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Floristic composition and species diversity of plant communities associated with genus *Atriplex* in Nile Delta coast, Egypt

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ABSTRACT

Chenopodiaceae including *Atriplex* (300 spp.) as the largest genus of the family, with an ecologically important group in the world. The present study aimed to describe the plant communities associated with *Atriplex* spp. and its edaphic factors in Deltaic Mediterranean coast. A total of 92 species (44 annuals, one biennial, and 47 perennials) belonging to 73 genera and 24 families were recorded in 67 sampled stands in the present study. Poaceae, Asteraceae, and Chenopodiaceae are the largest families (18.48, 16.30 and 14.13 % of the total recorded flora, respectively). Therophytes were the most abundant life form and accounted for 52.63% of the total species. The chorological data indicated that the abundance of the Mediterranean (67.38%) and Saharo-Sindian (39.12%) element in the study area. The application of TWINSPAN analysis yielded four distinct vegetation groups (A, B, C and D); each is linked to one or more of the studied *Atriplex* spp. Group B was the most diversified (64 species) among the recognized groups with average Simposn index of 0.81, Shannon–Wiener index of 3.63 and Shannon-evenness index of 0.78. The main soil factors affecting the study *Atriplex* spp. are electrical conductivity, cations, porosity, potassium adsorption ratio (PAR), calcium carbonate, bicarbonate, pH and organic carbon.

Key words: *Atriplex***,** Chenopodiaceae, vegetation, edaphic factors, diversity index, Deltaic coast.

INTRODUCTION

Atriplex is a large genus in family Chenopodiaceae, and include 25 genera and 300 species in the flora of Egypt, known by the common name of saltbush (Tackholm, 1974; Boulus, 2002). Most *Atriplex* species are annuals, herbaceous perennials or shrubs, with the scurfy or mealy crust. The genus is quite variable and nearly worldwide from subtropical to temperate and to subarctic regions. It includes many desert and seashore plants and halophytes, as well as plants of moist environments (Kadereit *et al*., 2010). No member of this genus contains any toxins; moreover, *Atriplex* is characterized by their high content of sodium chloride, they are said to be useful as edible fodder plants (Risk, 1986; El-Shaer & Attia-Ismail, 2015).

The Arab Republic of Egypt (≈ 1.01 million km²) is located in the north-eastern corner of Africa and south -western Asia. Topography, Egypt is divided into four major parts: 1) The Nile Valley and Delta, 2) The Western Desert, 3) The Eastern Desert and 4) The Sinai Peninsula (Zahran & Willis, 2009; El-Amier & AbdulKader, 2015). The Nile Delta is the delta formed in Lower Egypt, where the Nile River spreads out and drains into the Mediterranean Sea. It is one of the oldest intensely cultivated areas on earth. More than 90% of the population of Egypt today lives adjacent to and relies directly on the Nile and its delta. The northern coast of Egypt extends for about 1,050 km (650 mi) along the Mediterranean Sea from the eastern side of the Sinai Peninsula at Egypt- Palestinian border to the western village of Sallum at Egypt's border with Libya (Shalaby & Tateishi, 2007; El-Ramady *et al*., 2013; Ezzeldin *et al*., 2016).

In Egypt, the Mediterranean coast is classified into three parts: 1) the Western part (Mareoits coast) between Sallum at Lybian borders at west and Abu-Qir at east (550 km long), 2) the Middle part (Deltaic coast) between Abu-Qir at west and Port-Said at east (220 km), and 3) the Eastern part (Sinai coast) between Port-Said at west and Rafah at Palestinian borders at east (200 km) with an average width ranging between 10-25 km in north-south direction (Zahran & Willis, 2009). The vegetation of the Mediterranean coastal land can be divided into zones landward that vary in dominance, composition and extent depending upon (a) landform and (b) distance from the sea, lakes and cultivated lands. The flora of the Mediterranean coastal zone of Egypt is considered as one of its prime natural resources. The biomass production and quality of native rangeland in such areas vary considerably from season to season and from area to area depending on several factors, mainly environmental factors (El-Shaer, 2010). Ecologically, the study area comprises four habitats: salt marshes, sand formations, reed swamps, and fertile non-cultivated lands habitat.

Halophytes and psammophytes are representing a significant part of the natural vegetation in the Mediterranean coast and particularly the perennials and shrubby ones (El-Amier *et al*., 2014). Several attempts have

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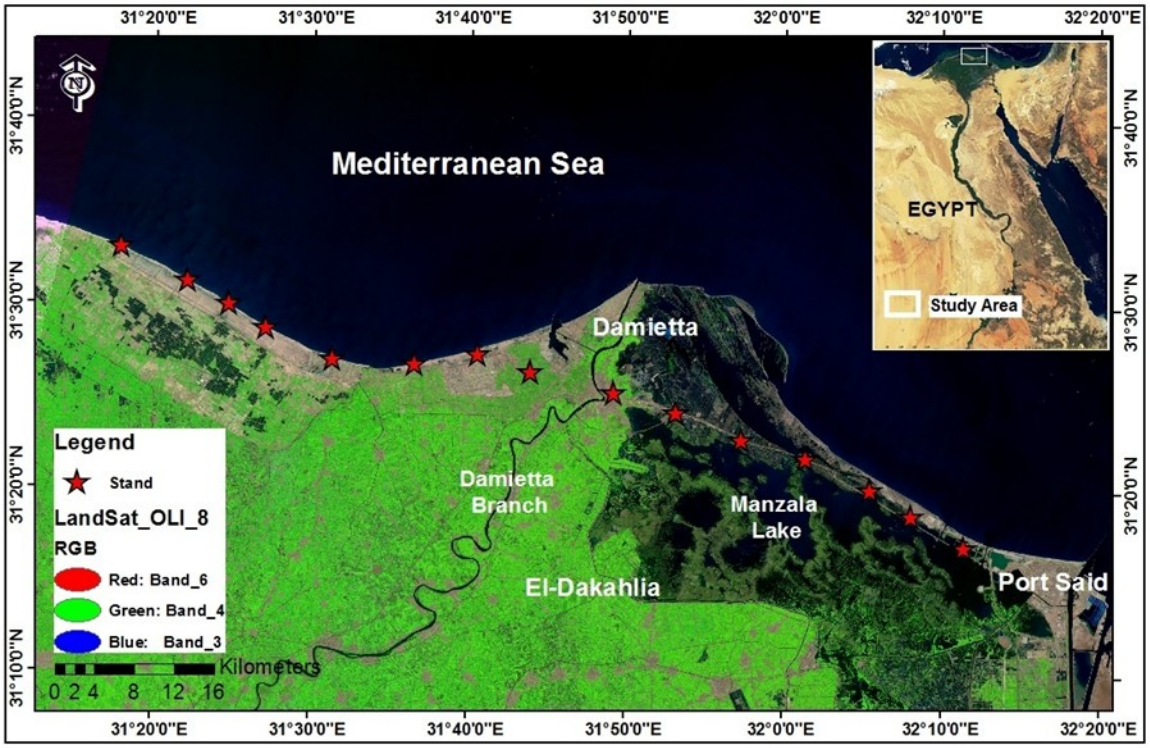

Figure 1. Map of the Nile Delta region showing different localities of the study area.

been made towards the utilization of such less and unpalatable halophytic and psammophytic plants through proper processing methods to improve their palatability and nutritional utilization. The supply of desert plants with other feed ingredients seemed to be the most convenient processing method under the prevailing condition of aridity in Egypt (Abou El-Nasr *et al*., 1996; El-Shaer & Attia-Ismail, 2015).

The coastal desert (Deltaic Mediterranean coast) has been studied ecologically and phytosociologically from several stand points by many researchers, e.g. Zahran *et al*. (1988), Shaltout *et al*. (1995), El-Halawany (2003), Galal & Fawzy (2007), Zahran & El-Amier (2013), El-Amier *et al*. (2014), Abd El-Gawad & El-Amier (2005) and Al-Hadithy *et al*. (2018). In last five years, the Deltaic coastal zones of Egypt suffer from several severe problems including unplanned development, land subsidence, excessive erosion rates, water logging, salt water intrusion, soil salinization, and ecosystem degradation. Besides, the Nile Delta coast hosts some highly populated cities such as Alexandria, Port-Said, Rosetta, Damietta, and New Mansoura City (Eid & El-Marsafawy, 2002; El-Amier and Abd El-Gawad, 2017). Therefore, the present study aimed to describe the plant communities associated with *Atriplex* species and its edaphic factors in Deltaic Mediterranean coast.

MATERIALS AND METHODS

Study area

The Nile Delta is the delta formed in Northern Egypt (Lower Egypt) where the Nile River spreads out and drains into the Mediterranean Sea. It is one of the world's largest river deltas from Alexandria in the west to Port Said in the east, it covers 220 km of Mediterranean coastline and is a rich agricultural region. From north to south the delta is approximately 180 km in length with an area about of 22,0000 km^2 and thus comprises 63% of the fertile Egyptian lands, while the area of the Nile Valley is about 13000 km^2. The Delta begins down-river slightly from Cairo. The Deltaic Mediterranean coast is a narrow belt influenced greatly by the sea (Figure 1). It is the coastal area extends from Abu-Quir (in the west, Long. 32°19' E) to Port-Said (in the east Long.31°19' E) with a length of about 180 km, and with a width in a N-S direction for about 15 km from the coast (Abu Al-Izz, 1971; Zahran & Willis, 2009).

The soils of the Nile Delta are dense in texture, rather compact at the surface and rich in humus (El-Gabaly *et al*., 1969a). According to the map of the world distribution of the arid regions (UNESCO, 1977), the soil of the study area is human-made variants of Gley soils and Fluvisoils that belong to the Pliocene and Pleistocene (El-Gabaly *et al*., 1969b). According to the map of the world distribution of the arid regions (UNESCO, 1977), the Nile Delta and Mediterranean coastal area of Egypt are belonging to the dry arid to the semiarid climatic zone of Koppen's (1931) classification system, where the rate of evaporation exceeds many times the rate of precipitation. Meteorological data of two stations (Baltim and Damietta stations) distributed within the study area are presented in Table 1.

Vegetation analysis

After a survey that was conducted between 2017 and 2018, 67 sample stands (20 m × 20 m) were randomly

Table 1. Long-term averages (≥ 20 years) of the climatic records at two stations in the northern sector of the Nile Delta (ANONYMOUS, 1980).

Meteorological variable	Baltim		Damietta	
	31º 33′ N, 31º 05′ E		31º 25′ N, 31º 48′ E	
	Range	Mean	Range	Mean
Minimum air temperature (ºC)	11.2–23.6	17.3	8.4-21.4	15.4
Maximum air temperature (ºC)	17.4–29.7	24.0	18.3– 31.0	24.9
Mean air temperature (ºC)	14.4–26.5	20.5	12.8-25.7	19.6
Relative humidity (%)	65.0–73.0	69.0	68-76	72
Evaporation (mm/day)	3.3–5.6	4.6	2.8-5.4	4.1
Rainfall (mm/month)	0.0–46.6	-	0.0-25.5	-

selected to represent a wide range of physiographic and environmental variation in the Deltaic Mediterranean coast of Egypt. The studied *Atriplex* species were *Atriplex halimus* L., *A. lindleyi* Moq., *A. protulacoids* L. and *A. semibaccata* R.Br. Specimens of the selected *Atriplex* species as well as the other associated species were collected from the Deltaic Mediterranean coastal strip. Plant density and cover have been estimated in each selected stand according to Shukla & Chandel (1989) and Canfield (1941). Relative values of density (RD) and cover (RC) were calculated for each plant species and summed up to give importance value (IV=200). Taxonomic nomenclature of species recorded is identified according to Tackholm (1974) and Boulos (1999-2005). The chorology of the plant species within the study area was cited, according to Zohary (1966 and 1972). The plant life forms were identified according to the scheme of Raunkiaer (1934 and 1937).

$$\mathrm{RD} = \left(\frac{\text{No. of individuals of plant species/Area of stands}}{\text{Total density of all species}}\right) \times 100$$

$$\mathrm{RC} = \left(\frac{\text{Average area cover of plant species/Area of stands}}{\text{Total cover of all species}}\right) \times 100$$

Plant species diversity

Various indices have been developed to describe the heterogeneity of species within a community. Species richness and evenness were calculated for each plant community by determination of Shannon-Wiener diversity index (H), Simpson Diversity Index (D) and Shannon-evenness index (E) using the following equations (Pielou, 1975; Magurran, 1988):

$$H = \sum_{i=1}^{s} P_i \ln (P_i)$$

$$\mathrm{E} = \mathrm{H}/\ln_s$$

$$\mathrm{D} = \frac{\sum_1 [n_1 \times (n_1 - 1)]}{[N \times (N-1)]}$$

Where Pi = ni/ N and ni is the total number of a particular species (s) and N is the total number of all species.

Soil analysis

Three soil samples were collected from the depth 0-20 cm from each stand, pooled together to form one composite sample, spread over sheets of paper, air-dried, passed through 2 mm sieve to remove gravel and debris, and packed in plastic bags to be ready for physical and chemical analyses. Physical and chemical analysis of soil samples was carried out, according to Piper (1947), Pierce *et al*. (1958), Jackson (1962) and Allen *et al*. (1974).

Data analysis

Two trends of multivariate analysis were applied in the present study (ordination and classification). Classification and ordination of the associated vegetation of the studied *Atriplex* species were performed using TWINSPAN analysis by the Community Analysis Package (CAP) computer program, version 2.3 (Hill & Smilauer, 2005). The relationships between vegetation groups and edaphic variables were performed using Canonical Correspondence Analysis (CCA-biplot) by the MVSP Program version 3.2 (ter Braak, 1988). The soil variables for each plant community were subjected to one-way ANOVA with equal replication at the 0.05 probability level (Duncan's test) using COSTAT 6.3 program.

RESULTS AND DISCUSSION

Floristic analysis

A total of 92 species (44 annuals, one biennial, and 47 perennials) belonging to 73 genera and 24 families were recorded in the present study (Table 2). The largest families are Poaceae, Asteraceae and Chenopodiaceae comprise 17, 15 and 13 species (18.48, 16.30 and 14.13 %) of the total recorded plant species, respectively, followed by family Fabaceae (7 species = 7.61%), Brassicaceae (5 species = 5.43%). They constituted 61.95% of the recorded species, and represent most of the floristic structure in the study area, while the other 8 families shared 26.08% of the species and 11 families were monospecific (Figure 2). The largest genera are arranged in the following sequence: Poaceae (15 genus) > Asteraceae (14 genus) > Chenopodiaceae (7 genus) > Fabaceae (5 genus) > Brassicaceae (4 genus). These families represent the most common in the Mediterranean North African flora (Quezel, 1978; Funk *et al*., 2009). Poaceae are the fifth-largest family of flowering plants, following the Asteraceae and Fabaceae in the world (Sutie *et al*., 2005; Funk *et al*., 2009).

Based on duration, the dominance of perennial species (≤ 50%) provides the permanent character of the

Table 2. Floristic composition and presence value (P%) of the recorded species in the studied area.

Species	Family	Life form	Chorotype	P%
Perennials				
Alhagi graecorum Boiss.	Fabaceae	H	PAL	8.96
Arthrocnemum macrostachyum (Moric.) K.Koch	Chenopodiaceae	Ch	ME+SA-SI	31.34
Atractylis carduus (Forssk.) C.Chr.	Asteraceae	H	ME+SA-SI	19.40
Atriplex halimus L.	Chenopodiaceae	Nph	ME+SA-SI	23.88
Atriplex portulacoides L.	Chenopodiaceae	Ch.	ME+IR-TR+ER-SR	17.91
Atriplex semibaccata R. Br.	Chenopodiaceae	H.	AUST	43.28
Calligonum comosum (L, Her.) Soskov	Polygonaceae	Nph	SA-SI+IR-TR	1.49
Cistanche phelypaea (L.) Cout.	Orobanchaceae	P, G	ME+SA-SI	4.48
Convolvulus arvensis L.	Convolvulaceae	H	COSM	2.99
Convolvulus lanatus Vahl	Convolvulaceae	Ch	SA-SI	2.99
Cressa cretica L.	Convolvulaceae	H	ME+IR-TR	1.49
Cynanchum acutum L.	Asclepiadaceae	H	ME+IR-TR	11.94
Cynodon dactylon (L.) Pers.	Poaceae	G	PAN	17.91
Cyperus capitatus Vand.	Cyperaceae	G	ME	17.91
Echinopus spinosus L.	Asteraceae	H	ME+SA-SI	23.88
Euphorbia terracina L.	Euphorbiaceae	H	ME	1.49
Frankenia hirsuta L.	Frankeniaceae	H	ME+ER-SR+IR-TR	2.99
Halocnemum strobilaceum (Pall.) M. Bieb.	Chenopodiaceae	Ch	ME+IR-TR+SA-SI	16.42
Heliotropium curassavicum L.	Boraginaceae	Ch	NEO	2.99
Imperata cylindica (L.) Raeusch.	Poaceae	H	ME+PAL	7.46
Inula crithmoides L	Asteraceae	Ch	ME+ER-SR+SA-SI	8.96
Juncus acutus L.	Juncaceae	He	ME+IR-TR+ER-SR	16.42
Juncus rigidus Desf.	Juncaceae	G, He	ME+IR-TR+ER-SR	20.90
Launaea mucronata (Forssk.) Muschl.	Asteraceae	H	ME+SA-SI	35.82
Launaea nudicaulis (L.) Hook. f.	Asteraceae	H	SA-SI	11.94
Lolium perenne L.	Poaceae	Th	ME+IR-TR+ER-SR	38.91
Lotus creticus L.	Fabaceae	H	ME	4.48
Lotus polyphyllos E.D.Clarke	Fabaceae	TH	ME	1.49
Moltkiopsis ciliata (Forssk.) I. M.Johnst.	Boraginaceae	Ch	ME+SA-SI+S-Z	1.49
Pancratium maritimum L.	Amaryllidaceae	G	ME	1.49
Paspalidium geminatum (Forssk.) Stapf	Poaceae	He	PAL	1.49
Phragmites australis (Cav.) Trin. ex Steud	Poaceae	G, He	COSM	29.85
Pluchea dioscoridis (L.) DC.	Asteraceae	NPh	SA-SI+S-Z	4.48
Polygonum equisetiforme Sm.	Polygonaceae	G	ME+IR-TR	8.96
Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	Nph	ME+IR-TR+SA-SI	13.43
Silene succulenta Forssk.	Caryophyllaceae	H	ME	11.94

Table 2 continued in next page

Sporobolus spicatus (Vahl) Kunth	Poaceae	G	ME+SA-SI+S-Z	5.95
Sporobolus pungens (Schreb.) Kunth.	Poaceae	G	PAN	1.49
Suaeda pruinosa Lange	Chenopodiaceae	Ch	ME	26.87
Symphotrichum squamatum (Spreng.) Nesom	Asteraceae	Ch	NEO	1.49
Tamarix nilotica (Ehrenb.) Boiss.	Tamaricaceae	Nph	SA-SI+S-Z	23.88
Zygophyllum aegyptium Hosny	Zygophyllaceae	Ch	ME	1.49
Zygophyllum album L.	Zygophyllaceae	Ch	ME+SA-SI	5.97
Zygophyllum coccineum L.	Zygophyllaceae	Ch	SA-SI	11.94
Biennials				
Spergularia marina (L.) Griseb.	Caryophyllaceae	Th	ME+IR-TR+ER-SR	19.40
Annuals				
*Aegilops bicornis (*Forssk.) Jaub. & Spach	Poaceae	Th	ME+SA-SI	2.99
Aegilops kotschyi Boiss.	Poaceae	Th	IR-TR+SA-SI	4.48
Anchusa humilis (Desf.) I. M.Johnst.	Boraginaceae	Th	ME+SA-SI	4.48
Atriplex lindleyi Moq.	Chenopodiaceae	Th	ME+IR-TR+ER-SR	8.96
Atriplex prostrata Boucher ex DC	Chenopodiaceae	Th	ME+IR-TR+ER-SR	10.45
Avena fatua L.	Poaceae	Th	PAL	4.48
Bassia indica (Wight) A. J. Scott	Chenopodiaceae	Th	IR-TR+S-Z	47.76
Bassia muricata (L.) Asch.	Chenopodiaceae	Th	IR-TR+SA-SI	2.99
Brassica nigra (L.) Koch	Brassicaceae	Th	COSM	1.49
Brassica tournefortii Gouan	Brassicaceae	Th	ME+IR-TR+SA-SI	1.49
Bromus diandrus Roth.	Poaceae	Th	ME	17.91
Bupleurum semicompositum L.	Asteraceae	Th	ME+IR-TR+SA-SI	2.99
Cakile maritima Scop.	Brassicaceae	Th	ME+ER-SR	50.75
Carduus getulus Pomel.	Asteraceae	Th	SA-SI	5.97
Carthamus tenuis (Boiss. & Blanche) Bornm.	Asteraceae	Th	ME	31.34
Chenopodium murale L.	Chenopodiaceae	Th	COSM	55.22
Daucus litoralis Sm.	Apiaceae	Th	ME	4.48
Emex spinosa (L.) Campd.	Polygonaceae	Th	ME+SA-SI	10.45
Erodium laciniatum (Cav.) Willd.	Poaceae	Th	ME	25.37
Frankenia pulverulenta L.	Frankeniaceae	Th	ME+ER-SR+IR-TR	1.49
Hordium marinum Huds.	Poaceae	Th	ME+IR-TR	34.33
Ifloga spicata (Forssk.) Sch. Bip.	Asteraceae	Th	SA-SI	13.43
Juncus bufonius L.	Juncaceae	Th	ME+IR-TR+ER-SR	1.49
Lepidium sativum L.	Brassicaceae	Th	ME	1.49
Lotus halophilus Boiss. & Spruner.	Fabaceae	Th	ME+SA-SI	23.88
Malva parviflora L.	Malvaceae	Th	ME+IR-TR	19.40
Melilotus indicus (L.) All.	Fabaceae	Th	ME+IR-TR+SA-SI	1.49
Mesembryanthemum crystallinum L.	Aizoaceae	Th	ME+ER-SR	35.82
Mesembryanthemum nodiflorum L.	Aizoaceae	Th	ME+SA-SI+ER-SR	31.34
Ononis serrata Forssk.	Fabaceae	Th	ME+SA-SI	11.94

Table 2 continued in next page

Parapholis incurva (L.) C.E. Hubb	Poaceae	Th	ME+IR-TR+ER-SR	23.88
Paronychia arabica (L.) DC.	Caryophyllaceae	Th	ME+SA-SI+S-Z	1.49
Phalaris minor Retz.	Poaceae	Th	ME+IR-TR	14.93
Picris asplenioides L.	Asteraceae	Th	ME+IR-TR	2.99
Plantago squarrosa Murray	Plantaginaceae	Th	ME	1.49
Poa annua L.	Poaceae	Th	COSM	1.49
Polypogon monspeliensis (L.) Desf.	Poaceae	Th	COSM	11.94
Portulaca oleracea L.	Portulacaceae	Th	IR-TR+SA-SI	1.49
Reichardia tingitana (L.) Roth	Asteraceae	Th	ME+IR-TR	20.90
Rumex pictus Forssk.	Polygonaceae	Th	ME+SA-SI	31.34
Salsola kali L.	Chenopodiaceae	Th	COSM	19.40
Senecio glaucus L.	Brassicaceae	Th	ME+IR-TR+ER-SR	70.15
Silene vivianii Steud.	Caryophyllaceae	Th	SA-SI	1.49
Sonchus oleraceus L.	Asteraceae	Th	COSM	5.97
Sphenopus divaricatus (Gouan) Rchb.	Poaceae	Th	ME+IR-TR+SA-SI	10.45
Suaeda maritima (L.) Dumort.	Chenopodiaceae	Th	COSM	16.42
Urospermum picroides (L.) F.W. Schmidt	Asteraceae	Th	ME+IR-TR	28.36

Life-form= Th: Therophytes, Ch: Chamaephytes, Nph: Nanophanerophytes, H: Hemicryptophytes, He: Helophytes, G: Geophytes, P: Parasites; Chorotypes= COSM: Cosmopolitan, PAL: Palaeotropical, NEO: Neotropical, ME: Mediterranean, SA-SI: Saharo-Sindian, S-Z: Sudano-Zambezian, ER-SR: Euro-Siberian, IR-TR: Irano-Turanina, AUST: Australian

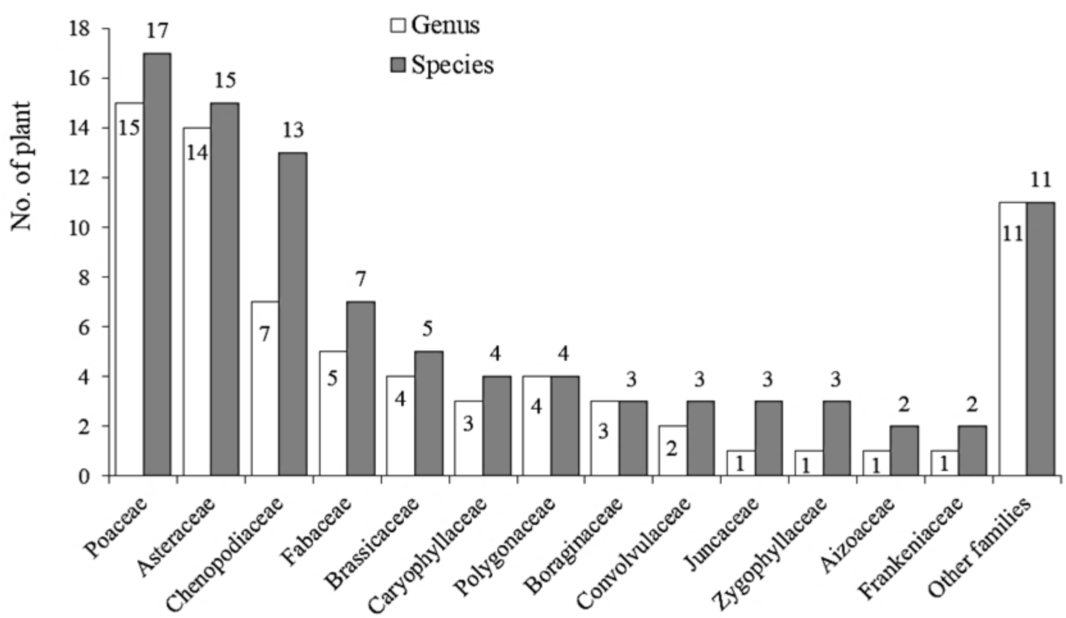

Figure 2. Total number of recorded plant genera and species in the families

plant cover in each habitat. This may be credited to the rather short rainfall, which is not adequate for the appearance of many annuals. On the other hand, the rainy season provides a better opportunity for the appearance of a considerable number of annuals, which constitute the second component floristic composition in the present study. Moreover, annuals have a higher reproductive capacity, ecological, morphological and genetic plasticity under high levels of disturbance (Harper, 1977) and agricultural practices (Grime, 1979). On the other hand, in the Deltaic Mediterranean coastal habitat the predominance of life-span is related to annual species (≥ 50%) this may be due to the time of field trip and climatic variables in the study area. This is not consistent with the studies of El-Kady *et al.* (1999), El-Halwany (2000), Shaltout *et al*. (2005), El-Amier *et al.* (2014), El-Amier (2016), but corresponds to El-Amier & Abd El-Gawad (2017). Through field trips, the unplanned development, salt water intrusion and hosts some populated cities such as Damietta and New Mansoura City in the study area are the reasons for ecosystem degradation in the study area.

The most abundant perennial species associated with the studied *Atriplex* species were *Lolium perenne* (38.91%), *Arthrocnemum macrostachyum* (31.34%), *Launaea mucronata* (35.82%) and *Phragmites australis* (29.85%). On the other hand, the most common annual species associated with the studied *Atriplex* species were *Atriplex semibaccata* (43.28%), *Bassia indica* (47.76%), *Cakile maritima* (50.75%), *Carthamus tenuis* (31.34%), *Chenopodium murale* (55.22%), *Hordium marinum* (34.33%), *Mesembryanthemum crystallinum* (35.82%), *M. nodiflorum* (31.34%), *Rumex pictus* (31.34%) and *Senecio glaucus* (70.15%) (Table 2). These findings were in line with those of El-Halwany (2000) and El-Amier *et al*. (2014) on floristic composition in Deltaic coast, Salama *et al*. (2003) along the western Mediterranean coast and El-Amier (2016) on vegetation structure of five common geophytes in coastal desert and El-Amier & Abd El-Gawad (2017) on plant communities along the international coastal highway of Nile delta.

The present field study indicated that *A. halimus* and *A. semibaccata* were recorded along the Mediterranean coast on saline sand flats. *A. protulacoids* was potential interest along the shores of Lake Manzala, on the other hand, *A. lindleyi* was recorded (6 stands only) and restricted around the international coastal highway in Damietta Governorate. This agrees with El-Amier *et al.* (2016) and El-Ameir & Shawky (2017), who reported that the most distributed *Atriplex* species were recorded in the Deltaic Mediterranean coast in sandy saltmarshes.

According to Raunkiaer (1934), the life-forms of the wild plant species of the present study (Table 2) are grouped under six types (Figure 3). Therophytes were the most abundant life form and accounted for 52.63% of the total species. At the same time, cryptophytes ranked second (13.68%), followed by chamaephytes (12.63 %), nanophanerophytes (5.26%) and hemicryptophytes (14.74%). The lowest value of life-forms is recorded as parasites, which attained a value of 1.05%. Therophytes are equally less adapted to drought and salinity and their presence is a seasonal phenomenon, they become abundant only during the rainy season and where salinity is not a limiting factor (Ayyad & El-Ghareeb, 1982). The nature of the prevailing arid climate in the study area, the degree of water availability and the sandy nature of the soil help therophytes to dominate during the favourable season. Moreover, the high frequency of cryptophytes as an active life-form in the study area could be related to certain features of both their growth habit and the nature of the soil. Most of the recorded cryptophytes are rhizomatous species; this is an advantage for their successful growth and their distribution (Serag, 1991). The percentage of cryptophytes (13.68%) in this study was lower than that found in Hassib (1951) who reported 25.8% of this life-form in the Egyptian flora, 15.9% in the Mediterranean region and 16.2% in the Egyptian Nile Delta region. This life form contributed about 25.8%, 20.5%, 20.5%, 26.3%, 18.49% and 13.91% in the studies of El-Sheikh (1989), Al-Sodany (1992), El-Halawany (2003), Shaltout *et al.* (2005), El-Amier *et al.* (2014) and El-Amier & Abd El-Gawad (2017), respectively.

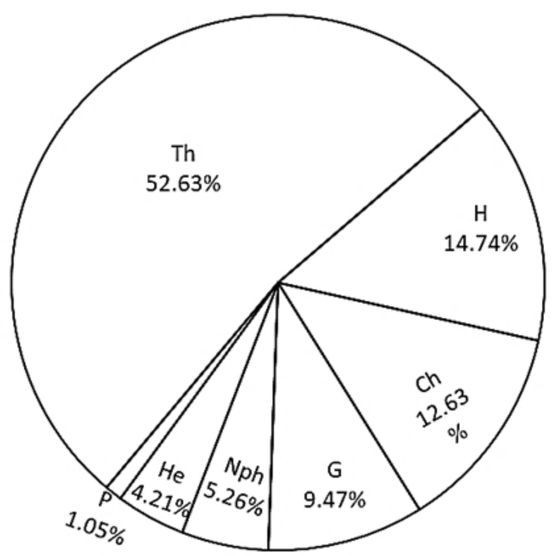

Figure 3. Life-form percentage of the plant species in the study area. Abbreviations: See Table 2.

Chorological affinities of the associated vegetation

The chorological spectrum of the recorded wild plant species is shown in Table 3. Mediterranean taxa include 62 species (67.38 % of the total number of recorded species). These taxa are either Pluriregional (23 species = 24.99 %), Biregional (39 species = 42.39 %) or Monoregional (14 species = 15.22 %). Also, the floristic data indicated the abundance of the Saharo-Sindian (mono-, bi - and Pluriregional) comprised 36 species (39.12%) of the total recorded flora. The worldwide chorotype (Cosmopolitan, Palaeotropical, Pantropical and Neotropical) were represented by 16 species (17.38%).

The Mediterranean elements extending into Saharo-Sindian element attained relatively high representation as compared with the Mediterranean taxa extending into the Euro-Siberian element. These results support finding that, the presence of a transitional Mediterranean chorotype in Egypt between the Mediterranean and the

Table 3. Number of species and percentage of various floristic categories in the study area.

No.	Floristic category	Total area No.	Total area %	Geographical distribution
1	COSM	9	9.78	World wide
2	NEO	2	2.17	
3	PAL	3	3.26	
4	PAN	2	2.17	
5	ME+IR-TR+ER-SR	12	13.04	Pluri-regional elements
6	ME+IR-TR+SA-SI	6	6.52	
7	ME+ER-SR+SA-SI	2	2.17	
8	ME+SA-SI+S-Z	3	3.26	
9	ME+PAL	1	1.09	Bi-regional elements
10	ME+IR-TR	9	9.78	
11	ME+ER-SR	2	2.17	
12	ME+SA-SI	13	14.13	
13	IR-TR+SA-SI	4	4.35	
14	IR-TR+S-Z	1	1.09	
15	SA-SI+S-Z	2	2.17	
16	ME	14	15.22	Mono-regional elements
17	SA-SI	6	6.52	
18	AUST	1	1.09	
	Total	92	100	

Life-form= Th: Therophytes, Ch: Chamaephytes, Nph: Nanophanerophytes, H: Hemicryptophytes, He: Helophytes, G: Geophytes, P: Parasites; Chorotypes= COSM: Cosmopolitan, PAL: Palaeotropical, NEO: Neotropical, ME: Mediterranean, SA-SI: Saharo-Sindian, S-Z: Sudano-Zambezian, ER-SR: Euro-Siberian, IR-TR: Irano-Turanina, AUST: Australian

Euro-Siberian chorotype at north, and between the Saharo-Sindian chorotype at south. Similar results had been obtained by El-Demerdash *et al*. (1990 & 1997), El-Halawany (2003), El-Amier *et al*. (2014) and El-Amier & Abd El-Gawad (2017). Generally, the present investigation favours that, the flora of north Nile Delta is mainly belonging to the Mediterranean chorotype. This opinion is supported by the findings in different directions such as the climatic constitution of the area, life-form spectra, floristic and vegetative features, distribution patterns, altitudinal zonation, and historical-floral events.

Vegetation analysis

The application of TWINSPAN classification based on the importance values of 92 plant species recorded in 67 sampled stands in the study area, led to the recognition of four vegetation groups (Figure 4 and Table 4). Each is linked to one or more of the studied *Atriplex* plants. Notably, ten of the recorded plant species were determined to have a wide ecological range of distribution and occurred in all the identified vegetation groups: *Arthrochemum macrostachyum, Atriplex portulacoides, A. semibaccata, Bassia indica, Cynodon dactylon, Hordeum murinum, Mesembryanthemum crystallinum, Parapholis incurva, Senecio glaucus* and *Spergularia marina.*

Group A consisted of 42 species that inhibiting 18 stands, dominated by *Lolium perenne* (IV=23.26). This group is linked to *A. halimus, A. portulacoides* and *A. semibaccata* with average Simposn index of 0.76, Shannon–Wiener index of 2.66 and Shannon-evenness index of 0.57. The other important species which attain relatively high importance values in this group are *Suaeda*

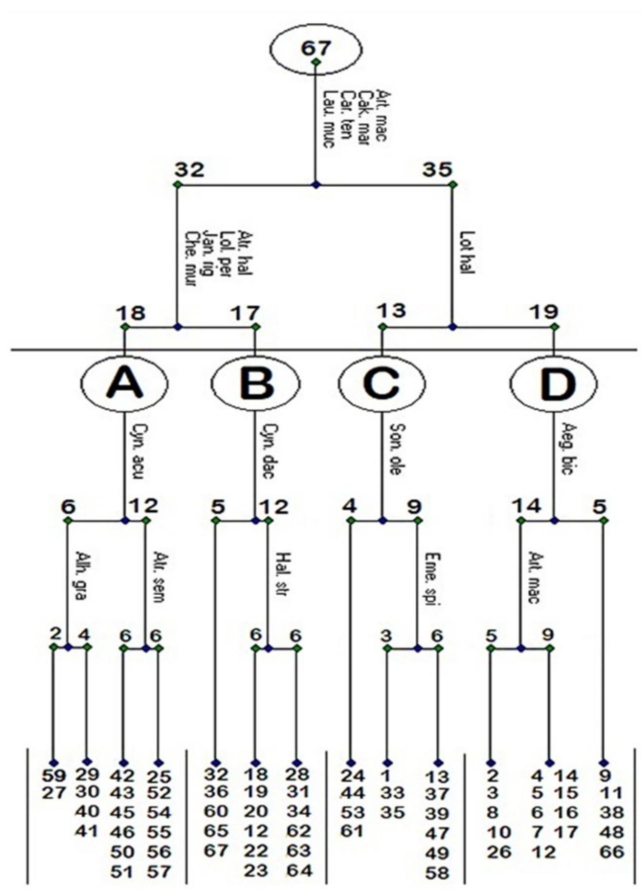

Figure 4. Dendrogram showing cluster analysis of the studied 67 stands, with the 4 vegetation groups (A-D) separated. The indicator species are abbreviated by the first three letters of genus and species respectively.

Table 4. Plant communities, species diversity, and invasive species in each community in the study area.

Community	Stand No.	Total Species	Species Diversity			Dominant species	Other important species	Indicator species	Invasive species
			Simposn index	Shannon–Wienner index	Shannon-even				
A	18	42	0.76	2.66	0.57	*Lolium perenne* (IV=23.26)	*Suaeda pruinosa* (IV=16.45) *Erodium laciniatum* (IV=14.45) *Senecio glaucus* (IV=13.18), *Atriplex semibaccata* (IV=12.89) *Urospermum picroides* (IV=10.48)	*Cynanechum acutum* (IV=1.89) *Atriplex semibaccata* (IV=12.89)	*Atriplex semibaccata* *Bassia indica* *Heliotropium curassavicum*
B	17	64	0.81	3.63	0.78	*Atriplex semibaccata* (IV=14.66) *Hordium marinum* (IV= 15.20)	*Polygonum equisetiforme* (IV=9.47) *Senecio glaucus* (IV=9.02) *Zygophyllum coccineum* (IV=8.84) *Echinopus spinosus* (IV=8.30)	*Cynodon dactylon* (IV = 6.44) *Halocnemum strobilaceum* (IV= 3.70)	*Atriplex semibaccata* *Bassia indica* *Heliotropium curassavicum*
C	13	47	0.78	2.91	0.70	*Zygophyllum coccineum* (IV=17.76) *Tamarix nilotica* (IV=16.19)	*Arthrocnemum macrostachyum* (IV=14.63) *Senecio glaucus* (IV=10.81) *Polypogon monospeliensis* (IV=10.46) *Parapholis incurva* (IV=10.36)	*Sonchus oleraceus* (IV = 1.24) *Emex spinosa* (IV = 1.51)	*Atriplex semibaccata* *Bassia indica*
D	19	38	0.75	2.65	0.55	*Phragmites australis* (IV=21.18)	*Juncus rigidus* (IV=16.89) *Atriplex halimus* (IV=16.33) *Hordeum murinum* (IV=14.28) *Juncus acutus* (IV=13.90) *Arthrocnemum macrostachyum* (IV=11.85)	*Arthrocnemum macrostachyum* (IV=11.85) *Aegilops bicornis* (IV=0.78)	*Atriplex semibaccata* *Bassia indica*

pruinosa (IV=16.45), *Erodium laciniatum* (IV=14.45), *Senecio glaucus* (IV=13.18), *Atriplex semibaccata* (indicator species, IV=12.89) and *Urospermum picroides* (IV=10.48). The indicator species in this group is *Cynanechum acutum* (IV=1.89). Stands of this group were found on soil rich in fine silt, WHC, $CaCO_3$, Cl^-, SO_4^{--} and lowest sand, electrical conductivity, OC, and cations (Table 5).

Vegetation group B includes 17 stands codominated by *Atriplex semibaccata* (IV=14.66) and *Hordium marinum* (IV= 15.20), and was the most diversified (64 species) among the recognized groups with average Simposn index of 0.81, Shannon–Wiener index of 3.63 and Shannon-evenness index of 0.78. This group is linked to four studied *Atriplex* species. The other important species in this group are *Polygonum equisetiforme* (IV=9.47), *Senecio glaucus* (IV=9.02), *Zygophyllum coccineum* (IV=8.84) and *Echinopus spinosus* (IV=8.30). In this group, the indicator species are *Cynodon dactylon* (IV = 6.44) and *Halocnemum strobilaceum* (IV= 3.70). The sites were characterized by high percentages of electric conductivity, HCO3, cations, and moderate contents of $CaCO_3$, OC and WHC (Table 5).

Group C comprises 13 stands and 47 species, codominated by halophytes *Zygophyllum coccineum* (IV=17.76) and *Tamarix nilotica* (IV=16.19). This group is linked to *Atriplex portulacoides, A. semibaccata* and *A. lindleyi* with average Simposn index of 0.78, Shannon–Wiener index of 2.91 and Shannon-evenness index of 0.70. In this group, the other important species are *Arthrocnemum macrostachyum* (IV=14.63), *Senecio glaucus* (IV=10.81), *Polypogon monospeliensis* (IV=10.46) and *Parapholis incurva* (IV=10.36). The indicator species are *Sonchus oleraceus* (IV = 1.24) and *Emex spinosa* (IV = 1.51). Most of the examined soil variables attained their moderate levels in the stands of this group, except sand and PAR attained the highest value (Table 5).

Floristic group D comprises 19 stands dominated by *Phragmites australis* (IV=21.18) and was the least diversified (38 species) among the recognized groups with average Simposn index of 0.75, Shannon–Wiener index of 2.65 and Shannon-evenness index of 0.55. This group is linked to *A. halimus, A. portulacoides* and *A. semibaccata* with. The other important species are *Juncus rigidus* (IV=16.89), *Atriplex halimus* (IV=16.33), *Hordeum murinum* (IV=14.28), *Juncus acutus* (IV=13.90) and *Arthrocnemum macrostachyum* (indicator species, IV=11.85). The indicator species in this group is *Aegilops bicornis* (IV=0.78). The stands were found to have the highest levels of fine clay, OC,

Table 5. Mean values, standard error (±SE) and ANOVA values of the soil variables in the vegetation groups (A-D) obtained by TWINSPAN classification in the study area.

Soil variable	Mean	Vegetation group				*P-value*
		A (n=18)	B (n=17)	C (n=13)	D (n=19)	
Sand %	91.14±0.53	90.17±0.52	90.40±0.29	92.46±0.33	91.55±0.24	0.923ns
Silt %	6.11±0.48	7.38±0.39	6.21±0.29	5.68±0.30	5.15±0.14	0.285ns
Clay %	2.65±0.31	2.45±0.15	3.08±0.18	1.86±0.05	3.21±0.14	0.074ns
Porosity %	37.81±2.10	34.17±0.41	39.40±0.43	34.67±0.42	43.02±0.45	0.140ns
WHC %	33.81±0.38	34.69±0.68	33.88±0.62	32.85±0.52	33.81±0.32	0.970ns
$CaCO_3$ %	9.38±1.68	12.99±0.70	10.29±0.81	9.36±0.76	4.88±0.22	0.0225*
OC %	0.40±0.04	0.34±0.01	0.40±0.02	0.37±0.01	0.50±0.01	0.0430*
pH	8.13±0.22	7.78±0.07	8.23±0.05	7.78±0.14	8.72±0.05	0.120ns
EC $mS.cm^{-1}$	0.67±0.11	0.46±0.01	0.97±0.02	0.64±0.04	0.60±0.03	0.157ns
Cl^- %	0.39±0.08	0.64±0.05	0.29±0.04	0.32±0.04	0.33±0.03	0.0003***
SO_4^- %	0.46±0.04	0.58±0.04	0.39±0.03	0.46±0.04	0.40±0.02	0.789ns
HCO_3 %	0.84±0.19	0.64±0.04	0.94±0.07	1.32±0.12	0.44±0.04	0.0000***
Na^+ mg /100g dry soil	218.75±17.87	90.93±7.21	304.09±23.03	278.53±21.92	201.47±9.71	0.0000***
K^+ mg /100g dry soil	68.18±12.82	14.28±0.83	112.12±10.84	99.25±10.11	47.05±3.58	0.0000***
Ca^{++} mg /100g dry soil	397.09±67.06	22.71±1.94	744.91±82.02	561.89±66.00	258.83±28.40	0.0000***
Mg^{++} mg /100g dry soil	121.21±15.79	14.46±1.01	211.60±22.01	181.64±21.15	77.15±7.89	0.0000***
SAR	21.01±1.56	17.61±0.70	20.19±0.65	21.10±0.99	25.13±0.66	0.0499*
PAR	4.18±0.39	3.19±0.10	4.59±0.18	4.97±0.21	3.96±0.08	0.0001***

Abbreviations: WHC = Water-holding capacity; EC = Electrical conductivity; OC = Organic carbon; SAR = Sodium adsorption ratio; PAR = Potassium adsorption ratio; ns = not significant at P < 0.05. *: Values are significant at P < 0.05, **: Values are significant at P < 0.01, ***: Values are significant at P < 0.001.

pH and SAR as well as lowest contents of silt, $CaCO_3$, HCO_3, (Table 5).

The most diverse groups A and B are characterized by mixed communities of sand flat and saltmarshes habitat such as halophytes (*A. halimus, A. portulacoides, A. semibaccata, S. pruinosa, Z. coccineum, H. strobilaceum,* etc.) and psammophytes (*L. perenne, E. laciniatum*, *S. glaucus, H. marinum, E. spinosus,* etc.), which could be related to higher concentration of salinity and soil mineral contents, perhaps due to animal grazing, rainfall, and floods (Pulford *et al*., 1992). On the other hand, the groups C and D were the least diversified, which characterized by some halophytes (*Z. coccineum, T. nilotica, A. macrostachyum, A. portulacoides, A. semibaccata, J. acutus, J. rigidus,* etc.). The latter species characterized vegetation groups inhabiting the Deltaic Mediterranean coastal strip (Zahran & El-Amier, 2013; El-Amier, 2016). *Tamarix* has been identified as a major cause of salt accumulation on the soil surface (Springuel & Ali, 1990). In Deltaic Mediterranean coastal strip, Zahran *et al*. (1990), Al-Sodany (1992), El-Amier *et al*. (2014), El-Amier (2016) and El-Amier & Abd El-Gawad (2017) recognized several plant associations, some of which are comparable to those of the current study.

The application of DCA on 67 stands along axes 1 and 2 indicated that the vegetation groups produced by the classification technique of the studied sites were distinguishable and having a clear pattern of segregation on the ordination plane (Figure 5).

Soil-vegetation relationships

The correlation between vegetation and soil characteristics is indicated on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot (Figure 6). In the present study, the application of CCA ordination indicated that the most effective soil variables correlated with the presence and distribution of the floristic elements in the vegetation of Deltaic Mediterranean coastal strip are: electrical conductivity, cations, porosity, potassium adsorption ratio (PAR), calcium carbonate, bicarbonate, pH and organic carbon (Figure 6). Plant communities are affected by many factors as farm management practices (Andersson & Milberg, 1998), crop type (Andreasen & Skovgaard, 2009), season (El-Demerdash *et al*., 1997) and soil characteristics (Pinke *et al*., 2010).

In the upper right side of CCA diagram, the codominant species (*Z. coccineum*) in group C and important species (*A. macrostachyum*) in groups C and D are collectively showed a limited relationship with pH, cations and PAR. While, in the upper left side of the diagram *P. monospeliensis* and *P. incurva* which are important species in group C and *E. laciniatum* which are important species in group A showed a close relationship with calcium carbonate, bicarbonate. On the other hand, in the lower right side, the dominant and codominant species (*H. murinum, T. nilotica* and *P. australis*) in groups B, C and D, respectively, and important species (*A. halimus, J. acutus* and *J. rigidus*) in group D, as well as *P. equisetiforme* which are the important species in group B showed a close relationship with porosity, EC and organic carbon. While, in the lower left side,

Table 6. Simple linear correlation coefficients between studied *Atriplex* species and soil variable.

Species	Soil variable																
	Sand	Silt	Clay	Por.	WHC	$CaCO_3$	OC	pH	EC	Cl^-	SO_4^{--}	HCO_3	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR
Atriplex halimus	-0.11	0.087	0.073	0.248*	0.072	-0.073	0.256*	0.167	0.284*	0.07	0.037	-0.128	-0.127	-0.167	-0.181	-0.183	0.111	-0.076
A. portulacoides	0.2	-0.208	-0.064	0.002	0.095	-0.167	0.167	0.061	-0.003	-0.147	-0.185	-0.17	-0.067	-0.017	0.018	0.008	-0.174	-0.109
A. semibaccata	-0.07	-0.036	0.272*	-0.075	0.041	-0.128	-0.041	-0.088	-0.181	-0.059	0.003	-0.106	0.098	0.154	0.202	0.18	-0.13	0.078
A. semibaccata	-0.18	0.241*	-0.044	-0.165	-0.247*	0.312*	-0.198	-0.046	-0.159	-0.084	0.008	0.373**	0.338**	0.353**	0.278*	0.350**	0.066	0.294*

Abbreviations: Por.: porosity, WHC: Water-holding capacity, EC: Electrical conductivity, OC: Organic carbon, SAR: Sodium adsorption ratio; PAR: Potassium adsorption ratio; *: Values are significant at $P < 0.05$, **: Values are significant at $P < 0.01$.

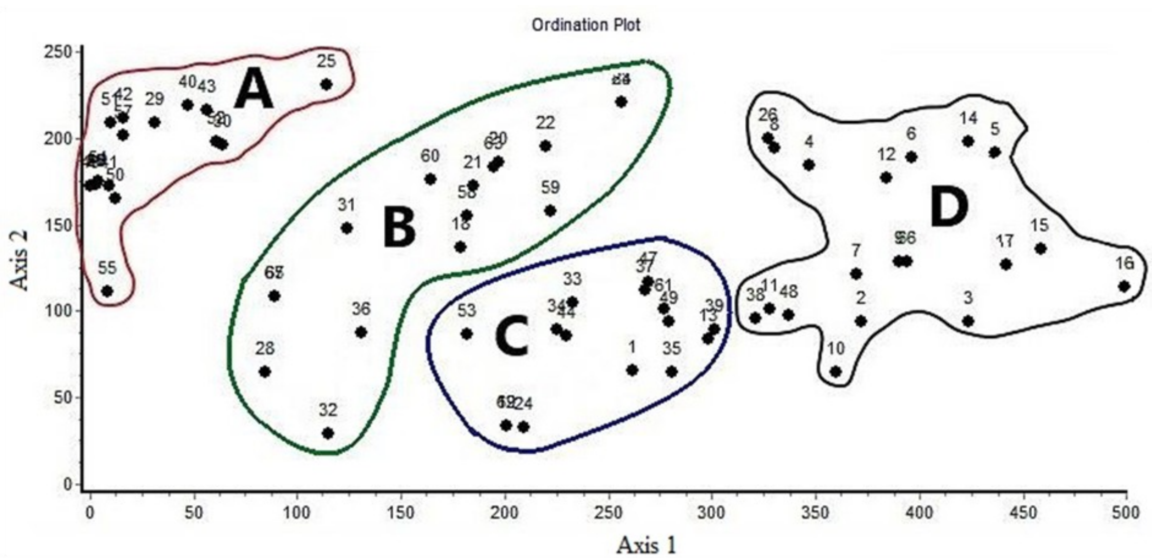

Figure 5. Detrended Correspondence Analysis (DCA) ordination diagram of the 67 stands on axes 1 and 2 within vegetation groups.

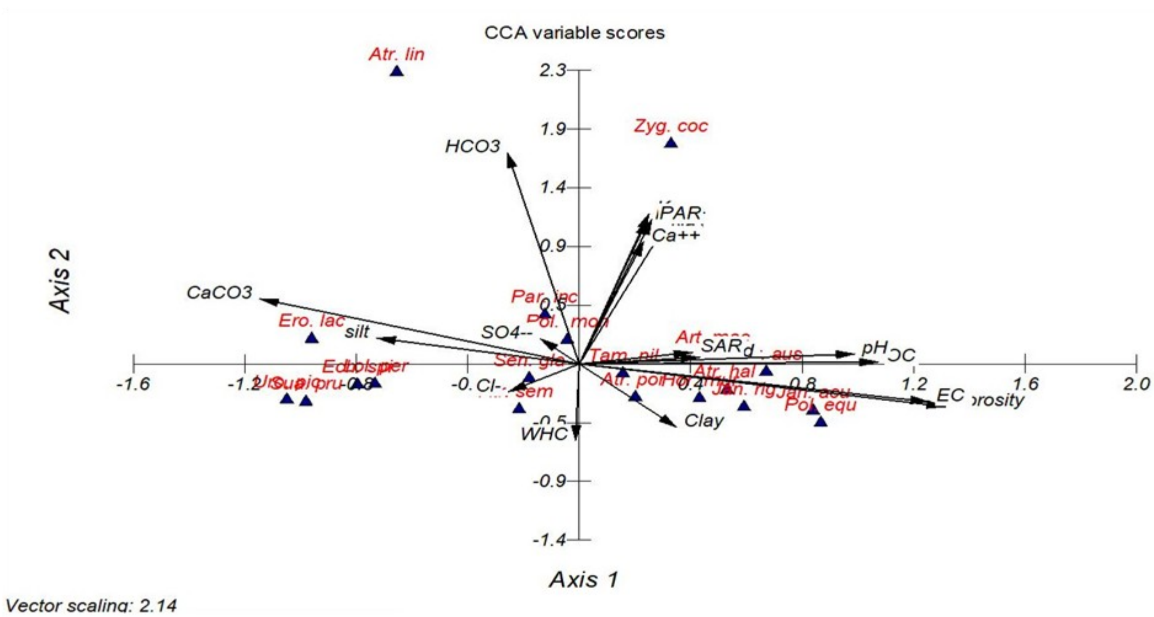

Figure 6. Canonical Correspondence Analysis (CCA) ordination diagram of plant species with soil variables represented by arrows in the study area. *Art. mac: Arthrochemum macrostachyum; Atr. hal: Atriplex halimus; Atr. por: Atriplex portulacoides; Atr. sem: Atriplex semibaccata; Atr. lin: Atriplex lindleyi; Ero. lac: Erodium laciniatum; Ech. spi: Echinops spinosus; Hor. mur: Hordeum murinum; Jun. acu: Juncus acutus; Jun. rig: Juncus rigidus; Lol. per: Lolium perenne; Par. inc: Parapholis incurva; Phr. aus: Phragmites australis; Pol. equ: Polygonum equisetiforme; Pol. mon: Polypogon monspellensis; Sen. gla: Senecio glaucus; Sua. pru: Suaeda pruinosa; Tam. nil: Tamarix nilotica; Uro. pic: Urospermum picroides; Zyg. coc: Zygophyllum coccineum.*

L. perenne (dominant species in group A) and *A. semibaccata* (codominant species in group B), as well as important species (*S. glaucus, U. picroides, S. pruinose* and *E. spinosus*) in groups A and B showed a limited relationship with WHC and Cl^-.

The simple linear correlation coefficient between some soil variables and studied *Atriplex* species indicated that *A. halimus* was positively significant (r = 0.248, 0.256 and 0.284) with porosity, organic carbon and electrical conductivity, respectively (Table 6). *A. semibaccata* had positively significant (r = 0.272) with clay, and *A. semibaccata* had positively significant (r = 0.241, 0.312, 0.373, 0.338, 0.353, 0.278, 0.350 and with silt, $CaCO_3$, HCO_3, Na^+, K^+, Ca^+, Mg^+ and PAR, respectively.

CONCLUSION

Feed resources deficiency is considered one of the fundamental constraints to improving animal productivity in arid and semi-arid regions in most countries. Therefore, the growth of halophytes plays an essential role in the grazing system in the arid environment. Besides, it provides a great opportunity to use land and water resources that are two salines for conventional crops and forages as well as improving soil stability. The flora of the Deltaic coastal zone of Egypt is considered as one of its prime natural resources. Therefore, it is essential to understand the structure and composition of native plant communities along the coastal zone and identify the main reasons for vegetation destruction. The present study concluded that the halophytic and psammophytic vegetation in the coastal region are abundant and require further studies to understand the nutritional value and economic importance of this species.

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