Vegetation Composition Related to Environmental Factors along the International Highway-West Alexandria, Egypt

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study aimed to characterize the ecological features of the vegetation along the international coastal road from El-Ajami to Ras El-Hekma, West Alexandria, Egypt. The cluster analysis of 60 stands was performed using the Community Analysis Package program and Detrended Correspondence Analysis (DCA). Canonical Correspondence Analysis (CCA) was used to identify the ecological relationships between the vegetation and the environment along the roadside. The total number of the recorded plant species surveyed in the present study was 84 species belonging to 74 genera and related to 25 families. Asteraceae, Poaceae, Fabaceae, and Chenopodiaceae were the largest families (53.57% of the total species, collectively). Therophytes is the most abundant life forms. Mediterranean chorotype (58.32%) was the most represented. On the basis of the presence values, cluster analysis yielded four vegetation groups. Group A was dominated by *Carthamus tenuis,* group B by *Lactuca serriola*, group C by *Bromus diandrus* and

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group D by *Suaeda pruinosa*. The application of CCA showed that the percentages of porosity, organic carbon, $CaCO_3$, Cl^-, SO_4^{--}, HCO_3 and cations are the most effective soil variables. Generally, the coastal sector in Egypt suffers from unplanned development and salinization of the soil, so the development of the highway needs a balance between conservation and development.

1. INTRODUCTION

Urbanization and related anthropogenic activities frequently disturb and alter plant composition and directly lead to the degradation of local biodiversity as well as alternation of ecosystem processes [1,2]. Coastal areas in Egypt suffer from a number of serious problems, including unplanned development, land degradation, excessive erosion rates, water cuts, the intrusion of saline water, salinization of soil and degradation of ecosystems [3]. Therefore, the development of highway infrastructure represents a particularly difficult balance between conservation and development.

Vegetation of the Mediterranean coastal region of Egypt is considered to be one of its major natural resources. Most of these species are therophytes that flourish during the rainy season, giving the coastal belt a temporary showy grassland desert [4]. Western desert of Egypt occurs on the west side of the river Nile. It extends from the Mediterranean coast in the north to the Egyptian-Sudanian border in the south (about 1073 km), and from the Nile valley in the east to the Egyptian-Libyan border in the west, a width between 600 and 750 km. it covers about 689.000 km^2 that represent approximately two-third of Egypt's area [5].

The international coastal highway, connecting the most eastern and western towns in Egypt, was constructed a parallel to the northern coast [6,7]. Human impact is the main factor affecting the abundance and distribution of natural vegetation in the desert [8]. Moreover, roadside vegetation is exposed to a variety of biotic and abiotic stresses that can affect the composition of vegetation. Drought, pollution, disease, insects, lack of nutrients, and roadbed management practices may potentially act alone or synergistically to adversely affect plants in proximity to the roadside [9,10].

Therophytes (67%) cover forms the permanent framework of the desert vegetation during rainy seasons, followed by geophytes (11%), halophytes and helophytes, and are the best indicator of the habitat conditions [11,5]. Flora and vegetation of the roadside habitat in Egypt attract the attention of many researchers [8,12-14]. Moreover, the vegetation of the international coastal highway from El Arish to Rafah in Sinai coast was studied by Abd El-Ghani and El-Sawaf [15] and from Port Said to Abu-Qir of Delta coast was studied by El-Amier and Abd El-Gawad [16]. However, the vegetation composition of the roadside habitat of the major part of the international coastal highway, northern Egypt, still not studied well. Therefore, the present study aimed to characterize the ecological features of the international coastal road-West Alexandria, Egypt.

2. MATERIALS AND METHODS

2.1 Study Area

The Mediterranean coastal desert of Egypt (the northern coast) extends from Sallum eastward to Rafah for about 970 km [5]. The area selected study lies between El-Ajami (31°0'31.91"N 29°37'29.54"E) and Ras El-Hekma (31°5'31.39"N 27°47'31.39"E). The sampled stands are distributed in two governorates of Egypt, namely: Alexandria and Marsa Matruh (Fig. 1).

Soils of the western Mediterranean coastal land of Egypt are young and essentially alluvial. They are derived from two main sources. First is Maruit tableland (inland plateau), composed essentially of limestone alternating with strata of limestone and shale, and the second source is beach deposits composed of calcareous oolitic grains [17].

Climatically, the study area generally falls under the arid Mediterranean type [5]. The Mediterranean coastal region of Egypt belongs to the warm coastal desert climate. The warmest month in summer has a mean temperature above 30°C. Occasional short rainstorms occur in winter, but most of the days
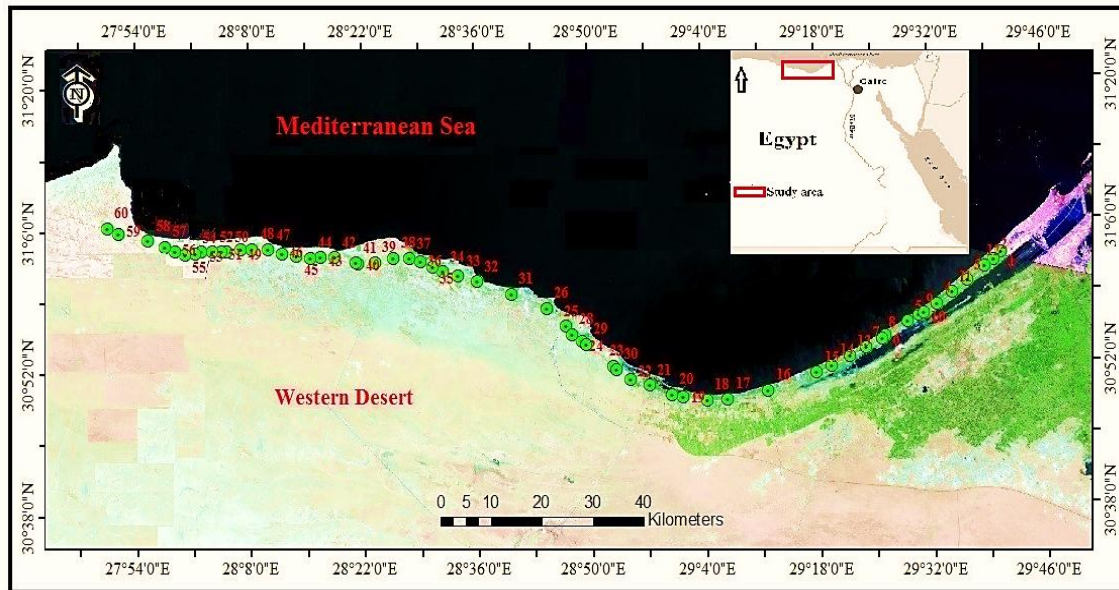
Fig. 1. The study area showing sampled stands

are sunny and mild [18]. The floristic elements of the western Mediterranean coastal belt enjoy better climatic conditions than those of the other parts of Egypt.

2.2 Vegetation Analysis

A quantitative survey of the roadside vegetation was conducted during the wet season from February to April 2016. Sixty stands (area = 10×10m each, It is about 2 meters from the road margin) were randomly chosen on the roadside of the international coastal highway for sampling vegetation (Fig. 1). Density and cover of each species have been estimated in each stand according to Shukla and Chandel [19] and Canfield [20]. Relative values of density and cover were calculated for each plant species and summed up as the importance value (IV). Nomenclature and floristic categories of plant species within the study area were given according to Tackholm [21], Boulos [22] and Zohary [23]. Plant life forms were identified according to the scheme of Raunkiaer [24].

2.3 Soil Analysis

Sixty samples of surface soil were collected as a mixture from 0 to 25 cm in depth. It has been air-dried and sieved to obtain representative sub-samples (fine soil) for physical and chemical analysis. Soil texture, water holding capacity (WHC), porosity, organic carbon and sulfate content were determined according to Piper [25], while calcium carbonate content was determined by titration against 1 N NaOH and expressed as a percentage [26]. Electric conductivity and pH were determined in soil-water (1:5) in the manner adopted by Jackson [26]. Carbonates and bicarbonates were determined by titration using 0.1 N HCl [27]. Sodium and potassium were determined by flame photometry, while calcium and magnesium were estimated using atomic absorption spectrometer [28].

2.4 Data Analysis

Cluster analysis (TWINSPAN) of 60 stands and 84 species was performed using the Community Analysis Package program, version 1.2 and Detrended Correspondence Analysis (DCA) into groups according to Hill and Smilauer [29]. Canonical Correspondence Analysis (CCA) was used to identify the ecological relationships between the vegetation and the environment along the roadside [30]. Linear correlations coefficient (r) was calculated for assessing the relationship between the estimated soil variables. The soil variables for each community were subjected to one-way ANOVA and the mean values were separated based on Duncan's test at 0.05 probability level, using COSTAT 6.3 program.

3. RESULTS

3.1 Floristic Analysis

The total number of the recorded plant species in the present study is 84 species (44 annuals, two biennial, and 38 perennials) belonging to 74 genera and 25 families (Table 1). The largest families were Asteraceae (18 species), Poaceae (12 species), Fabaceae (8 species) and Chenopodiaceae (7 species). These four families are represented collectively by 45 species (53.57% of the total species). While the other 9 families shared 32.15% of the species and 12 families were monospecific.

According to Raunkiaer [24], the life-forms of the flora in the present study are grouped under six types as follows: therophytes, geophytes, helophytes, hemicryptophytes, chamaephytes, and nanophanerophytes. The majority of the recorded species are therophytes (54.65%) followed by chamaephytes (16.28%) then hemicryptophytes (12.79%) and geophytes, nanophanerophytes (5.81%, each). The lowest value of life-forms is recorded as helophytes which attained a value of 4.65%.

The chorological analysis of the floristic data reveals that 49 species (58.32 %) of the total number of recorded species are Mediterranean taxa (Table 2). These taxa are either Pluriregional (18 species =21.42%), Biregional (17 species =20.23%) or Monoregional (14 species = 16.67 %). The other floristic categories are constituted 18 species (14.52%) of the recorded species consisting of Saharo-Sindian (14.29), Saharo-Sindian + Irano-Turanian (5.95), Cosmopolitan (10.71%), Palaeotropical (2.38%) and Neotropical (1.19%).

3.2 Vegetation Analysis

The application of TWINSPAN classification on the importance values (out of 200) of 84 plant species recorded in 60 stands representing the study area, led to the recognition of four vegetation groups (Table 1 and Fig. 2).

Group A: It comprises 8 stands dominated by *Carthamus tenuis* with the highest mean importance value (IV = 15.26), the abundant species include *Urtica urens* (IV = 14.31), *Urospermum picroides* (IV = 12.06) and *Cynodon dactylon* (IV = 11.25). The indicator species in this group which attains low IV were *Brassica*

tournefortii (IV= 4.53) and *Chenopodium murale* which attained low IV is 0.36 (Table 1). The soil in these stands showed that it has the highest values for many measured soil variables (sand, pH, SO_4^- and cations) (Table 3).

Vegetation group B consists of twelve stands of the studied area dominated by *Lactuca serriola* (IV =22.75). The abundant species include *Onobrychis crista-galli* (IV = 21.41), *Paranochia argentea* (IV = 20.91), *Medicago polymorpha* (IV = 17.34) and *Astragalus spinosia* (IV = 17.31). The indicator species in this group are *Bromus diandrus* (IV = 13.41) and *Centaurea aegyptiaca* which attains low IV is 0.66 (Table 1). The soil of this group was characterized by high content of $CaCO_3$, cations and high percentage of silt and porosity (Table 3).

Group C is dominated by *Bromus diandrus* (IV = 20.44) inhibiting 17 stands. The abundant species include *Mesembryanthemum nodiflorum* (IV = 13.89), *Melilotus indicus* (IV = 10.39), *Atractylis carduus* (IV = 10.20) and *Atriplex halimus* (IV = 9.64). The indicator species in this group was *Avena fatua* (IV=6.17) (Table 1). Most of the examined soil variables in this group (pH, EC, anions, and cations) attained their highest levels in the stands of this group (Table 3).

Floristic group D consists of 23 stands dominated by *Suaeda pruinosa* (IV = 10.70). The abundant species in this group include *Cynodon dactylon* (IV = 8.79), *Phragmites australis* (IV = 8.14) and *Fagonia arabica* (IV = 8.01). In this group, the indicator species is *Tamarix nilotica* (IV = 5.15) (Table 1). Soils of the stands of this group were rich in their silt, clay, WHC, OC, Cl⁻ and HCO_3^- (Table 3).

3.3 Ordination of Stands

The application of DCA on 60 stands along axes 1 and 2 indicated that the vegetation groups yielded by TWINSPAN classification are distinguishable and having a clear pattern of segregation on the ordination plane except for groups C and D interconnected (Fig. 3). Stands of group A is separated at the upper part of the middle of the DCA diagram. Group B is clear segregated (the right side) along the two axes of DCA. While Group C is separated from the middle part of the DCA diagram. On the other hand, group D is segregated at the lower part of the middle of the DCA diagram.

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Table 1. Floristic composition and mean of the importance values (out of 200) of the recorded species in the different vegetation group resulted from TWINSPAN classification of the study area. Per = Perennial; Ann = Annuals; Bi = Biennial; Th = Therophytes; Ch = Chamaephytes; H = Hemicryptophytes; He = Helophytes; G = Geophytes; Nph = Nanophanerophytes; COSM = Cosmopolitan; PAL= Palaeotropical; PAN= Pantropical; NEO= Neotropical; ME = Mediterranean; SA-SI = Saharo-Sindian; IR-TR = Irano-Turanian; ER-SR = Euro-Siberian; S-Z = Sudano-Zambezian; AUST = Australion; NAT = Naturalized

No.	Species	Family	Duration	Life form	Chorotype	Vegetation groups			
						A	B	C	D
	No. of stands					8	12	17	23
	No. of species					47	39	52	71
1	*Achillia santolina* L.	Asteraceae	Per	Ch	ME	-	1.08	5.88	-
2	*Aegilops bicornis* (Forssk)	Poaceae	Ann	Ch	SA-SI	-	-	2.79	2.48
3	*Ammophila arenaria* (L.) Link	Poaceae	Per	Ch	SA-SI + IR-TR	0.45	-	-	3.27
4	*Anagallis arvensis* L	Primulaceae	Ann	H	ME+ SA-SI	1.09	-	1.75	0.22
5	*Anchusa humilis* (Desf.) I.M. Johnst	Boraginaceae	Ann	Nph	ME+SA-SI	-	-	0.31	0.78
6	*Artemisia judiaca* L.	Chenopodiaceae	Per	H	AUST	6.24	-	0.15	4.65
7	*Astragalus bombycinus* Boiss.	Fabaceae	Ann	He	SA-SI+S-Z	-	-	3.73	0
8	*Astragalus peregrinus* Vahl	Fabaceae	Ann	H	COSM	-	-	3.47	0.22
9	*Astragalus spinosia* (Forssk) Muschl.	Fabaceae	Per	H	ME+IR-TR	2.06	17.31	-	0.93
10	*Atractylis carduus* (Forssk.) C.Chr.	Asteraceae	Per	G	COSM	-	-	10.2	0.08
11	*Atriplex lindleyi* Moq.	Chenopodiaceae	Per	H	ME+SA-SI	0.68	-	1.41	0.69
12	*Atriplex halimus* L.	Chenopodiaceae	Per	H	ME	0.85	1.33	9.64	7.25
13	*Atriplex semibaccata* R.Br.	Chenopodiaceae	Per	H	ME	2.06	-	1.34	1.37
14	*Avena fatua* L.	Poaceae	Ann	Ch	ME	10.94	-	6.17	4.96
15	*Bassia indica* (Wight) A. J. Scott.	Chenopodiaceae	Ann	Ch	SA-SI	0.62	-	0.43	6.02
16	*Brassica tournefortii* Gouan	Brassicaceae	Ann	Ch	ME	4.53	-	3.22	0.65
17	*Bromus diandrus* Roth	Poaceae	Ann	Ch	ME+IR-TR+SA-SR	1.87	13.41	20.44	3.87
18	*Cakile maritima* Scop.	Brassicaceae	Ann	H	PAL	1.28	-	2.96	4.4
19	*Carduus getulus* Pomel	Asteraceae	Ann	He	ME+IR-TR+ER-SR	-	0.5	-	-
20	*Carduus pycnocephalus* L.	Asteraceae	Ann	H	SA-SI	0.36	0.24	-	1.59
21	*Carthamus tenuis* (Boiss. & Blanche) Bornm.	Asteraceae	Ann	G, He	SA-SI	15.26	-	-	2.28
22	*Cenchrus cillaris* L.	Poaceae	Per	Th	ME+ER-SR+ IR-TR	8.25	-	-	0.5
23	*Centaurea aegyptiaca* L.	Asteraceae	Bi	Th	ME	-	0.66	3.22	3.63
24	*Chenopodium murale* L.	Chenopodiaceae	Ann	Nph	SA-SI+S-Z	-	1.44	2.31	6.76
25	*Convolvulus arvensis* L.	Convolvulaceae	Per	Ch	ME+ SA-SI+S-Z	4.18	-	-	1.38
26	*Cynanchum acutum* L.	Asclepiadaceae	Per	Ch	NAT	2.07	2.21	1.29	1.03
27	*Cynodon dactylon* (L.) Pers.	Poaceae	Per	G	ME	11.25	5.42	1.56	8.79

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	No. of species					47	39	52	71
28	*Echinops spinosus* L.	Asteraceae	Per	Ch	ME+SA-SI+S-Z	-	-	-	2.11
29	*Echium angustifolium* Mill.	Boraginaceae	Per	G, He	COSM	-	-	0	1.34
30	*Emex spinosa* (L.) Campd.	Polygonaceae	Per	Nph	SA-SI+S-Z	5.02	4.16	6.52	6.21
31	*Enarthrocarpus lyrotus* (Boiss)	Boraginaceae	Ann	G	ME+IR-TR	1.33	7.74	0.45	0
32	*Erodium laciniatum* (Cav.) Willd.	Geraniaceae	Ann	Nph	SA-SI	-	-	1.59	0.23
33	*Euphorbia terracina* L.	Euphorbiaceae	Ann	H	ME+IR-TR+ER-SR	-	3.5	-	0.18
34	*Euphorbia helioscopia* L.	Euphorbiaceae	Ann	Ch	ME	3.7	3.3	-	0.57
35	*Euphorbia paralias* L.	Euphorbiaceae	Ann	Ch	NEO	2.47	1.95	3.44	3.7
36	*Euphorbia peplus* L.	Euphorbiaceae	Ann	Nph	SA-SI	9.95	-	7.31	0.34
37	*Fagonia arabica* L	Zygophyllaceae	Per	Ch	ME	-	0.28	2.3	8.01
38	*Fagonia cretica* L	Zygophyllaceae	Per	Th	SA-SI	1.5	0.34	4.21	4.68
39	*Filago desertorum* Pomel	Asteraceae	Per	Th	ME+ER-SR+ IR-TR	1.51	14.2	0.6	-
40	*Halocnemum strobilaceum* (Palla.) M. Bieb.	Chenopodiaceae	Per	Th	ME+SA-SI	-	-	5.74	0.3
41	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Per	Th	COSM	6.34	0.85	-	3.67
42	*Juncus acutus* L.	Juncaceae	Per	Th	ME+SA-SI	-	-	-	1.47
43	*Lactuca serriola* L.	Asteraceae	Ann	H	SA-SI+IR-TR	-	22.75	1.09	3.44
44	*Launaea nudicaulis* (L.)Hook.f.	Asteraceae	Per	Th	SA-SI	3.25	-	-	3.06
45	*Lavatera cretica* L.	Malvaceae	Ann	Th	ME+IR-TR+ER-SR	0.79	12.9	-	2.9
46	*Legousia speculum-veneris* (L.) Chaix	Campanulaceae	Per	Th	PAL	-	-	-	1.38
47	*Limonium pruinosum* (L.) Chaz.	Plumbaginaceae	Per	Th	S-Z+IR-TR	-	-	3.77	-
48	*Lobularia arabica* (Boiss) Muschl	Brassicaceae	Ann	Th	ME+IR-TR+SA-SI	1.11	0.58	5.52	1.02
49	*Lolium perenne* L.	Poaceae	Per	Th	ME	8.06	-	3.82	4.4
50	*Lotus polyphyllos* E. D. Clarke	Fabaceae	Per	Th	ME+ER-SR	1.36	11.05	2.94	0.7
51	*Lycium shawii* Roem	Solanaceae	Per	Th	SA-SI		2.99	1.66	3.58
52	*Malva parviflora* L.	Malvaceae	Ann	Th	SA-SI	6.29	1.53	4.48	2.13
53	*Medicago polymorpha* L.	Fabaceae	Ann	Th	ME	1.44	17.34	-	-
54	*Melilotus indicus* (L.) All.	Fabaceae	Ann	Th	COSM	7.57	3.68	10.39	3.67
55	*Mesembryanthemum crystallinum* L.	Aizoaceae	Ann	Th	ME+SA-SI	-	-	4.2	5.19
56	*Mesembryanthemum nodiflorum* L.	Aizoaceae	Ann	Th	SA-SI	-	-	13.89	1.45
57	*Moltkiopsis ciliata* (Forssk.) I. M. Jonst.	Boraginaceae	Per	Th	ME	-	1.83	-	2.29
58	*Nicotiana glauca* R. C. Graham	Solanaceae	Per	Th	ME+IR-TR+SA-SI	-	-	-	2.41
59	*Onobrychis crista-galli.*	Fabaceae	Ann	Th	ME+IR-TR+ER-SR	1.91	21.41	-	-
60	*Pancratium maritimum* L.	Amaryllidaceae	Per	Th	SA-SI+IR-TR	-	-	-	0.7

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	No. of stands					8	12	17	23
	No. of species					47	39	52	71
61	*Paranochia argentea* L.	Gaeyophyllaceae	Per	Th	ME+IR-TR+ER-SR	1.37	20.91	2.56	-
62	*Parapholis incurra* (L) C.E. Hubb.	Poaceae	Ann	Th	ME	-	-	0.13	-
63	*Phragmites australis* (Cav.) Trin.ex Steud.	Poaceae	Per	Th	ME+ IR-TR	-	-	3.55	8.14
64	*Plantago lagopus* L.	Plantaginaceae	Ann	Th	ME	-	-	2.81	3.21
65	*Pluches dioscoridis* (L)	Asteraceae	Per	Th	ME+IR-TR	-	1.64	-	1.11
66	*Poa annua* L.	Poaceae	Ann	Th	M+IR-TR+SA-SI	-	-	0.76	-
67	*Polygonum equsetiforme* Sm.	Polygonaceae	Per	Th	ME+IR-TR+SA-SI	-	1.66	-	4.79
68	*Polypogon monospenlensis* (L.) Desf.	Poaceae	Ann	Th	ME+ER-SR	0.63	-	-	0.62
69	*Reichardia tingitana* (L.) Roth	Asteraceae	Ann	Th	ME+SA-SI+ER-SR	9.93	1.36	5.12	5.02
70	*Reseda decursiva* Forssk.	Resedaceae	Ann	Th	IR-TR+SA-SI	-	-	-	3.2
71	*Retama raetam* (Forssk.) Webb & Berthel.	Fabaceae	Per	Th	ME+IR-TR+ER-SR	-	-	-	2.18
72	*Senecio glaucus* L.	Asteraceae	Ann	Th	ME+IR-TR	9.96	4.16	5.08	6.13
73	*Silybum marianum* (L.) Gaertn.	Asteraceae	Per	Th	COSM	-	0.14	4	-
74	*Sisymbrium irio* L.	Brassicaceae	Per	Th	COSM	7.39	0.85	5.8	4.54
75	*Solainum nigrum* L.	Solanaceae	Ann	Ch	SA-SI+IR-TR	-	-	0.95	0.99
76	*Sonchus oleraceus* L.	Asteraceae	Ann	Th	ME+IR-TR	0.53	-	-	0.23
77	*Spergularia marina* (L.) Griseb.	Caryophyllaceae	Bi	Th	SA-SI	2.45	-	4.06	2.06
78	*Stellarra pallida* (Dumort.)Murb.	Caryophyllaceae	Ann	Th	ME+IR-TR+SA-SI	3.17	12.28	-	-
79	*Suaeda pruinosa* Lange	Chenopodiaceae	Per	Th	ME + SA-SI+ IR-TR+ER-SR	-	3.58	1.56	10.7
80	*Symphyotichum squamatum* (Spreng)	Asteraceae	Per	Th	COSM	6.66	-	-	0.88
81	*Tamarix nilotica* (Ehrenb.)Bunge	Tamaricaceae	Per	Th	COSM	-	-	0.4	5.15
82	*Urospermum picroides* (L.) F.W. Schmidt	Asteraceae	Ann	Th	ME+ER-SR	12.06	1.57	-	2.39
83	*Urtica urens* L.	Urticaceae	Ann	Th	ME+IR-TR	14.31	-	-	0.41
84	*Zygophyllum aegyptium* Hosny	Zygophyllaceae	Per	Th	ME+IR-TR+ER-SR	0.94	-	-	3.9

Table 2. Number of species and percentage of various floristic categories of the study area

No.	Floristic category	No.	%	Type
1	COSM	9	10.71	World wide
2	NEO	1	1.19	
3	PAL	**2**	**2.38**	
4	ME+IR-TR+SA-SI+ER-SR	**1**	1.19	Pluriregional
5	ME+IR-TR+ER-SR	9	10.71	
6	ME+IR-TR+SA-SI	5	5.95	
7	ME+SA-SI+ER-SR	1	1.19	
8	ME+S-Z+SA-SI	**2**	**2.38**	
9	ME+IR-TR	7	8.33	Biregional
10	ME+ER-SR	**3**	**3.57**	
11	ME+SA-SI	7	8.33	
12	IR-TR+SA-SI	5	5.95	
13	S-Z+IR-TR	1	1.19	
14	S-Z+SA-SI	3	3.57	
15	ME	14	16.67	Monoregional
16	SA-SI	12	14.29	
17	AUST	1	1.19	
18	NAT	1	1.19	
Total		84	100	

Abbreviation: COSM = Cosmopolitan; PAL= Palaeotropical; PAN= Pantropical; NEO= Neotropical; ME = Mediterranean; SA-SI = Saharo-Sindian; IR-TR = Irano-Turanian; ER-SR = Euro-Siberian; S-Z = Sudano-Zambezian; AUST = Australion; NAT = Naturalized

Table 3. Soil variables (mean ± standard error) in the stands representing the different vegetation groups obtained by TWINSPAN classification in the study area. WHC: Water holding capacity, OC: Organic carbon, EC: Electrical conductivity

Soil variable	Vegetation groups				LSD$_{0.05}$
	A	**B**	**C**	**D**	
Sand %	76.92±1.90	75.88±2.50	75.90±1.24	73.07±1.55	**10.72**
Silt %	14.55±0.97	15.38±1.36	14.58±0.65	16.62±0.86	**4.94**
Clay %	8.54±1.03	8.76±1.22	9.52±0.68	10.31±0.73	**2.75**
Porosity %	27.08±1.48	29.88±1.00	25.95±0.87	25.78±0.74	**6.76**
WHC %	28.64±1.84	30.50±1.98	29.21±1.06	30.94±1.33	**4.89**
CaCO$_3$ %	3.18±0.23	3.20±0.25	2.82±0.17	2.61±0.16	**0.72****
OC %	0.95±0.15	1.03±0.15	1.01±0.09	1.07±0.09	**0.41***
pH %	8.04±0.08	7.95±0.07	8.04±0.05	8.03±0.04	**0.92**
EC (mS.cm^{-1})	2.02±0.14	1.86±0.11	2.15±0.10	2.00±0.08	**1.05***
Cl$^-$ %	0.18±0.03	0.11±0.02	0.20±0.03	0.20±0.02	**0.17***
SO$_4^{--}$ %	0.05±0.01	0.04±0.00	0.05±0.01	0.04±0.00	**0.03**
HCO$_3^-$ %	0.05±0.01	0.04±0.01	0.06±0.01	0.06±0.00	**0.02****
Na$^+$ mg/100g dry soil	81.31±12.89	76.32±9.09	90.34±9.11	83.99±5.31	**27.28****
K$^+$ mg/100g dry soil	11.02±1.54	10.73±1.24	11.47±1.18	10.36±0.65	**4.38**
Ca^{++} mg/100g dry soil	22.58±3.28	20.98±2.50	24.49±2.51	22.67±1.40	**4.03****
Mg^{++} mg/100g dry soil	8.76±1.24	8.31±0.99	9.39±1.06	8.46±0.59	**2.88**

The significant difference after Duncan's test (P≤0.05)

3.4 Soil-Vegetation Relationships

The soil analysis of the represented stands of the four separated vegetation groups indicated considerable significant variations in soil variables (Table 3). Soil texture in all groups is formed mainly of coarse fraction (sand) and partly of fine fractions (silt and clay). Calcium carbonate, organic carbon, electrical conductivity, chloride, bicarbonate, sodium, and calcium showed clear significant differences between groups at $P < 0.01$ and $P < 0.05$, respectively. Some other soil variables showed no significant correlation such as soil texture (silt, sand, and clay), water-holding capacity, porosity, pH, sulfates, potassium, and magnesium.

The correlation coefficient (r) between the different soil variables in the sampled stands are shown in Table 4. It has been found that most

soil variables are significant positively correlated with other soil variables. It has been also found that some soil variables such as sand, pH, and $CaCO_3$ have significant negative correlation or no correlation with soil variables was shown.

The correlation between vegetation and soil characteristics is shown on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot of species-environment. As shown in Fig. 4, it is clear that, the percentages of sand, clay, porosity, $CaCO_3$, Cl^-, SO_4^{--}, HCO_3^- and cations (Na^+, K^{++}, Ca^{++} and

Mg^{++}) are the most effective soil variables, which showed a high significant correlations with the first and second axes of CCA ordination diagram. The dominant (*Lactuca serriola*) and abundant species (*Paranochia argentea* and *Astragalus spinosia*) of group B are separated at the upper right side of CCA-biplot diagram. These species in group B showed a close relationship with sand, porosity, and $CaCO_3$. The dominant species (*Carthamus tenuis*) and abundant species (*Urospermum picroides*, *Cynodon dactylon, Fagonia arabica,* and *Avena fatua*) in groups A, C and D are separated at the upper
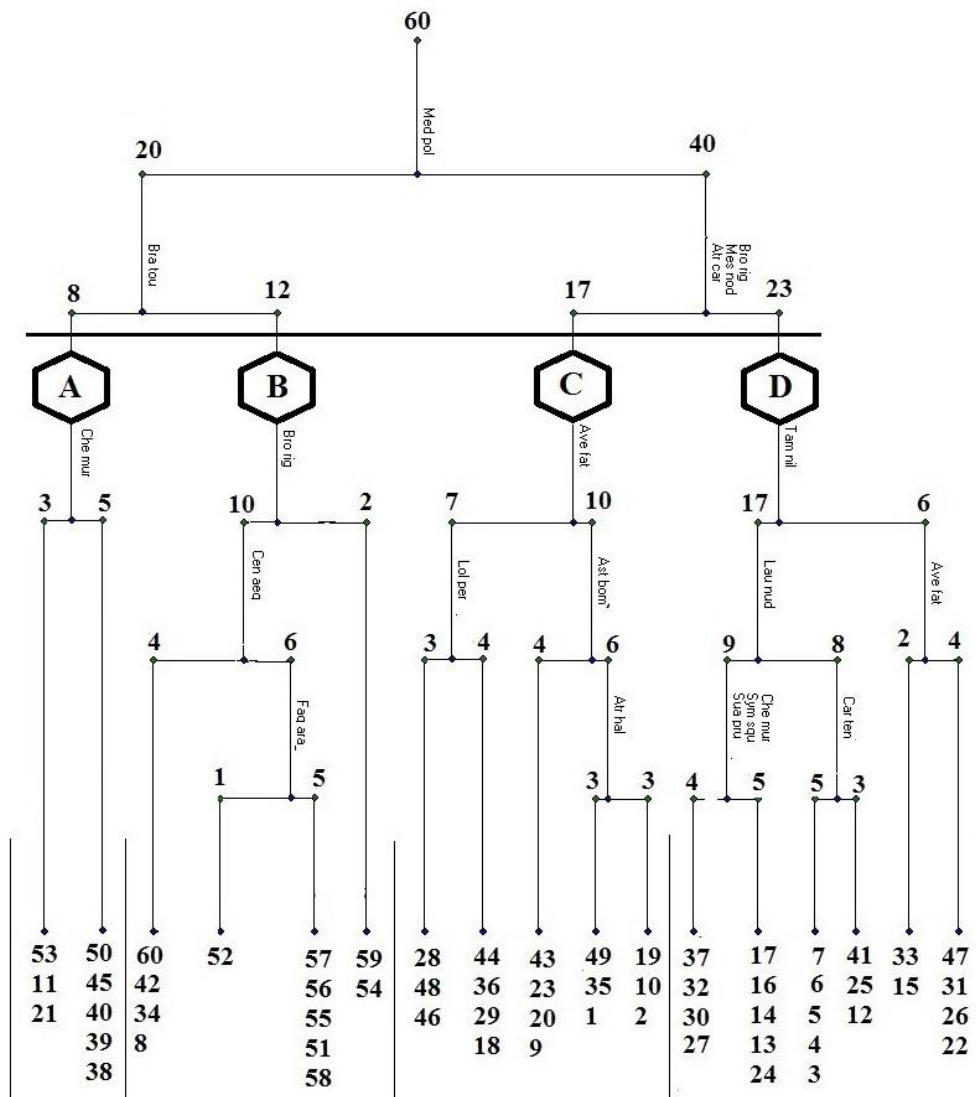

Fig. 2. Two Way Indicator Species Analysis (TWINSPAN) dendrogram of the 60 sampled stands based on the importance values of the 84 species. The indicator species are abbreviated by the first three letters of genus and species respectively
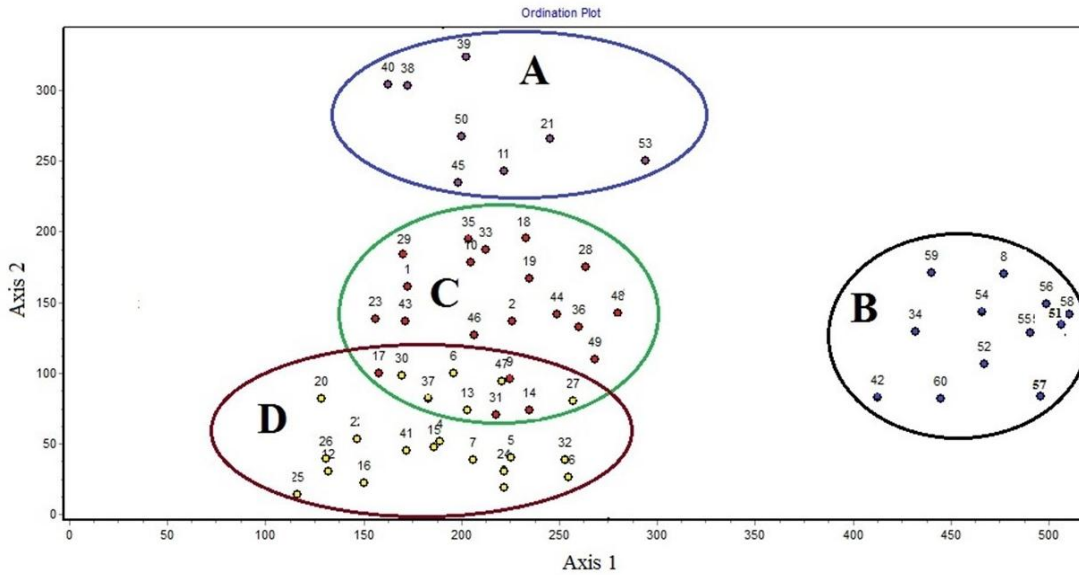
Fig. 3. Detrended Correspondence Analysis (DCA) ordination diagram of 60 stands of the study area
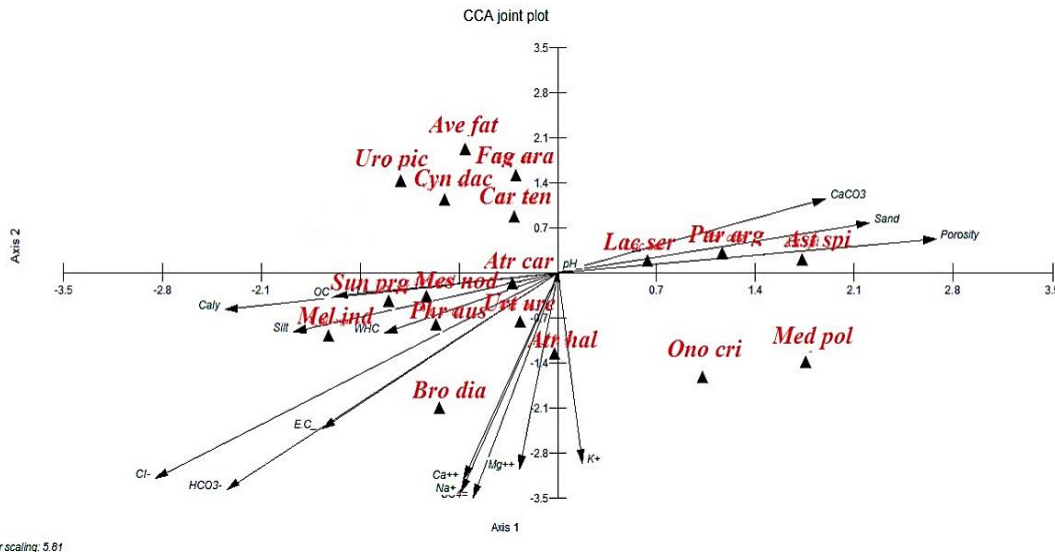

Fig. 4. Canonical Correspondence Analysis (CCA) ordination diagram of the first two axes showing the distribution of the plant species with soil variables in the study area

left side of CCA biplot diagram and no correlation is shown with any soil variables. *Onobrychis crista-galli* and *Medicago polymorpha* as the abundant species in group B are segregated at the lower right side of the diagram. These species exhibited a clear relationship with potassium only. On the other hand, dominant species (*Bromus diandrus* and *Suaeda pruinosa*) in groups C and D, respectively, and abundant

species (*Mesembryanthemum nodiflorum*, *Melilotus indicus*, *Atractylis carduus* and *Atriplex halimus*) of group C as well as *Phragmites australis* as the abundant species in group D are segregated at the lower left side of the diagram. These species exhibited a clear relationship with Cl^-, SO_4^{--}, HCO_3^- and cations (Na^+, Ca^{++} and Mg^{++}).

Table 4. Pearson-moment correlation (r) between the soil variables in the stands surveyed in the study area. Por.: Porosity; WHC: Water holding capacity; EC: Electrical conductivity; OC: Organic carbon, *: Values are significant at P < 0.05, **: Values are significant at P < 0.01

Soil variables	Sand	Silt	Clay	Por.	WHC	CaCO$_3$	OC	pH	EC	Cl$^-$	SO$_4^{--}$	HCO$_3^-$	Na$^+$	K$^+$	Ca^{++}
Silt	-0.965 **														
Clay	-0.957 **	0.848 **													
Por.	-0.397 **	0.357 **	0.410 **												
WHC	-0.973 **	0.927 **	0.945 **	0.566 **											
CaCO$_3$	0.725 **	-0.616 **	-0.787 **	-0.332 **	-0.703 **										
OC	-0.921 **	0.814 **	0.964 **	0.601 **	0.955 **	-0.715 **									
pH	0.812 **	-0.703 **	-0.866 **	-0.785 **	-0.903 **	0.630 **	-0.956 **								
EC	-0.071	-0.02	0.165	0.062	0.09	-0.184	0.216	-0.185							
Cl$^-$	-0.314 *	0.24	0.371 **	-0.148	0.239	-0.511 **	0.291 *	-0.157	0.614 **						
SO$_4^{--}$	-0.218	0.153	0.272 *	0.115	0.203	-0.362 **	0.288 *	-0.255 *	0.592 **	0.834 **					
HCO$_3^-$	-0.322 *	0.259 *	0.365 **	-0.257 *	0.228	-0.346 **	0.277 *	-0.129	0.538 **	0.904 **	0.858 **				
Na$^+$	-0.248	0.163	0.322 *	0.151	0.255 *	-0.418 **	0.335 **	-0.309 *	0.631 **	0.865 **	0.957 **	0.849 **			
K$^+$	-0.156	0.086	0.221	0.310 *	0.2	-0.329 *	0.294 *	-0.330 **	0.627 **	0.750 **	0.939 **	0.712 **	0.961 **		
Ca^{++}	-0.224	0.145	0.292 *	0.216	0.237	-0.406 **	0.329 *	-0.319 *	0.638 **	0.835 **	0.971 **	0.805 **	0.986 **	0.980 **	
Mg^{++}	-0.195	0.133	0.247	0.221	0.206	-0.353 **	0.291 *	-0.291 *	0.594 **	0.779 **	0.982 **	0.785 **	0.950 **	0.958 **	0.976 **

4. DISCUSSION

Roads, being a major human promoter of urbanization, allow for plants to be dispersed by transportation and road building materials. Roads are ecological corridors which support the expansion of a taxon's geographical distribution [31].

Floristic analysis of the present study revealed that roadside habitat of the international highway comprises 84 plant species, mainly annuals, where, the rainy season provides a better opportunity for the appearance of a considerable number of annuals [32-34]. In addition to, annual plants characterized by high reproductive capacity, as well as ecological, morphological and genetic plasticity [35,36]. The Western Mediterranean coastal belt is by far the richest part of Egypt in its floristic composition owing to its relatively high rainfall in the winter season [5].

In association with other relevant studies, Asteraceae, Poaceae, Chenopodiaceae, Fabaceae, and Brassicaceae were the major families and also is the most common families in Mediterranean North African flora [37,38,16]. Asteraceae is the largest and most widespread family of the flowering plants in the world [39]. Poaceae recorded the highest number of species because of its ability to grow in various habitats. In addition, Boulos and Fahmy [40] recorded that grasses in Egypt grow in many different ecosystems (salt marshes and arid lands, etc.). The wide distribution of some family in the current study may be interpreted as species with wide ecological amplitude and characterized by phenotypic plasticity and heterogeneity [41,42].

The life-forms of the flora in the present study showed that therophytes are the most represented form, where it may be attributed to their short lifespan, they become abundant only during the rainy season, which enables them to resist the instability of environmental conditions, the Mediterranean climate, topography variation and biotic influence [43,44]. Moreover, the relatively high frequencies of both chamaephytes and hemicryptophytes in the present study may be attributed to distinct defense against the physiological stresses and ability of these species to resist sand accumulation and grazing [45,46,16]. El-Amier and Abd El-Gawad [16] recorded 56.95%, 13.25% and 9.93% of therophytes, hemicryptophytes, and chamaephytes in the vegetation analysis of the international coastal highway along north Nile delta. Abd El-Ghani and El-Sawaf [15] illustrated that chamaephytes were the predominant life form (32%) of the recorded flora of the international coastal highway along El Arish and Rafah, followed by therophytes (31%) and hemicryptophytes (17%). Also, Abd El-Ghani et al. [8] reported that about 31.15%, 28% and 18% of therophytes, hemicryptophytes, and chamaephytes are represented in the vegetation of Qift-Qusier roadside, respectively.

The prevalence of the Mediterranean chorotype of the listed flora in the study area reflects the Mediterranean climate of the studied area. This result agrees with most of the related studies [47-49,16]. Saharo- Sindian and Mediterranean chorotypes accounted for 30.96% of recorded plants. This may be attributed to the fact that plants of the Saharo-Arabian species are good indicators for harsh desert environmental conditions, while Mediterranean species are considered as indicators to mesic environment [50,51]. The whole country lies within the Saharo-Arabian belt of the Holarctic floristic realm [51]. The area is covered by hot deserts, semideserts and savanna, as well as about a quarter of the species, especially in the families Asteraceae, Brassicaceae, and Chenopodiaceae, are endemic. Furthermore, a combination of different floristic elements such as Cosmopoliton, Palaeotropical, Neotropical, Saharo-Sindian, and Irano-Turanuian are represented by a variable number of species in the roadside environment. This can be attributed to the roadside environments that may be exposed to many potential biotic and abiotic pressures on a plant community as well as the ability of certain floristic elements to penetrate the study area from several adjacent phytogeographical regions [5].

The roadside habitat of the international coastal highway dominated with different plant communities. In the present study, we determine four communities, two (communities C and D) were the richest and diverse, while community A and B is the smallest and less diverse. In accordance, the ordination of the plant communities showed that clear pattern of segregation on the ordination plane for A and B groups, while groups C and D interconnected, reflecting more similar vegetation structure and environmental variables. Among the identified communities, community D, dominated with *Suaeda pruinosa* and abundant species (*Mesembryanthemum nodiflorum*, *Atractylis carduus*, and *Atriplex halimus*) of group C were mainly correlated with salinity, cations and

organic matter which could be correlated to the intrusion of saline water and the anthropogenic activities [37,16]. From my point of view the high species diversity of groups C and D in the study area may be related to the high disturbance of their substrates as a result of agriculture practicing, farming processes, and other excessive human disturbances.

Moreover, the vegetation composition of groups A and B in the present study has very much in common with that in Israel [52,53], and in the middle Mediterranean coast of Egypt [38,16]. Low species presence in these vegetation groups may be related to their high soil salinity. Such salinity stress on species diversity in the study area and related areas was reported by Moustafa and Klopatek [54]; Shaltout et al. [55] and Abd El-Ghani and El-Sawaf [15].

5. CONCLUSION

The present study concluded that the vegetation analysis of the study area indicates that, the Mediterranean taxa are represented by relatively highest percentage of plant species, and are used as a source for human food, animal fodder, and agro-industrial raw materials and for the medicinal purposes. Therefore, the conservation of natural habitats of this coastal desert is of vital importance and need judicious utilization for sustainable development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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