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Composition and Diversity of Plant Communities in Sand Formations Along the Northern Coast of the Nile Delta in Egypt.

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ABSTRACT

The present study aims to investigate the floristic composition and diversity of plant communities and relation to soil variables in sand formations along the northern sector of the Nile Delta region. One hundred stands were selected to represent the variations in sand formation habitats (sand dunes and sand flats). Ninety two species belonging to 27 families and related to 78 genera were recorded. The classification of vegetation using the two way indicator species analysis (TWINSPAN) resulted in the four vegetation groups named after the first and second dominant species: group A) *Rumex pictus - Cutandia memphitica*, group B) *Elymus farctus - Cakile maritima,* group C) *Senecio glaucus - Rumex pictus* and group D) *Erodium laciniatum - Echinops spinosus,* which attained the lowest species richness. Detrended Correspondence Analysis (DCA) showed that these groups were clearly distinguished by the first two DCA axes. Soil texture, organic carbon, pH value, chlorides, calcium carbonate and sulphates showed significant correlations with some dominant species and vegetation groups, these results suggest the effective role of these soil variables in the sand formations community structure and diversity.

Key words: Sand formations, vegetation, soil, classification, ordination, Nile Delta.

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INTRODUCTION

Coastal sand dunes are natural structures, which are common in different parts of the world and protect the coastal environment by absorbing energy from wind, tide and wave action. The plants grown on coastal sand dunes are called psammophytic species, which are playing a vital role in protecting the coast from erosion and flooding [1, 2]. The Egyptian coastlines stretch for more than 3,500 km along the Mediterranean Sea, the Red Sea and south Sinai, it is located in an arid to semi-arid zone with a terrain of desert plateau interrupted by the Nile Valley and Delta [3]. The Mediterranean coastal land of Egypt has a narrow coastal belt that extends between Sallum (on the Libyan borders) eastward to Rafah (on the Palestinian borders) for about 970 km with an average width ranging between 20-25 km in north – south direction [4],

The coastal zones of Egypt suffer from a number of serious problems including: unplanned development, land subsidence, excessive erosion rates, water logging, salt water intrusion, soil salinization and ecosystem degradation. The Nile Delta coast, hosts a number of highly populated cities such as Alexandria, Rosetta, Damietta and Port-Said. An international coastal road connecting the most eastern and western towns in Egypt was constructed parallel to the Northern coast [5, 6],

The Deltaic Mediterranean coastal land of Egypt is differentiated into four habitats: sand formations, salt marshes, fertile sandy lands and reed swamps [7]. The sand formations are mainly composed of silecous deposits and they are distinguished into three subhabitat types: sand mounds, sand sheets and sand dunes. The sand mounds occupy the frontal belt of the zonation pattern in the Deltaic coast; they are low, medium or large sized.

The sand sheets are irregularly scattered between sand dunes and salt marshes and they are either saline or non-saline sand flats. The sand dunes are the main geomorphic features in the greatest part of the Deltaic coast. These dunes are classified into three kinds: mobile sand dunes, partial stabilized sand dunes and stabilized sand dunes which are usually of varying sizes and heights. Also there are salt marshes in the depressed areas between sand dunes. These are usually wetted by water seeped from the sea and lakes especially during water season. The fertile sandy lands are found on the well drained less saline soils. They are formed by transportation of sands from the shifting sand dunes to neighbouring low lands. Some patches of this habitat type have been farmed with many vegetables, crops and orchards. The reed swamps are frequent in the Deltaic Mediterranean coast. They are formed by accumulation of water seeped from the lakes, Mediterranean Sea and / or drainage systems of the Delta in depressed area [8-10].

Previous studies on the Deltaic Mediterranean Coast, covered the fields of plant ecology and phytosociology by many authors e.g. [11] and [12], Recently [13], [14], [15] and [16]. The present study aims to investigate firstly: the floristic composition and vegetation types of sand formations in Deltaic Mediterranean Coast and secondly to analyses the composition and diversity of plant communities in relation to soil variables.

MATERIAL AND METHODS

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 borders of four Governorates namely: Damietta, El-Dakahlia, Kafr El-Sheikh and El-Behira. Ecologically, the study area comprises four habitats: salt marshes, sand formations, reed swamps and fertile sandy lands (Fig. 1).

According to the map of the world distribution of arid regions [17], the climate of the whole stretch of the Mediterranean coastal desert is, generally, less arid than the remaining southern parts of Egypt. The climatic conditions are warm summers (20–31ºC) and mild winters (10–20ºC). Long-term climatic averages recorded at three meteorological stations distributed within the study area are presented in Table (1) afterAnonymous [18].

Vegetation Sampling

One hundred stands were selected to represent the main habitats in the study area. The stand size was about 10 × 10 m in all habitats. In each stand, the annual and perennial species were listed. Nomenclature, identification and floristic categories were carried out according to Zohary [19], Tackholm [20], Feinbrun-Dothan [21] and up to date by Boulos [22]. Life forms were identified according to the scheme of Raunkiaer [23].

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

Table 1: Long-term averages (≥ 20 years) of the climatic records at three stations in northern sector of the Nile Delta [18]

Meteorological variable	Rosetta		Baltim		Damietta	
	31º 24′ N, 30º 25′E		31º 33′ N, 31º 05′ E		31º 25′ N, 31º 48′ E	
	Range	Mean	Range	Mean	Range	Mean
Maximum air temperature (ºC)	18.1–30.4	24.6	17.4–29.7	24.0	18.3– 31.0	24.9
Minimum air temperature (ºC)	10.8–23.4	17.0	11.2–23.6	17.3	8.4-21.4	15.4
Mean air temperature (ºC)	13.0–26.3	19.8	14.4–26.5	20.5	12.8-25.7	19.6
Relative humidity (%)	65.0–72.0	69.0	65.0–73.0	69.0	68-76	72
Evaporation (mm/day)	3.3 – 4.8	4.2	3.3–5.6	4.6	2.8-5.4	4.1
Rainfall (mm/month)	0.0–50.3	-	0.0–46.6	-	0.0-25.5	-

The density and cover of each species have been estimated in each selected stand. The density of each plant species was measured by counting the number of individuals of the species within randomly stands [24]. The plant cover of each species in the surveyed stands was measured by using the line intercept method [25]. Relative values of density and cover were calculated for each plant species and summed up to give an estimate of its importance value (IV) in each stand which is out of 200.

Soil Analysis

Two soil samples were collected from the stands (0-20 and 20-50 cm depth) then mixed to give a composite sample representing the different habitats of the study area. Soil texture, water holding capacity (WHC), soil porosity, organic carbon and sulphate were determined according to Piper [26]. Calcium carbonate content was determined by titration against 1 N NaOH and expressed as a percentage [27]. Available phosphorus is extracted from the soil with 0.5 M NaHCO3 at a nearly constant pH of 8.5 according to the method described by Watanabe and Olsen [28]. The available nitrogen in the soil sample was determined by Kjeldahl method [29]. The soil solution (1:5) was prepared for each soil sample. The electrical conductivity, pH and chlorides were determined by the method adopted by Jackson [27]. Carbonates and bicarbonates were determined by titration using 0.1 N HCl [30], The extractable cations Na^+ and K^+ contents were determined using Flame Photometer (Model PHF 80 Biologie Spectrophotometer), while Ca^{2+} and Mg^{2+} were estimated using atomic absorption spectrometer (A PerkineElmer, Model 2380.USA) [31]. The sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) were calculated to express the combined effects of different ions in the soil [32].

Data Analysis

Two way indicator species analysis (TWINSPAN) and Detrended Correspondence Analysis (DCA) were applied for the classification of stands into groups and ordinate stands in two-dimensional space based on the importance values of species [33]. The relation between the vegetation and soil gradients was assessed using Canonical Correspondence Analysis (CCA) [34-36]. Data of the soil variables of the vegetation groups identified by TWINSPAN were compared by one-way ANOVA. Species richness (alpha diversity) was calculated for each vegetation group as the average number of species per stand. Species turnover (beta diversity) was calculated as a ratio between the total number of species in a certain vegetation group and its alpha diversity. Relative evenness or equitability (Shannon–Weiner index) of the importance value of species was expressed as: $H' = \sum_{i=1}^{s} Pi \ln(Pi)$, where *Pi = ni/ N* = proportional abundance of species *i* in a habitat made up of *s* species, *ni* = the number of stands containing species *i* and N = S *ni*. The Relative concentration of dominance (Simpson index) is the second group of heterogeneity indices and is expressed by Simpson's index: D = 1/C and $C = \sum^{s} (Pi)^2$, where S is the total number of species and P*i* is the relative importance value of species of the *i*th species [37-39] Linear correlations coefficient (r) was calculated for assessing the relationship between the estimated soil variables on one hand and the community variables, on the other hand. The one-way ANOVA and correlation analyses were conducted using SPSS 16 for Windows.

RESULTS

Floristic Composition

Two main subhabitat types were recognized in the coastal sand formations in the study area: sand flats and sand dunes. A total of 92 species of vascular plants include 46 perennial species, one biennial species and 45 annual belonging to 78 genera and related to 27 families were recorded (Table 2). Eighty-six species (about 93.48% of the total recorded species) were recorded in the sand flats and classified into 44 annuals (51.16%), one biennial (1.16%) and 41 perennials (47.67%). In the sand dunes, 63 species (about 68.48% of the total) were recorded and grouped into 30 annuals (47.62%) and 33 perennials (52.38%). Twenty-eight perennial species have a wide ecological amplitude (P =100%) such as *Alhagi graecorum*, *Arthrocnemum macrostachyum*, *Atractylis carduus, Calligonum polygonoides, Cistanche phelypaea, Cynanchum acutum, Cynodon dactylon* etc. Eighteen abundant perennial species have a moderate ecological amplitude (P = 50%) such as *Asparagus stipularis, Astragalus fruticosus*, *Cressa cretica*, *Echium angustifolium*, *Frankenia hirsuta*, *Heliotropium curassavicum*, etc. *Spergularia marina* only one biennial species was recorded in one habitat (P=50%). Twenty-nine annual species have a wide ecological amplitude (P = 100%), these species include *Aegilops bicornis, Aegilops kotschyi, Anchusa humilis, Bassia indica, Bromus diandrus, Cakile maritima, Carduus getulus, Carthamus tenuis,* etc. Sixteen annual species have percentage of 50%, among these species are *Astragalus peregrinus, Atriplex prostrata, Avena fatua, Bassia muricata, Carduus pycnocephalus, Emex spinosa,* etc.

The most leading families were Poaceae (20 species) and Asteraceae (15 species) followed by Chenopodiaceae and Fabaceae (8 species each), Boraginaceae, Caryophyllaceae and Polygonaceae (4 species each). Other families were represented in different numbers of species. Monospecific families (13 families) attained less than 48.19% of the total recorded families. Generally, the family size is small: 25 families have less than 10 species and only two families have more than 10 species. Obviously, genus with higher number of species included *Zygophyllum* (3 species). Another 12 genera were represented by 2 species, including, amongst others, *Aegilops, Astragalus, Bassia* and *Carduus*.

Life form spectrum of the wild species recorded in the present study revealed that, the majority of the recorded species were therophytes (48 species = 52.17%) followed by cryptophytes (17 species =18.49%). Hemicryptophytes attained value of 13.04% (12 species), while the chamaephytes attained value of 10.87% (10 species) and phanerophytes attained value of 7.61% (7 species). The lowest value of life-forms was that of parasites which attained value of 1.10% (one species).

Chorological Affinities

Chorological analysis revealed that the widely distributed species are belonging to bi- and pluriregional Mediterranean elements represented by 47 species or 51.1% of the recorded flora (Table 3). Monoregional chorotypes were presented by 22 species, of which pure Mediterranean species were very rich represented (14 species). On the other hand, Cosmopolitan, Palaeotropical, Pantropical and Neotropical chorotypes constituted 10 species. While Saharo-Sindian chorotype, either pure or penetrated into other regions was represented by 46 species of the total recorded flora. This may reflect the equal effect of both Mediterranean and Saharo- Sindian chorotypes in the flora of the study area. Apparently, the combinations of Mediterranean + Saharo-Sindian (ME+SA-SI), Mediterranean + Irano-Turanian + Euro-Siberian (ME+IR-TR+ER-SR) and Mediterranean + Irano- Turanian + Saharo-Sindian (ME+IR-TR+SA-SI) were the most important, represented by 15, 9 and 9 species, respectively. Those of Mediterranean + Irano-Turanian (ME+IR-TR) and Saharo-Sindian + Sudano-Zambezian (SA-SI+S-Z) were moderately represented by5 species, each.

Classification of Stands

The application of TWINSPAN classification technique on the important values of 92 plant species recorded in 100 sampled stands led to the separation of four vegetation groups (A–D, Fig. 2). Each vegetation group comprises a set of stands which are similar in their vegetation and named after the first and second dominant species with the highest important values (IV) (Table 4). Group A: *Rumex pictus - Cutandia memphitica* were mainly occupied the sand flats; group B: *Elymus farctus - Cakile maritima* were inhabited the sand dunes; two vegetation groups extend their occurrence in the two subhabitats: *Senecio glaucus - Rumex pictus* and *Erodium laciniatum - Echinops spinosus* groups (C and D, respectively). Fifteen species were recorded in all 4 separated groups.

Ordination of Stands

Ordination of the 100 stands given by application of DCA on the same set of data (Fig. 3) indicated that the vegetation groups produced by TWINSPAN classification are distinguishable and showed a clear pattern of segregation on the ordination planes. The vegetation groups were clearly distinguished and distributed mainly along axis 1 from left to right in the order: groups C, D, B and A. The eigenvalues for the first two DCA axes (1 & 2) are 0.544 and 0.432, respectively. The high eigenvalue for DCA axis 1 indicated the major variation in species composition of the vegetation groups.

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Table 2. Floristic composition of the plant species of the sand formations in the north Nile Delta region.

No.	Species	Life Span	Life Form	Floristic Category	Sand formation		Presence	% Presence
					Sand dune	Sand flat		
1	*Aegilops bicornis* (forssk.) Jaub & Spach	Ann.	Th	ME+ SA-SI	+	+	2	100
2	*Aegilops kotschyi* Boiss.	Ann.	Th	IR-TR+SA-SI	+	+	2	100
3	*Alhagi graecorum* Boiss.	Per.	H	PAL	+	+	2	100
4	*Anchusa humilis* (Desf.) I.M. Johnst.	Ann.	Th	ME+ SA-SI	+	+	2	100
5	*Arthrocnemum macrostachyum* (Moric.) K. Koch	Per.	Ch	ME+ SA-SI	+	+	2	100
6	*Atractylis carduus* (Forssk.) C. Chr.	Per.	H	SA-SI+ME	+	+	2	100
7	*Bassia indica* (Wight) A.J.Scott.	Ann.	Th	S-Z+IR-TR	+	+	2	100
8	*Bromus diandrus* Roth	Ann.	Th	ME	+	+	2	100
9	*Cakile maritima* Scop.	Ann.	Th	ME+ER-SR	+	+	2	100
10	*Calligonum polygonoides* L.	Per.	Nph	SA-SI+IR-TR	+	+	2	100
11	*Carduus getulus* Pomel	Ann.	Th	SA-SI	+	+	2	100
12	*Carthamus tenuis* (Boiss. & Blanche) Bornm.	Ann.	Th	ME	+	+	2	100
13	*Chenopodium murale* L.	Ann.	Th	COSM	+	+	2	100
14	*Cistanche phelypaea* (L.)Cout.	Per.	P,G	SA-SI+ME	+	+	2	100
15	*Cutandia memphitica* (Spreng.) Benth.	Ann.	Th	ME+IR-TR+SA-SI	+	+	2	100
16	*Cynanchum acutum* L.	Per.	H	ME+IR-TR	+	+	2	100
17	*Cynodon dactylon* (L.) Pers.	Per.	G	PAN	+	+	2	100
18	*Cyperus capitatus* Vand.	Per.	G	ME	+	+	2	100
19	*Cyperus conglomeratus* Rottb.	Per.	G	SA-SI+S-Z	+	+	2	100
20	*Daucus litoralis* Sm.	Ann.	Th	ME	+	+	2	100
21	*Echinops spinosus* L.	Per.	H	ME+SA-SI	+	+	2	100
22	*Elymus farctus* (Viv.) Runem.ex Melderis	Per.	G	ME	+	+	2	100
23	*Erodium laciniatum* (Cav.) Willd.	Ann.	Th	ME	+	+	2	100
24	*Halocnemum strobilaceum* (Pall.) M. Bieb.	Per.	Ch	ME+IR-TR+SA-SI	+	+	2	100

Table 2. Continued.

25	*Hordeum murinum* L.	Ann.	Th	ME+IR-TR+ER-SR	+	+	2	100
26	*Ifloga spicata* (Forssk.) Sch.Bip.	Ann.	Th	SA-SI+ME	+	+	2	100
27	*Launaea mucronata* (Forssk.) Muschl.	Per.	H	ME+SA-SI	+	+	2	100
28	*Limonium pruinosum* (L.) Chaz.	Per.	H	SA-SI	+	+	2	100
29	*Lolium perenne* L.	Per.	Th	ER-SR+ME+IR-TR	+	+	2	100
30	*Lotus halophilus* Boiss.	Ann.	Th	ME+SA-SI	+	+	2	100
31	*Lotus polyphyllos* E.D. Clarke	Per.	Th	ME	+	+	2	100
32	*Mesembryanthemum crystallinum* L.	Ann.	Th	ME+ER-SR	+	+	2	100
33	*Mesembryanthemum nodiflorum* L.	Ann.	Th	ME+SA-SI+ER-SR	+	+	2	100
34	*Moltkiopsis ciliata* (Forssk.) I. M. Johnst.	Per.	Ch	SA-SI+S-Z+ME	+	+	2	100
35	*Ononis serrata* Forssk.	Ann.	Th	ME+SA-SI	+	+	2	100
36	*Pancratium maritimum* L.	Per.	G	ME	+	+	2	100
37	*Parapholis incurva* (L.) C.E. Hubb	Ann.	Th	ME+IR-TR+ER-SR	+	+	2	100
38	*Paronychia arabica (L.) DC.*	Ann.	Th	SA-SI+ME+S-Z	+	+	2	100
39	*Phoenix dactylifera* L.	Per.	MMPh	CULT.	+	+	2	100
40	*Phragmites australis* (Cav.) Trin. ex Steud	Per.	G,He	COSM	+	+	2	100
41	*Picris asplenioides* L.	Ann.	Th	ME+IR-TR	+	+	2	100
42	*Plantago squarrosa* Murray	Ann.	Th	SA-SI+ME	+	+	2	100
43	*Poa annua* L.	Ann.	Th	COSM	+	+	2	100
44	*Reichardia tingitana* (L.) Roth.	Ann.	Th	ME+SA-SI+IR-TR	+	+	2	100
45	*Ricinus communis* L.	Per.	NPH	CULT and NAT	+	+	2	100
46	*Rumex pictus* Forssk.	Ann.	Th	ME+SA-SI	+	+	2	100
47	*Salsola kali* L.	Ann.	Th	COSM	+	+	2	100
48	*Senecio glaucus* L.	Ann.	Th	ME+SA-SI+IR-TR	+	+	2	100
49	*Silene succulenta* Forssk.	Per.	H	ME	+	+	2	100
50	*Silene vivianii* Steud.	Ann.	Th	SA-SI	+	+	2	100
51	*Stipagrostis lanata* (Forssk.) De Winter	Per.	G	SA-SI	+	+	2	100

Table 2. Continued.

52	*Suaeda maritima* (L.) Dumort.	Ann.	Th	COSM	+	+	2	100
53	*Tamarix nilotica* (Ehrenb.) Bunge	Per.	Nph	ME+ER-SR+IR-TR	+	+	2	100
54	*Tamarix tetragyna* Ehrenb.	Per.	Nph	SA-SI+S-Z	+	+	2	100
55	*Zygophyllum aegyptium* Hosny	Per.	Ch	ME	+	+	2	100
56	*Zygophyllum album* L.	Per.	Ch	SA-SI+ME	+	+	2	100
57	*Zygophyllum coccineum* L.	Per.	Ch	SA-SI+S-Z	+	+	2	100
58	*Asparagus stipularis* Forssk.	Per.	G	ME+ SA-SI	-	+	1	50
59	*Astragalus fruticosus* Forssk.	Per.	Ch	SA-SI	-	+	1	50
60	*Astragalus peregrinus* Vahl	Ann.	Th	SA-SI	-	+	1	50
61	*Atriplex prostrata* DC.	Ann.	Th	ME+ER-SR+IR-TR	-	+	1	50
62	*Avena fatua L.*	Ann.	Th	PAL	-	+	1	50
63	*Bassia muricata* (L.) Asch.	Ann.	Th	SA-SI+IR-TR	-	+	1	50
64	*Brassica tournefortii* Gouan	Ann.	Th	ME+IR-TR+SA-SI	-	+	1	50
65	*Carduus pycnocephalus* L.	Ann.	Th	SA-SI	-	+	1	50
66	*Cressa cretica* L.	Per.	H	ME+PAL	+	-	1	50
67	*Echium angustifolium* Mill.	Per.	H	ME	-	+	1	50
68	*Emex spinosa* (L.) Campd.	Ann.	Th	ME+SA-SI	-	+	1	50
69	*Frankenia hirsuta* L.	Per.	H	ME+ER-SR+IR-TR	-	+	1	50
70	*Frankenia pulverulenta* L.	Ann.	Th	ME+ER-SR+IR-TR	-	+	1	50
71	*Heliotropium curassavicum* L.	Per.	Ch	NEO	+	-	1	50
72	*Imperata cylindrica* (L.) Raeusch.	Per.	H	PAL+ME	-	+	1	50
73	*Juncus rigidus* Desf.	Per.	He,G	ME+SA-SI+IR-TR	-	+	1	50
74	*Launaea nudicaulis* (L.) Hook.f.	Per.	H	SA-SI+S-Z+IR-TR	+	-	1	50
75	*Limbarda crithmoides* (L.) Dumort.	Per.	Ch	ME+ER-SR+SA-SI	-	+	1	50
76	*Limoniastrum monopetalum* (L.) Boiss.	Per.	Ch	ME	-	+	1	50
77	*Lycium schweinfurthii* Dammer	Per.	NPh	ME	-	+	1	50
78	*Malva parviflora* L.	Ann.	Th	ME+IR-TR	+	-	1	50

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Table 2. Continued.

79	*Melilotus indicus* (L.) All.	Ann.	Th	ME+IR-TR+SA-SI	-	+	1	50
80	*Panicum repens* Forssk.	Per.	G	SA-SI+S-Z	+	-	1	50
81	*Phalaris minor* Retz.	Ann.	Th	S-Z+SA-SI	-	+	1	50
82	*Polygonum equisetiforme* Sm.	Per.	G	ME+IR-TR	-	+	1	50
83	*Polypogon monspeliensis* (L.) Desf.	Ann.	Th	COSM	-	+	1	50
84	*Retama raetam* (Forssk.) Webb& Berthel.	Per.	Nph	ME+IR-TR+SA-SI	-	+	1	50
85	*Schoenus nigricans* L.	Per.	G	ME+IR-TR+ER-SR	-	+	1	50
86	*Sonchus oleraceus* L.	Ann.	Th	COSM	-	+	1	50
87	*Spergularia marina* (L.) Griseb.	Bi	Th	ER-SR+ME+IR-TR	-	+	1	50
88	*Sphenopus divaricatus* (Gouan) Rchb.	Ann.	Th	ME+IR-TR+SA-SI	-	+	1	50
89	*Sporobolus spicatus* (Vahl) Kunth	Per.	G	S-Z+SA-SI+ME	-	+	1	50
90	*Stipagrostis scoparia* (Trin. & Rupr.) De Winter	Per.	G	SA-SI	+	-	1	50
91	*Urospermum picroides* (L.) F.W. Schmidt	Ann.	Th	ME+IR-TR	-	+	1	50
92	*Volutaria lippii* (L.) Cass.ex Maire	Ann.	Th	ME	-	+	1	50

Abbreviations:

Life Span	Life Form	Floristic Category
Per. = Perennials	H. = Hemicryptophytes	COSM = Cosmopolitan
Bi. = Biennials	G. = Geophytes	PAN = Pantropical
Ann. = Annuals	He. = Helophytes	PAL = Palaeotropical
	Th. = Therophytes	NEO = Neotropical
	Nph. = Nanophanerophytes	ME = Mediterranean
	Ch. = Chamaephytes	SA-SI = Saharo-Sindian
	MMPh = Meso & Megaphanerophytes	Cult. & Nat. = Cultivated and Naturalized
	P = Parasites	ER-SR = Euro-Siberian
		IR-TR = Irano-Turanian
		S-Z = Sudano-Zambezian

Species Diversity

Rumex pictus - Cutandia memphitica (Group A) has the highest species richness (1.18 species/stand), while *Erodium laciniatum - Echinops spinosus* (group D) has the highest species turnover with a value of 85.89 (Table 4). On the other hand, *Senecio glaucus - Rumex pictus* (group C) has the highest relative evenness and relative concentration of species dominance represented by 3.35 and 0.95, respectively. *Elymus farctus - Cakile maritima* (Group B) has the second level of species richness (1.07 species/stand), third level of species turnover (41.12), second level of relative evenness (3.21) and relative concentration (0.94) of species dominance.

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

Floristic category	Total area		Habitat type (Sand formation)			
			Sand dune		Sand flat	
	No.	**%**	**No.**	**%**	**No.**	**%**
COSM	7	7.60	5	7.93	7	8.13
PAN	1	1.08	1	1.58	1	1.16
PAL	2	2.17	1	1.58	2	2.32
NEO	1	1.08	1	1.58	-	-
ME+IR-TR+ER-SR	9	9.78	4	6.34	9	10.46
ME+IR-TR+SA-SI	9	9.78	4	6.34	9	10.46
ME+SA-SI+ER-SR	2	2.17	1	1.58	2	2.32
ME+SA-SI+S-Z	3	3.26	2	3.17	3	3.48
SA-SI+S-Z+IR-TR	1	1.08	1	1.58	-	-
ME+IR-TR	5	5.43	3	4.76	4	4.65
ME+ER-SR	2	2.17	2	3.17	2	2.32
ME+PAL	2	2.17	1	1.58	1	1.16
ME+SA-SI	15	16.30	13	20.63	15	17.44
SA-SI+S-Z	5	5.43	4	6.34	4	4.65
SA-SI+IR-TR	3	3.26	2	3.17	3	3.48
S-Z+IR-TR	1	1.08	1	1.58	1	1.16
ME	14	15.21	10	15.87	14	16.27
SA-SI	8	8.69	5	7.93	7	8.13
Cult. & Nat.	2	2.17	2	3.17	2	2.32
Total	**92**	**100**	**63**	**100**	**86**	**100**

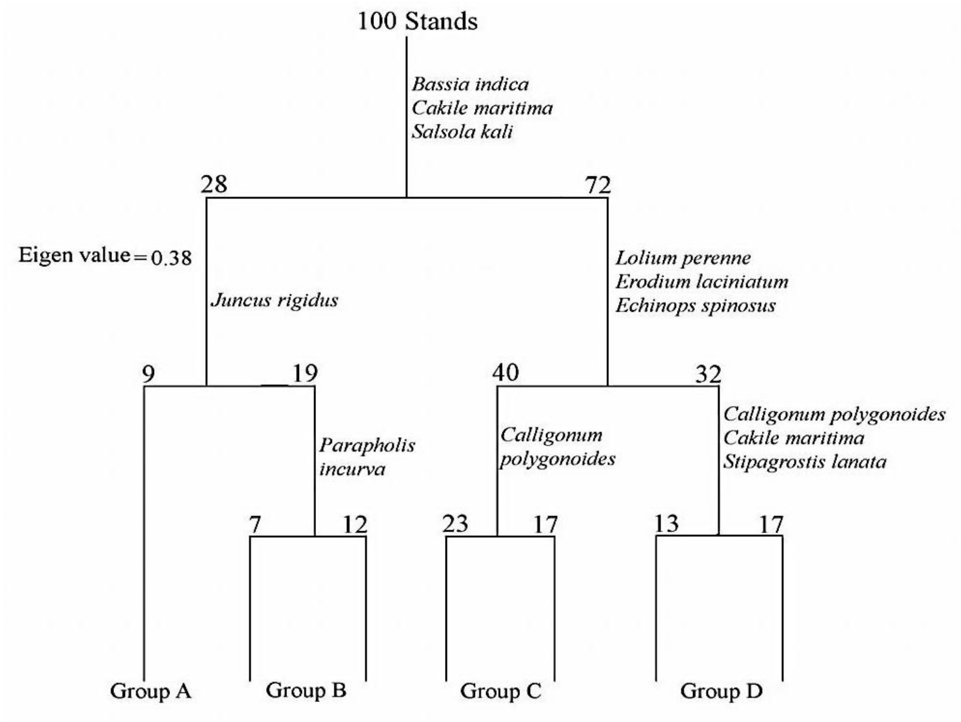


Fig. 2. TWINSPAN dendrogram of the 100 stands based on the importance values of species.

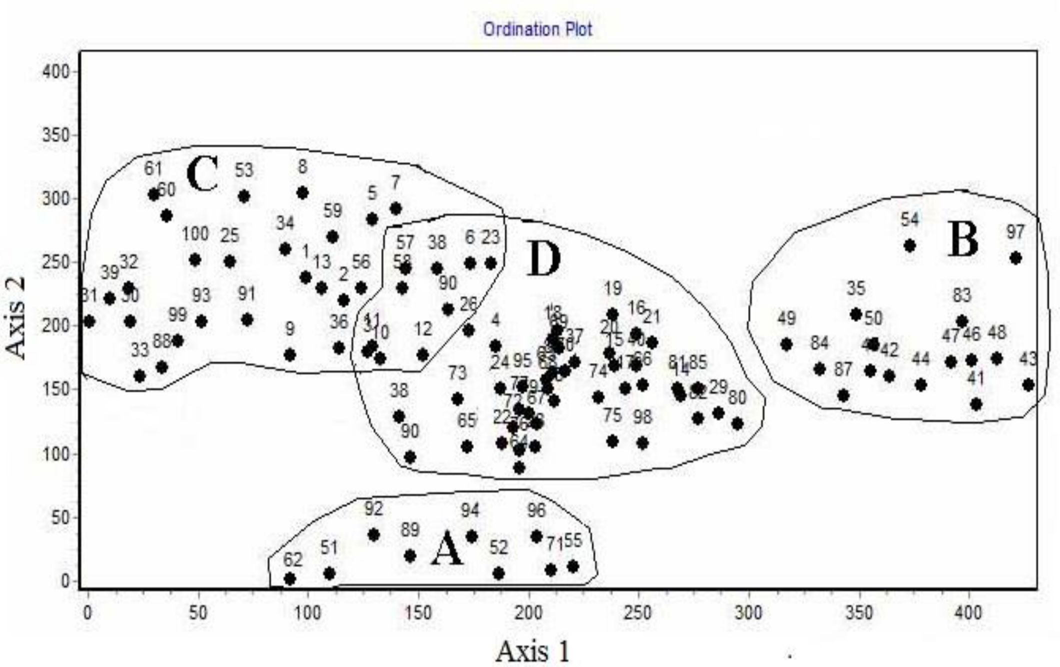


Fig. 3. DCA ordination of the 100 stands based on the importance values of 92 species with the vegetation groups resulted from TWINSPAN superimposed.

Soil–Vegetation Relationships

Edaphic characteristics of the 4 vegetation groups of stands derived from TWINSPAN classification indicated considerable variations in the edaphic factors among the stands of the different groups (Table 5). Organic carbon, electrical conductivity, chlorides, sulphates and sodium showed significant correlations ($P < 0.05$) among vegetation groups. Vegetation groups A and B showed higher values of organic carbon (0.44 and 0.49%, respectively) than in groups C and D (0.39 and 0.43%, respectively). Also, the percentages of chlorides and sulphates were relatively higher in groups A and B (1.77, 1.20% and 1.27, 0.86%, respectively) as compared with groups C and D (1.16, 0.79% and 1.13, 0.77%, respectively). Electrical conductivity was higher in groups A and D (1066.78 and 426.69 µmohs/cm, respectively) than in groups B and C (336.63and 286.08 µmohs/cm, respectively). Vegetation groups B and D showed values of sodium (78.96 and 65.20 mg/100g dry soil, respectively) which were higher than in groups A and C (54.82 and 55.01 mg/100g dry soil).

The correlation coefficient (r) between the different soil variables in the sampled stands are shown in Table 6. It has been found that, some soil variables were significant positively correlated with other soil factors such as water-holding capacity with organic carbon, sodium, potassium, calcium and magnesium (r = 0.595, 0.308, 0.341, 0.331 and 0.341, respectively) and organic carbon with chlorides, sulphates, sodium, potassium, calcium, magnesium, SAR and PAR (r = 0.403, 0.410, 0.478, 0.553, 0.511, 0.482, 0.362 and 0.413, respectively).

Some other soil variables showed significant negatively correlation such as silt with chlorides, sulphates (r = -0.331 and -0.351, respectively) and available nitrogen with potassium, calcium and magnesium (r = -0.264, -0.286 and -0.253, respectively). On the other hand, some soil variables such as sand, calcium carbonate, bicarbonates and available phosphorus exhibited no significant correlations with any soil variables.

Correlations of edaphic variables with the importance values of the dominant and abundant species are shown in Table 7. Sand and silt correlated significantly with *E. farctus* (r= -0.357 and 0.380), *S. glaucus* (r = -0.199 and 0.225) and *E. laciniatum* (r = 0.304 and -0.319). Organic carbon exhibited significant correlations with *R. pictus* (r = -0.277) and *C. dactylon* (r = 0.198). Exception of *C. memphitica, C. maritima, S. glaucus* and *C. dactylon* all the tested dominant and abundant species showed significant correlations with pH. Chlorides and sulphates were correlated significantly with *R. pictus* (r = -0.337 each), *C. memphitica* (r = -0.211 each) and *E. spinosus* (r = -0.224 each). *C. dactylon* showed significant correlations with available nitrogen (r = 0.252), sodium (r = -0.214) and SAR (r = -0.233) while, *S. glaucus* correlated significantly with potassium (r = 0.206) and SAR (r = 0.235).

The correlation between the identified vegetation groups and the soil factors is indicated by CCA (Fig. 4). *Rumex pictus - Cutandia memphitica* (Group A) and *Elymus farctus - Cakile maritima* (Group B) showed high correlations with clay, $CaCO_3$, magnesium, potassium and PAR. *Senecio glaucus - Rumex pictus* (group C) was highly correlated with water-holding capacity, porosity, available nitrogen and organic carbon. *Erodium laciniatum - Echinops spinosus* (Group D) showed a high correlation with silt and SO_4^{--}.

Table 4. Characteristics of the 4 vegetation groups derived after the application of TWINSPAN classification on the 100 stands on the sand formations. VG: Vegetation Group; N: Number of stands; NS: Number of species per group; P: Presence; IV: Importance Value; SR: Species Richness; ST: Species turnover; H´: Shannon index; and SI: Simpson index

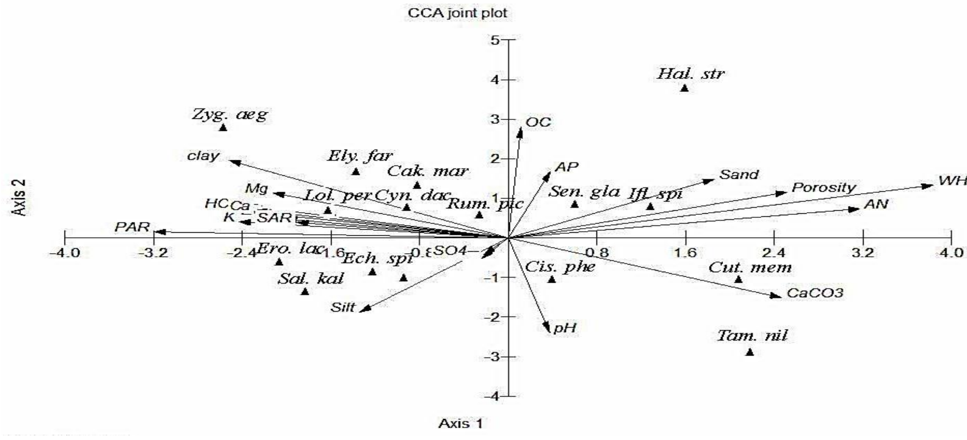
VG	N	NS	Habitats	1st Dominant	P%	IV%	2nd Dominant	P%	IV%	Species Diversity			
										SR	ST	H´	SI
A	9	42	SF	*Rumex pictus*	88.89	20.09	*Cutandia memphitica*	44.45	15.06	1.18	35.59	3.07	0.93
B	19	44	SD	*Elymus farctus*	78.95	29.38	*Cakile maritima*	89.47	25.04	1.07	41.12	3.21	0.94
C	40	68	SF, SD	*Senecio glaucus*	85.0	15.94	*Rumex pictus*	75.0	15.73	0.95	71.58	3.35	0.95
D	32	53	SF, SD	*Erodium laciniatum*	78.2	19.70	*Echinops spinosus*	84.38	18.80	0.90	85.89	3.17	0.94

Table 5. Mean and standard error of the different soil variables in the stands representing the different vegetation groups obtained by TWINSPAN classification in the study area.

Soil variable		Vegetation group A (n= 9)	B (n=19)	C (n=40)	D (n=32)	*F-ratio*	*P*
Sand	%	96.28±0.96	95.04±0.82	94.04±0.47	95.44±0.54	1.23	0.32ns
Silt		2.47±0.70	4.42±0.86	4.70±0.50	3.26±0.43	1.34	0.28ns
Clay		1.25±0.88	0.54±0.13	1.27±0.13	1.29±0.25	0.99	0.41ns
Porosity		40.37±2.19	44.45±2.54	41.65±1.37	55.84±10.06	0.85	0.48ns
WHC		34.37±1.32	34.33±0.56	33.73±0.83	33.77±0.83	0.14	0.94ns
$CaCO_3$		3.28±0.23	3.32±0.30	3.01±0.15	3.14±0.17	1.03	0.39ns
OC		0.44±0.04	0.49±0.05	0.39±0.03	0.43±0.03	0.20	0.90*
pH		8.02±0.17	8.23±0.14	8.21±0.09	7.90±0.07	0.26	0.85ns
EC µmohs/cm		1066.78±153.77	336.63±139.97	286.08±94.21	426.69±132.80	8.53	0.08**
Cl^-	%	1.77±0.15	1.27±0.12	1.16±0.13	1.13±0.13	1.30	0.29***
SO_4^{--}		1.20±0.10	0.86±0.08	0.79±0.09	0.77±0.09	1.31	0.29***
HCO_3^-		0.05±0.01	0.07±0.01	0.11±0.06	0.06±0.01	0.22	0.88ns
AN	mg/100g dry soil	2.56±0.24	5.04±1.78	2.94±0.18	2.88±0.15	0.63	0.60ns
Ap		0.53±0.04	0.60±0.03	0.52±0.02	0.57±0.02	0.05	0.98ns
Na^+		54.82±11.46	78.96±14.37	55.01±10.80	65.20±12.50	0.24	0.87*
K^+		16.45±1.41	12.93±2.16	9.07±1.69	7.12±1.56	0.34	0.80ns
Ca^{++}		15.80±3.24	20.72±3.83	16.02±3.00	17.64±3.09	0.19	0.90ns
Mg^{++}		6.17±1.12	8.41±1.49	6.26±1.04	7.15±1.26	0.19	0.90ns
SAR		15.77±1.79	19.77±2.08	14.60±1.29	15.86±1.81	0.14	0.93ns
PAR		2.18±0.21	3.01±0.26	2.51±0.19	2.87±0.31	0.55	0.65ns

*P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001

Fig. 4. CCA species–soil variable biplot in different habitat types of the study area.



DISCUSSION

The vegetation of the Mediterranean coastal region of Egypt is considered to be one of its major natural resources [40]. The vegetation structure in the study area comprises 92 plant species, including 45 annuals, one biennial and 46 perennials were recorded in the two habitats of the sand formations of north Nile Delta Coast. This number represents 64.2% of the species recorded by Galal and Fawzy [15], in the coastal sand dune of Nile Dlta, 67.5% by [41] in the sand formations of Burullus Wetland, 52.2% by Ayyad [42] and Scholten, *et al.* [43], 39.1% by Ayyad and El-Bayyoumy [44] on the sand dunes of the western Mediterranean coast and 40.9% by Mashaly [7] in El-Dakahlia- Damietta coastal region. Some species recorded in this study such as *Arthrocnemum Macrostachyum*, *Lotus halophilus, Lotus polyphyllos Schoenus nigricans, Picris asplenioides, Cistanche phelypaea* were not recorded by Galal and Fawzy [15]. Also, *Calligonium polygonoides, Astragalus fruticosus, Anchusa humilis, Lotus polyphyllos* recorded in the present investigation but not recorded by Shaltout and Khalil [45].

On the other hand, some species recorded by Galal and Fawzy [15] such as *Asphodelus viscidulus, Brassica rapa, Calendula arvensis, Herniaria hemistemon, Mellilotus messanensis, Neurada procumbens, Schismus barbatus* were not recorded in this study. Shaltout and Khalil [45] recorded *Sarcocorina fruticosa, Trigonella stellate, Orobanche crenata* but absent in this study. Some species were recorded on the sand dunes of the western Mediterranean coast [44] were not recorded in the present study such as *Ammophila arenaria, Euphorbia paralias.* Also, *Reseda decursiva, Euphorbia paralias, Diplotaxix acris, Varthemia candicans* and *Saliva lanigers* were recorded by Abbas, *et al.* [46] but not in the present study.

It is worth noting, that the species composition of the studied sand formations in the middle Nile Delta coast varied considerably from those of the western Mediterranean coast. This may be attributed mainly to the differences in the nature of soil sediments. The floristic elements of the western Mediterranean coastal belt enjoy better climatic conditions than those of the other parts of Egypt [47].

Eighty six species were recorded on sand flats and 63 species on the sand dunes. These differences in plant cover may be because the sand flats are not subjected to the direct effect of strong north winds which lower the temperature and may uproot many seedlings on the sand dunes [10]. The sand dunes were dominated by the pioneer psammophytes *Elymus farctus*, *Stipagrostis lanata* and *S. scoparia* with abundance of *Moltkiopsis ciliata, Calligonum polygonoides, Silene succulenta* and *Echinops spinosus* [10, 48].

The abundance of *Calligonum polygonoides*, *Senecio glaucus, Rumex pictus*, *Cakile maritima* and *Echinops spinosus* in most sites may suggest to their resistance to variability in soil characteristics. The reduction in the number of species in response to climatic and edaphic factors as well as unplanned development, salt water intrusion, grazing practices may change the habitat fitness for many species [5, 49].

The 92 recorded species were distributed within 27 families. The four major families were Poaceae, Asteraceae, Chenopodiaceae and Fabaceae. They accounted for about 55.44% of the total recorded flora of the study area. These leading families were reported to be the most frequent in the sand dunes in other investigations [50, 51] in the Deltaic Mediterranean coast [15], in sand dune vegetation in the coast of Nile Delta; [46], in coastal sand dune rangelands in the north-west of Egypt. Hassan, et al. [52] in vegetation types of Lake Burullus protected area. Moreover, these families represent the most common in the Mediterranean North African flora [53].

The high contribution of annuals can be attributed to time of study (March – May 2013) and short life cycle that enables them to resist the instability of the agro-ecosystem. Moreover, they are generally characterized by high allocation of resources to the reproductive organs [54] and the production of flowers early in their lifespan to ensure some seed production even in a year when the growing season is cut short [55]. The dominance of perennials may be related to the nature of the habitat types in the present study in which the reproductive capacity, ecological, morphological and genetic plasticity are the limiting factors [54, 56].

The life form spectra provide information which may help in assessing the response of vegetation to variations in environmental factors [57]. Raunkiaer [58] designated the Mediterranean climate type as "therophyte climate" because of the high percentage (more than 50% of the total species) of this life-form in the Mediterranean floras. The present study demonstrated that therophytes was represented by 52.17% of the total recorded species, 18.49% cryptophytes, 13.04% hemicryptophytes, 10.87% chamaephytes and 7.61% phanerophytes.

The above results agree with those of other reports [51, 59-61]. The dominance of therophytes over the other life forms seems to be a response to Mediterranean climate, topography variation and biotic influence [62]. The highest values of hemicryptophytes and chamaephytes may be attributed to the ability of species to resist drought, salinity, sand accumulation and grazing [63, 64].

Chorological analysis revealed that the widely distributed species belonging to bi- and pluriregional Mediterranean chorotypes included 47 species (51.1% of the total recorded flora). Mono-regional Mediterranean species were represented by14 species. The dominance of interregional species (bi- and pluri-regionals) over mono-regional ones is referred to the presence of interzonal habitats, such as anthropogenic or hydro-, halo- and psammophilous sites [65].

Saharo-Sindian chorotypes, either pure or penetrated into other regions, comprised 46 species of the total recorded flora. This may reflect the effect of both Mediterranean and Saharo-Sindian chorotypes in the flora of the study area. The presence of the different chorological elements in the study area is believed to be a reflection of intense climatic changes and/or the degradation of the Mediterranean ecosystem which facilitated the invasion of some floristic elements from the adjacent regions [66], Similar results were reported in other studies [15, 51, 60, 61].

The vegetation structure is distinguished by TWINSPAN classification into four vegetation groups in the sand formation habitats. Each group is characterized by dominant and/or codominant species as well as by a number of indicator and/or preferentional species. *Rumex pictus* - *Cutandia memphitica* (group A) mainly occupied the sand flats; *Elymus farctus* - *Cakile maritima* (group B) inhabited the sand dunes; two vegetation groups (C and D) extend their occurrence in the two subhabitats: *Senecio glaucus* - *Rumex pictus* and *Erodium laciniatum* - *Echinops spinosus* groups. The sand formation vegetation communities were more or less related to the plant communities described by Serag [67], Mashaly [7], Zahran, et al. [50], Mashaly [4] and Galal and Fawzy [15] . These groups were separated markedly along DCA ordination axes. It is of interest to note that, interspecific relationships between the above mentioned vegetation groups may be due to the close similarities of their floristic composition and natural habitats. The diversity of plant communities in sand flat was higher than in sand dune. This may be attributed to the differences in soil characteristics, cultivation or urbanization. Moreover, the high diversity of such habitat was associated with the increase of annuals during spring [10, 69, 70].

Soil texture, salinity and organic carbon can affect phytodiversity of wild communities [71-73]. In the present study linear correlation of soil variables with the importance values of some dominant species indicates significant associations between the floristic composition of the sand formations and the edaphic factors such as soil texture, organic carbon, pH, chlorides and sulphates. Moreover, silt, clay, organic carbon, $CaCO_3$, SO_4^{--}, magnesium and potassium exhibited significant differences between vegetation groups (A-D). These results suggest the effective role of these soil parameters in the sand formations community structure and diversity. The present findings agree with those of El-Sheikh [74], Al-Sodany [11], Mashaly [4], El-Halawany [75] and Hammad [76]. Soil texture may affect soil or productivity via influence on the soil water holding capacity, infiltration rate, moisture availability for plants and consequently plant nutrition [77, 78],

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Table 6. Pearson-moment correlation (r) between the soil variables in the stands surveyed in sand formations of the study area.

Soil variables	Sand	Silt	Clay	Por.	WHC	$CaCO_3$	OC	pH	EC	Cl^-	SO_4^{--}	HCO_3^-	AP	AN	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR
Sand	1																			
Silt	-0.916**	1																		
Clay	-0.269**	-0.139	1																	
Por.	0.062	-0.028	-0.087	1																
WHC	0.028	-0.093	0.153	-0.072	1															
$CaCO_3$	0.044	-0.041	-0.008	-0.031	-0.148	1														
OC	-0.025	0.016	0.022	-0.035	0.595**	0.061	1													
pH	-0.125	0.195	-0.158	-0.123	-0.103	0.00	0.162	1												
EC	0.012	-0.054	0.100	-0.106	0.021	0.00	0.028	-0.167	1											
Cl^-	0.320**	-0.331**	0.005	-0.1	0.216*	0.149	0.403**	-0.007	0.178	1										
SO_4^{--}	0.320**	-0.351**	0.005	-0.1	0.216*	0.149	0.410**	-0.007	0.177	1.000**	1									
HCO_3^-	0.064	-0.077	0.027	-0.069	0.028	-0.013	0.024	-0.014	0.077	0.03	0.03	1								
AP	-0.041	0.08	-0.091	0.017	0.123	-0.015	0.121	0.215*	0.124	-0.048	-0.048	-0.024	1							
AN	-0.143	0.246*	-0.236*	-0.001	0.256*	-0.038	0.021	-0.021	-0.044	0.077	0.077	-0.185	0.255*	1						
Na^+	0.052	-0.102	0.118	-0.069	0.308**	-0.01	0.478**	0.038	0.642**	0.021	0.02	0.174	0.127	-0.249*	1					
K^+	0.015	-0.05	0.083	-0.057	0.341**	-0.019	0.553**	0.097	0.514**	-0.048	-0.048	0.153	0.131	-0.264**	0.958**	1				
Ca^{++}	0.023	-0.076	0.128	-0.063	0.331**	-0.005	0.511**	0.026	0.604**	0.004	0.004	0.167	0.12	-0.286**	0.984**	0.973**	1			
Mg^{++}	0.030	-0.077	0.11	-0.069	0.341**	0.012	0.482**	0.005	0.652**	0.012	0.012	0.157	0.132	-0.253*	0.965**	0.945**	0.980**	1		
SAR	0.075	-0.132	0.13	-0.103	0.248*	-0.001	0.362**	0.003	0.705**	0.04	0.04	0.173	0.132	-0.184	0.948**	0.864**	0.894**	0.882**	1	
PAR	0.045	-0.04	-0.015	-0.049	0.252*	-0.032	0.413**	0.051	0.363**	-0.062	-0.062	0.065	0.116	-0.077	0.677**	0.800**	0.672**	0.647**	0.641**	1

Abbreviations:

Por. = Porosity AP = Available phosphorus * = Significant at $p \le 0.05$

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EC = Electrical conductivity | AN = Available nitrogen | ** = Significant at p ≤ 0.01
W.H.C. = Water holding capacity | SAR = Sodium adsorption ratio
O.C. = Organic carbon | PAR = Potassium adsorption ratio

Table 7. Linear correlation coefficients (r) between edaphic factors and the importance values of the dominant and abundant species.

Species	Edaphic factor																			
	Sand	**Silt**	**Clay**	**Por.**	**WHC**	**$CaCO_3$**	**OC**	**pH**	**EC**	**Cl^-**	**SO_4^{--}**	**HCO_3**	**AN**	**AP**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**SAR**	**PAR**
Rum. pic.	-0.04	0.012	0.07	-0.128	-0.169	-0.008	-0.277**	-0.241*	-0.004	-0.337**	-0.337**	-0.058	-0.185	-0.142	-0.029	-0.022	-0.016	-0.016	-0.048	0.043
Cut. mem.	-0.014	0.024	-0.024	-0.122	0.047	-0.041	-0.046	-0.034	-0.097	-0.211*	-0.211*	0.075	-0.054	-0.165	-0.057	-0.053	-0.034	-0.031	-0.069	-0.109
Ely. far.	-0.357**	0.380**	-0.032	-0.027	0.006	0.078	0.123	0.256*	-0.083	-0.185	-0.185	-0.013	0.029	-0.07	0.111	0.180	0.147	0.116	0.013	0.19
Cak. mar.	0.047	-0.033	-0.035	0.058	-0.11	-0.064	0.001	0.119	0.024	-0.094	-0.094	0.009	0.094	0.039	0.101	0.068	0.07	0.081	0.162	0.033
Sen. gla.	-0.199*	0.225*	-0.048	-0.042	-0.044	-0.023	0.09	0.09	0.109	-0.127	-0.127	0.031	-0.028	-0.043	0.174	0.206*	0.177	0.183	0.235*	0.126
Ero. lac.	0.304**	-0.319**	0.014	0.131	0.036	-0.063	-0.006	-0.271**	0.067	-0.056	-0.056	-0.036	-0.097	-0.126	0.097	0.073	0.096	0.104	0.083	0.025
Ech. spi.	0.177	-0.155	-0.065	0.003	0.022	-0.067	-0.14	-0.193*	-0.177	-0.224*	-0.224*	-0.018	-0.057	0.07	-0.127	-0.135	-0.161	-0.177	-0.167	-0.051
Lol. per.	0.183	-0.181	-0.017	0.164	0.077	-0.051	0.021	-0.242*	0.011	0.077	0.078	-0.067	-0.07	0.189	-0.05	-0.046	-0.064	-0.071	-0.03	0.106
Cyn. dac.	-0.013	0.089	-0.18	-0.004	0.077	-0.051	0.198*	-0.014	0.18	0.068	0.069	-0.007	0.252*	0.171	0.214*	0.19	0.193	0.195	0.233*	0.148
Ifl. spi.	-0.105	0.03	0.186	-0.081	0.092	0.176	-0.017	0.212*	-0.104	-0.05	-0.05	0.249*	-0.043	-0.138	-0.014	0.007	0.00	-0.028	-0.056	-0.053
Hal. str.	0.1	-0.179	0.185	-0.071	0.004	-0.027	-0.189	-0.240*	0.207*	-0.057	-0.057	0.001	-0.103	-0.169	0.114	0.066	0.119	0.156	0.131	0.017

Abbreviations:

Por. = Porosity | AP = Available phosphorus | * = Significant at p ≤ 0.05
EC = Electrical conductivity | AN = Available nitrogen | ** = Significant at p ≤ 0.01
WHC = Water holding capacity | SAR = Sodium adsorption ratio
OC = Organic carbon | PAR = Potassium adsorption ratio

Rum pic: Rumex pictus, Cut mem: Cutandia memphitica, Ely far: Elymus farctus, Cak mar: Cakile maritima ; Sen gla: Senecio glaucus, Ero lac: Erodium laciniatum, Ech spi: Echinops spinosus, Lol per: Lolium perenne, Cyn dac: Cynodon dactylon, Ifl spi: Ifloga spicata, Hal str: Halocnemum strobilaceum

CONCLUSION

The sand formation vegetation types of the Deltaic Mediterranean coast include many species which can be used as important resources for raw materials. No doubt that, the natural vegetation of the sand formation in north Nile Delta is changed and suffers from the growing rate of human population. Therefore, the conservation of natural habitats of this coast especially the sand formations, which will be threatened by agriculture, urban expansions and exposed to serious erosion, are of vital importance. The recorded 92 plant species can play a vital role in the economic and medicinal purposes. Hence, the Deltaic Mediterranean coast especially sand formations need for judicious utilization and sustainable development.

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