in species. This due to hot-dry conditions, and human factors in the study area **[24]**. The prevalence of Saharo-Sindian elements is a better indicator of sever-conditions **[26]**.

The current study includes a mixture of chorotypes. This finding reveals the ability of one floristic category to inhabit the region from other adjacent phytogeographic -regions **[31]**.

The complete description and classification of vegetation in a specific area provides an overall view about biodiversity status and ecosystem services. Concerning vegetation classification, the vegetation that characterizes the study area was apportioned by the TWINSPAN into three groups or community types. The groups: (A): *Tamarix nilotica-Arthrocnemum macrostachyum*, (B): *Atriplex halimus-Carthamus tenuis* and (C): *Avena fatua- Arthrocnemum macrostachyum*. The vegetation in the study area is close similar to those in previous studies in the same study area **[19, 23, 35-36]**.

Regarding the correlation between characteristic and target species in the identified plant groups and soil factors through CCA, the following soil factors: pH, Clay, SO_4, TN, SO_4, WHC, EC were the main factors affecting the distribution of the vegetation in the sampled stands. *Atriplex halimus* is closely related to K and Mg, *T. nilotica* is related to HCO_3, Cl and OC, *A. macrostachyum* is linked to $CaCO_3$, while *L. crithmoides* is linked to sand fraction, K, Cl^- and OC. These findings agreed with [35, 36].

5. Conclusions

The Mediterranean coastal region of Egypt is subjected to the recent human-threats affecting the vegetation and habitats, so a conservation plan for them is critically required. A total of 52 plant species is recorded in the 55 sampled stands as associated species within the community of the target halophytes. pH, Clay, SO_4, TN, SO_4, WHC, EC were the main factors affecting the distribution of the vegetation in the sampled stands

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