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REGULAR ARTICLE

Plant communities along the international coastal highway of Nile delta, Egypt

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Abstract

The construction of highways promotes several changes in the roadside habitat, vegetation, and plant invasion. The present study aimed to describe the plant communities-environment interactions of the international coastal highway from Port-Said to Abu-Qir, northern Nile delta coast of Egypt. A total of 146 species (83 annuals, 4 biennials, and 59 perennials), belonging to 116 genera and 33 families were recorded in 80 stands. The Mediterranean chorotype is the most represented. The cluster analysis of stands yielded four communities. The community I was dominated by *Silybum mariannum*, community II was dominated by *Mesembryanthemum crystalinum*, Community III is the largest one and was co-dominated by *Hordeum murinum* and *Senecio glaucus* and community IV was co-dominated by *Cakile maritima* and *S. glaucus*. Diversity indices showed more richness of communities II and more evenness of community IV. Electric conductivity, porosity, soil texture, Na^+, Cl^- and bicarbonate showed significant variation among communities. The soil of *C. maritima* and *S. glaucus* community was more saline (1.78 ms cm^{-1}). The application of CCA showed that communities II and III were mainly correlated with salinity and organic matter. The present study revealed that roadside habitat of the international coastal highway dominated by different plant communities which correlated with the habitat structure, salinity, and anthropogenic activities. Furthermore, nine invasive species were recorded in this study which could be attributed to the increment of human activities after the construction of the highway.

Key words: Roadside habitat, highway vegetation, invasive plants, salinity

Introduction

The coastal areas of Egypt face several serious problems including high erosion rates, water logging and soil salinization, as well as several anthropogenic activities especially unplanned construction of villages and ecosystem degradation. The Nile Delta coast has a number of big cities with high population such as Alexandria, Rosetta, Damietta, and Port-Said. The international coastal highway, connecting the most eastern and western towns in Egypt, was constructed a parallel to the northern coast (El Raey, 1997; Eid and El-Marsafawy, 2002).

The Egyptian coastlines extend for about 3500 km along both Mediterranean Sea and Red Sea. The Mediterranean coastal land of Egypt 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 (Zahran and Willis 2009).

The number of roads is progressively increased today all over the world as human development grows and people rely on cars for

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transportation on a daily basis (Forman, and Alexander, 1998). The highways and agricultural (small) roads in Egypt make a network connected together with about 41000 km. Most of these roads are found in Nile Delta (18.7%) followed by Nile Valley (15.7%). In addition, the rate of car traffic ranged between 1000-2000 vehicle/day on the regional roads to more than 6000 vehicle/day on international coastal highways (Iraqi et al., 2002).

In natural vegetation of the deserts, the main factor affecting the abundance is the anthropogenic activities (Abd El-Ghani et al., 2013). Road and rail construction are some of these activities creating direct like degradation and/or fragmentation of the existing habitats and indirect impact on vegetation (Spellerberg, 1998; Jackson, 2000).

In roadside areas, the vegetation is mainly influenced by anthropogenic factors, geographical differentiation, and topography (Ullmann et al., 1990). The roadsides are characterized by a high proportion of therophytes and provide the main habitat for invasive species (Stottele, 1995). The impacts of invasive species on roadside vegetation have hardly been quantified as most studies focused on the impact on vegetation in the adjacent landscape (Sargent, 1984). Moreover, soil disturbance and modification of roadside substrates due to road construction result in increased non-native species cover and richness at roadsides (Greenberg et al., 1997).

The flora and the vegetation of the roadside habitat in Egypt attract the attention of many researchers (Morsy et al., 2008; Abdel Rahman and El Hadidy, 1958; Abd El-Ghani et al., 2013; El-Amier and Abdulkader, 2015). Moreover, the vegetation of the international coast highway from ElArish to Rafah on Sinai coast of Egypt was studied by Abd El-Ghani and El-Sawaf (2005). However, the vegetation composition of roadside habitat of the major part of the international coastal highway, northern Egypt, still not studied well. Therefore, the present study aimed to describe the plant communities of the international coastal highway from Port-Said to Abu-Qir, northern Nile delta coast of Egypt, as well as determine the vegetation-environment interactions.

Materials and methods

Study area

The international coastal highway along the middle section of the Egyptian Mediterranean coastal zone is located in north Nile delta, between Abu-Qir (31°19′27.5″N 30°04′00.6″E) and Port Said (31°16′09″N 32°18′19.1″E), and extends for about 230 km (Fig. 1). The area was chosen for its high environmental diversity. It represents the middle part of the international coastal highway that links Egypt with the countries of North Africa in the west, and those of the eastern Mediterranean in the east.

In coastal belt of Nile Delta, desert reclamation and agricultural processes were practiced and salient features in the study area. Irrigated gardens are another conspicuous feature along part of the seashore. In many instances, cultivation of barley, maize, tomato, sesame and watermelons was achieved.

Although, the climate of Nile delta coast is not so different from climates of the western and eastern Mediterranean sections, its vegetation is so different. Moreover, it is not only affected by sea water but also affected the leakage water from the River Nile branches (Damietta and Rosetta branches) as well as the northern lakes (Zahran and Willis, 2009).

Vegetation analysis

A quantitative survey of the roadside vegetation was made during the period from March to May of the year 2015 and 2016. Eighty stands were randomly chosen in the roadside of the international coastal highway where considerable variation in vegetation was encountered. In each of the studied stands, three plots (5 m × 5 m) were distributed in the left and right sides as well as in the central part of the road, if any. Plant density and cover were measured according to Shukla and Chandel (1989) in each plot. Relative values of density and cover were calculated for each plant species and summed up as the importance value (IV). The lists of species recorded are 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).

Fig. 1. Map showing the Nile delta with the study are in the northern part.

Plant species diversity

Species richness and evenness were calculated for each community by determination of Shannon-Wiener diversity index (H), Simpson Diversity Index (D) and Shannon-evenness index (E) using the following equations:

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

$$D = \frac{\sum_i [n_i \times (n_i - 1)]}{[N \times (N - 1)]}$$

$$E = \frac{H}{\ln s}$$

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

Analysis of soil samples

One composite soil sample was collected from each stand (0-20 cm depth) and transferred to the laboratory in a polyethylene bags. The soil samples were dried, sieved and stored until further analysis. For the dry samples, soil texture, water holding capacity (W.H.C.), porosity, amount of organic carbon and sulfate content were determined according to Piper (1947), while calcium carbonate content was determined according to Jackson (1962). Soil solution (1:5) was prepared and electrical conductivity and pH values were recoded immediately using portable meter (Model Corning, NY 14831 USA) (Jackson, 1962). Moreover, chloride content was determined by the method adopted by Jackson (1962). Carbonate and bicarbonate were determined by titration using 0.1N HCl (Pierce et al., 1958). However, Na^+ and K^+ concentration was estimated by Flame Photometer (Model PHF 80 Biologie Spectrophotometer), while Ca^{2+} and Mg^{2+} were determined using atomic absorption spectrometer (A Perkin-Elmer, Model 2380.USA) (Allen et al., 1974).

Data analysis

The cluster analysis of the stands was performed using the Community Analysis Package program, version 1.2 according to Hill and Smilauer (2005). However, the ordination of stands (Principal Component Analysis, PCA) and Canonical Correspondence Analysis (CCA) were performed using MVSP Program version 3.2 (ter Braak, 1988). 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.

Results

Floristic analysis

A total of 146 species (83 annuals, 4 biennials and 59 perennials) belonging to 116 genera and 33 families were recorded. The largest families were Asteraceae (24 species), Poaceae (23 species), Chenopodiaceae (14 species), Fabaceae (13 species) and Brassicaceae (11 species). They constituted about 58.22% of the recorded species, and represented most of the floristic structure in the northern sector of Nile Delta in Egypt. Thirteen families were represented by only one species. *Atriplex* and *Cyperus* were the largest genus represented by four species (Table 1).

Table 1. Floristic composition and presence value (P%) of the recorded species in the studied area.

Species	Family	Life form	Chorotype	P%
Perennials				
**Acacia saligna* (Labill.) Wendl.f.	Fabaceae	Nph	AUST	1.25
Alhagi graecorum Boiss.	Fabaceae	H	ME+IR-TR	16.25
Arthrocnemum macrostachyum (Moric.) K. Koch	Chenopodiaceae	Ch	ME+ SA-SI	26.25
**Arundo donax* L.	Poaceae	G, He	CULT and NAT	1.25
Astragalus spinosus (Forssk.) Muschl.	Fabaceae	Ch	SA-SI + IR-TR	2.50
Atractylis carduus (Forssk.) C. Chr.	Asteraceae	H	ME+ SA-SI	2.50
Atriplex halimus L.	Chenopodiaceae	Nph	ME+SA-SI	1.25
**Atriplex semibaccata* R. Br.	Chenopodiaceae	H	AUST	8.75
Calligonum polygonoides L.	Polygonaceae	Nph	SA-SI+ IR-TR	28.75
Cistanche phelypaea (L.) Cout.	Orobanchaceae	P, G	ME+SA-SI	7.50
Convolvulus arvensis L.	Convolvulaceae	H	COSM	6.25
Convolvulus lanatus Vahl	Convolvulaceae	Ch	SA-SI	2.50
Cressa cretica L.	Convolvulaceae	H	ME+IR-TR	2.50
Cynanchum acutum L.	Asclepiadaceae	H	ME+IR-TR	25.00
Cynodon dactylon (L.) Pers.	Poaceae	G	COSM	26.25
Cyperus capitatus Vand.	Cyperaceae	G	ME	1.25
Cyperus conglomeratus Rottb.	Cyperaceae	G	SA-SI+S-Z	1.25
Cyperus laevigatus L.	Cyperaceae	G, He	PAN	1.25
**Cyperus rotundus* L.	Cyperaceae	G	PAN	1.25
Echinops spinosus L.	Asteraceae	H	ME+SA-SI	18.75
Echium angustifolium Mill.	Boraginaceae	H	ME	6.25
Elymus farctus (Viv.) Runemark. ex Melderis	Poaceae	G	ME	3.75
Euphorbia terracina L.	Euphorbiaceae	H	ME	2.50
Fagonia cretica L.	Zygophyllaceae	H	ME+ SA-SI	1.25
Halocnemum strobilaceum (Pall.) M. Bieb.	Chenopodiaceae	Ch	ME+IR-TR+SA-SI	8.75
**Heliotropium curassavicum* L.	Boraginaceae	Ch	NEO	8.75
**Imperata cylindrica* (L.) Raeusch	Poaceae	H	ME+PAL	2.50
Juncus acutus L.	Juncaceae	He	ME+IR-TR+ER-SR	15.00
Juncus rigidus Desf.	Juncaceae	G, He	ME+IR-TR+ER-SR	15.00
Launaea fragilis (Asso) Pau	Asteraceae	H	ME+SA-SI	1.25
Launaea nudicaulis (L.) Hook.f.	Asteraceae	H	SA-SI	2.50
Launea mucronata (Forssk.) Muschl.	Asteraceae	H	ME+SA-SI	46.25
Limbarda crithmoides (L.) Dumort.	Asteraceae	Ch	ME+ER-SR+SA-SI	13.75
Lobularia maritima (L.) Desv.	Brassicaceae	H	ME	2.50
Lotus creticus L.	Fabaceae	H	ME	6.25
Medicago sativa L. subsp. *sativa* L.	Fabaceae	H	ME+IR-TR+ER-SR	1.25
Moltkiopsis ciliata (Forssk.) I.M. Johnst.	Boraginaceae	Ch	ME+SA-SI+S-Z	6.25
**Nicotiana glauca* Graham	Solanaceae	Ch	NAT	3.75
Pancratium maritimum L.	Amaryllidaceae	G	ME	1.25
Panicum repens L.	Poaceae	G	PAN	2.50
Pennisetum setaceum (Forssk.) Chiov.	Poaceae	H	ME+PAL	1.25
Phragmites australis (Cuv.) Trin. ex Steud.	Poaceae	G, He	COSM	55.00
Phyla nodiflora (L.) Greene	Verbenaceae	Ch	PAN	1.25
Plantago major L.	Plantaginaceae	H	COSM	1.25
Pluchea dioscoridis (L.) DC.	Asteraceae	NPh	SA-SI+S-Z	13.75
Polygonum equisetiforme Sm.	Polygonaceae	G	ME+IR-TR	26.25

Table 1. Contd..

Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	Nph	SA-SI	1.25
Ricinus communis L.	Euphorbiaceae	NPh	CULT and NAT	1.25
Silene succulenta Forssk.	Caryophyllaceae	H	ME	8.75
Sonchus bulbosa (L.) N. Kilian & Greuter	Asteraceae	G	ME	1.50
Sporobolus spicatus (Vahl) Kunth	Poaceae	G	ME+SA-SI+S-Z	6.25
Stipagrostis scoparia (Trin. & Rupr.) de Winter	Poaceae	G	SA-SI	3.75
Suaeda pruinosa Lang	Chenopodiaceae	Ch	ME	10.00
**Symphyotrichum squamatum* (Spreng.) Nesom	Asteraceae	Ch	NEO	7.50
Tamarix nilotica (Ehrenb.) Bunge	Tamaricaceae	Nph	SA-SI+S-Z	27.50
Thymelaea hirsuta (L.) Endl.	Thymelaeaceae	NPh	ME	2.50
Zygophyllum aegyptium Hosny	Zygophyllaceae	Ch	ME	54.75
Zygophyllum album L.	Zygophyllaceae	Ch	ME+SA-SI	11.50
Zygophyllum coccineum L.	Zygophyllaceae	Ch	SA-SI+S-Z	6.25
Biennials				
Beta vulgaris L.	Chenopodiaceae	Th	ME+IR-TR+ER-SR	17.50
Centaurea aegyptiaca L.	Asteraceae	Th	SA-SI	3.75
Rorippa palustris (L.) Besser	Brassicaceae	Th	ME+IR-TR+ER-SR	1.25
Spergularia marina (L.) Griseb.	Caryophyllaceae	Th	ME+IR-TR+ ER-SR	20.00
Annuals				
Aegilops bicornis (Forssk.) Jaub & Spach	Poaceae	Th	ME+ SA-SI	25.00
Amaranthus lividus L.	Amaranthaceae	Th	ME+IR-TR	5.00
Anagallis arvensis var. *arvensis* L.	Primulaceae	Th	COSM	6.25
Anagallis arvensis var. *caerulea* (L.) Gouan	Primulaceae	Th	COSM	1.25
Anchusa hispida Forssk.	Boraginaceae	Th	SA-SI+IR-TR	3.75
Anchusa humilis (Desf.) I.M. Johnst.	Boraginaceae	Th	ME+ SA-SI	17.50
Atriplex portulacoides L.	Chenopodiaceae	Ch	ME+IR-TR+ER-SR	15.00
Atriplex prostrata DC.	Chenopodiaceae	Th	ME+IR-TR+ER-SR	2.50
Avena fatua L.	Poaceae	Th	PAL	27.50
**Bassia indica* (Wight) Scott.	Chenopodiaceae	Th	S-Z+IR-TR	51.25
Brassica nigra (L.) Koch	Brassicaceae	Th	COSM	6.25
Brassica tournefortii Gouan	Brassicaceae	Th	ME+IR-TR+SA-SI	27.50
Bromus diandrus Roth	Poaceae	Th	ME	40.00
Cakile maritima Scop. subsp. *aegyptiaca* (Willd.) Nyman	Brassicaceae	Th	ME+ER-SR	66.25
Carduus pycnocephalus L.	Asteraceae	Th	SA-SI	17.50
Carthamus tenuis (Boiss & Blanche) Bornm.	Asteraceae	Th	ME	30.00
Chenopodium album L.	Chenopodiaceae	Th	COSM	13.75
Chenopodium ambrosioides L.	Chenopodiaceae	Th	COSM	1.25
Chenopodium murale L.	Chenopodiaceae	Th	COSM	56.25
Conyza bonariensis (L.) Cronquist	Asteraceae	Th	NEO	6.25
Coronopus didymus (L.) Sm.	Brassicaceae	Th	COSM	2.50
Cutandia memphitica (Spreng.) Benth.	Poaceae	Th	ME+IR-TR+SA-SI	23.75
Dactyloctenium aegyptium (L.) Willd.	Poaceae	Th	PAL	1.25
Daucus litoralis Sm.	Apiaceae	Th	ME	5.00
Echinochloa crusgalli (L.) P. Beauv.	Poaceae	Th	PAN	1.25
Emex spinosa (L.) Campd.	Polygonaceae	Th	ME+SA-SI	23.75
Erodium laciniatum (Cav.) Willd.	Geraniaceae	Th	ME	31.25
Eruca sativa L.	Brassicaceae	Th	CULT and NAT	7.50
Frankenia pulverulenta L.	Frankeniaceae	Th	ME+ER-SR+IR-TR	3.75
Fumaria bractcosa Pomel	Fumariaceae	Th	ME+ER-SR+IR-TR	1.25
Herniaria hemistemon J.Gay	Caryophyllaceae	Th	ME+ SA-SI	1.25
Hordeum murinum L.	Poaceae	Th	ME+IR-TR+ER-SR	62.50
Ifloga spicata (Forssk.) Sch. Bip.	Asteraceae	Th	SA-SI	20.00
Juncus bufonius L.	Juncaceae	Th	ME+IR-TR+ER-SR	1.25
Lactuca serriola L.	Asteraceae	Th	ME+IR-TR+ER-SR	3.75
Lavatera cretica L.	Malvaceae	Th	ME	5.00
Lepidium sativum L.	Brassicaceae	Th	ME	3.75

Table 1. Contd..

Lobularia arabica (Boiss.) Muschl.	Brassicaceae	Th	ME	3.75
Lolium perenne L.	Poaceae	Th	ME+IR-TR+ER-SR	60.00
Lotus halophilus Boiss.	Fabaceae	Th	ME+SA-SI	23.75
Lotus polyphyllos E.D.Clarke	Fabaceae	Th	ME	1.25
Malva parviflora L.	Malvaceae	Th	ME+IR-TR	53.75
Medicago intertexta (L.) Mill.	Fabaceae	Th	ME+ER-SR	7.50
Melilotus indicus (L.) All.	Fabaceae	Th	ME+IR-TR+SA-SI	48.75
Mesembryanthemum crystallinum L.	Aizoaceae	Th	ME+ER-SR	70.00
Mesembryanthemum nodiflorum L.	Aizoaceae	Th	ME+ER-SR+SA-SI	32.50
Neurada procumbense L.	Neuradaceae	Th	SA-SI + S-Z	1.25
Ononis serrata Forssk.	Fabaceae	Th	ME+SA-SI	5.00
Parapholis incurva (L.) C.E. Hubb.	Poaceae	Th	ME+IR-TR+ER-SR	25.00
Parietaria alsinifolia Delile	Urticaceae	Th	SA-SI	1.25
Paronychia arabica (L.) DC.	Caryophyllaceae	Th	ME+SA-SI+S-Z	2.50
Phalaris minor Retz.	Poaceae	Th	ME+IR-TR	30.00
Picris asplenioides L.	Asteraceae	Th	ME+IR-TR	2.50
Plantago lagopus L.	Plantaginaceae	Th	ME + IR-TR	1.25
Plantago squarrosa Murray	Plantaginaceae	Th	ME	10.00
Poa annua L.	Poaceae	Th	COSM	2.50
Polypogon monspeliensis (L.) Desf.	Poaceae	Th	COSM	36.25
Portulaca oleracea L.	Portulacaceae	Th	IR-TR+SA-SI	3.75
Raphanus raphanistrum L.	Brassicaceae	Th	ME+ER-SR	6.25
Reicharadia tingitana (L.) Roth	Asteraceae	Th	ME+IR-TR	35.00
Rumex dentatus L.	Polygonaceae	Th	ME+IR-TR+ER-SR	10.00
Rumex pictus Forssk.	Polygonaceae	Th	ME+SA-SI	50.00
Salsola kali L.	Chenopodiaceae	Th	COSM	25.00
Scorzonera undulata Vahl	Asteraceae	Th	IT-TR + SA-SI	1.25
Senecio aegyptius L.	Asteraceae	Th	ME+IR-TR+ER-SR	3.75
Senecio glaucus L.	Asteraceae	Th	ME+IR-TR+SA-SI	71.25
Setaria verticillata (L.) P. Beauv.	Poaceae	Th	COSM	2.50
Silene aegyptiaca (L.) L. f.	Caryophyllaceae	Th	ME	3.75
Silene vivianii Steud.	Caryophyllaceae	Th	SA-SI	10.00
Silybum marianum (L.) Gaertn.	Asteraceae	Th	ME+IR-TR+ER-SR	7.50
Sisymbrium irio L.	Brassicaceae	Th	ME+IR-TR+ER-SR	8.75
Solanum nigrum L.	Solanaceae	Th	COSM	3.75
Sonchus oleraceus L.	Asteraceae	Th.	COSM	42.50
Sphenopus divaricatus (Gouan) Rchb.	Poaceae	Th	ME+IR-TR+SA-SI	2.50
Stellaria pallida (Dumort.) Murb.	Caryophyllaceae	Th	ME+ER-SR	5.00
Suaeda maritima (L.) Dumort.	Chenopodiaceae	Th	COSM	1.25
Torilis arvensis (Huds.) Link	Apiaceae	Th	ME+IR-TR+ER-SR	3.75
Trifolium resupinatum L.	Fabaceae	Th	ME+IR-TR	1.25
Urospermum picroides (L.) F.W.Schmidt	Asteraceae	Th	ME+IR-TR	22.50
Urtica urens L.	Urticaceae	Th	ME+IR-TR+ER-SR	15.00
Veronica syriaca Roem. & Scult.	Scrophulariaceae	Th	ME	1.25
Vicia sativa L.	Fabaceae	Th	ME+IR-TR+ER-SR	2.50
Volutaria lippii (L.) Cass. Ex Maire	Asteraceae	Th	SA-SI	1.25

Nph = Phanerophytes, H = Hemicryptophyte, Ch = Chemaephytes, Th = Theophytes, G = Geophytes, SA-SI = Saharo-Sindian, S-Z = Sudano-Zambezian, IR-TR = Irano-Turanian, ER-SR = Euro-Siberian, ME = Mediterranean, NEO = Neotropical, PAL = Palaeotropical, PAN = Pantropical, COSM = Cosmopolitan, AUST = Australian. The asterisk before the name means invasive plant species

Launea mucronata, Phragmites australis and *Zygophyllum album* have the highest presence value of among the perennial recorded species. However, several annual plant species have a wide ecological range of distribution and attained high presence such as *Bassia indica Cakile maritima, Chenopodium murale, Hordeum murinum, Lolium pernne, Malva parviflora, Melilotus indicus, Mesembryanthemum crystallinum, Rumex pictus, Senecio glaucus* and *Sonchus oleraceus.*

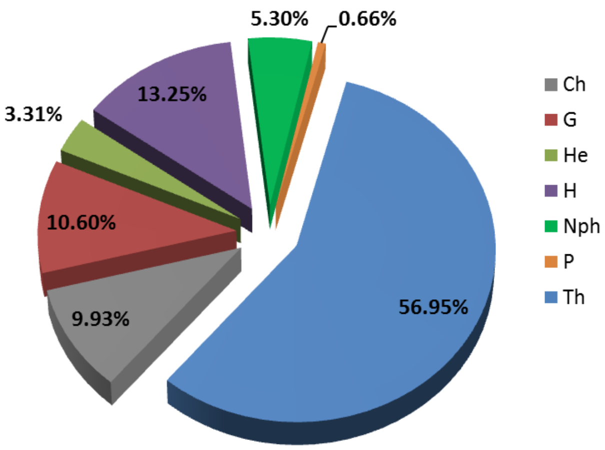

Fig. 2. Life-form percentage of the plant species along the international coastal highway. Ch = chamaephyte, Th = therophyte, Ph= phanerophyte, H = hemicryptophyte, P = parasite, and G= geophyte.

According to Raunkiaer (1934), the life-forms of the wild species of the present study (Table 1) are grouped under seven types. The majority of the recorded species are therophytes (86 species = 56.95%) followed by hemicryptophytes (20 species = 13.25%), geophytes (16 species =10.60%), chmaephytes (15 species =9.93%), nanophanerophytes (8 species = 5.30%), helophytes (5 species = 3.31%) then parasite attained value of 0.66% (one species) (Fig. 2).

Chorological affinities

Chorological analysis of the surveyed flora in the study area (Table 1) revealed that 68 species (46.58% of the total flora) were bi- and pluriregional Mediterranean elements. Monoregional chorotypes extending their distribution all over the Saharo-Sindian (10 species) and Mediterranean regions (23 species) amounted to 22.6% of the recorded flora. On the other hand, Cosmopolitan, Palaeotropical, Pantropical and Neotropical chorotypes constituted 28 species of the total recorded flora (Fig. 3).

Vegetation analysis

The TWINSPAN classification based on the importance value of 146 plant species, recorded in 80 stands, separating 4 plant communities (eigenvalue = 0.37) was shown in Fig. (4). Each plant community 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 (Table 2). Community I was dominated by *Silybum mariannum*; as well as this community was the smallest one and consequently less diverse and resembled by 5 stands. Moreover, this community also contained other important associated species with high importance value such as *Hordeum* murinum, *Malva parviflora*, *Chenopodium murale*, *Carduus pycnocephalus* and *Urtica urens* (Table 2). However, community II was dominated by the ice plant (*Mesembryanthemum crystalinum*), with 97 associated plant species distributed in 19 stands, amoung these associated species, *Melilotus indicus* and *Malva parviflora* were the most important.

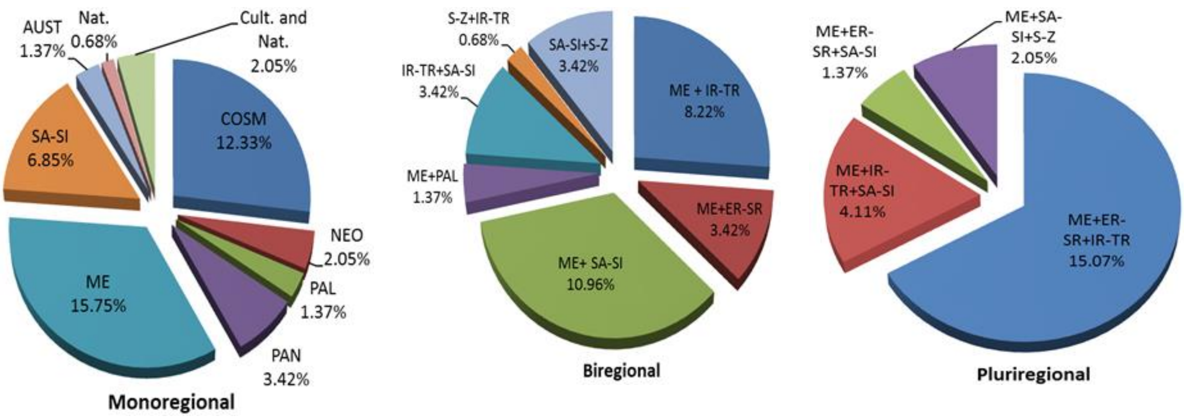

Fig. 3. Chorological analysis of the recorded species along the coastal international road. COSM = Cosmopolitan, PAL = Palaeotropical, PAN = Pantropical, SA = Saharo-Arabian, SZ = Sudano-Zambezian, Me = Mediterranean, and IT = Irano-Turanian.

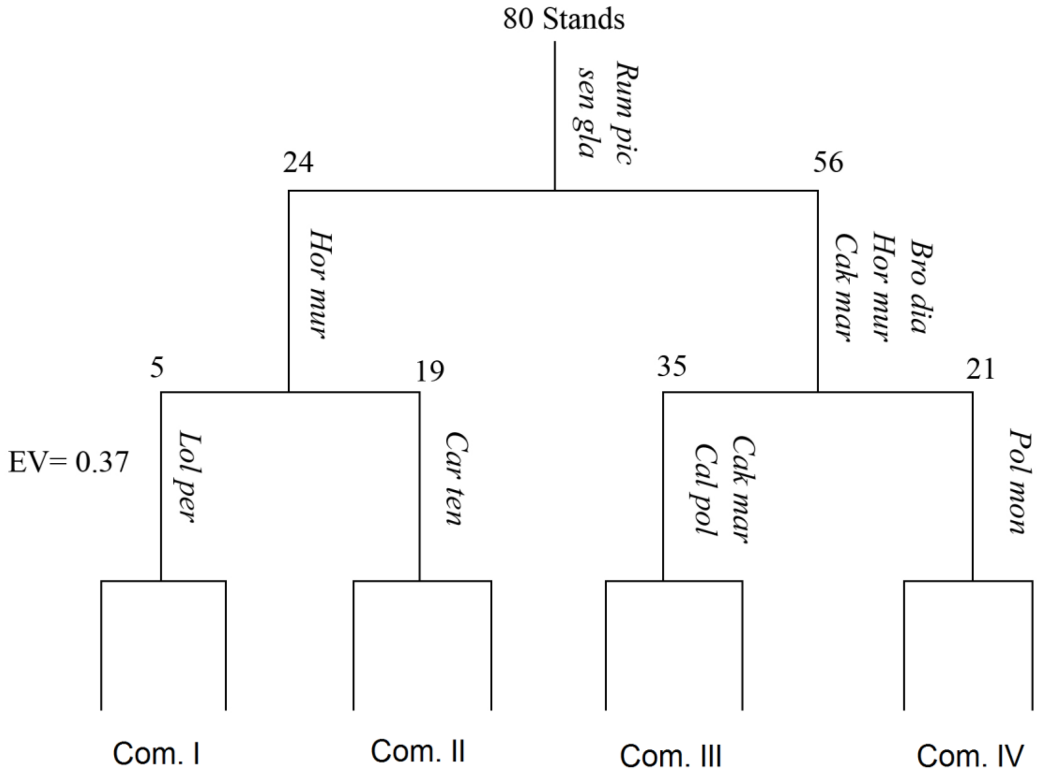

Fig. 4. TWINSPAN dendrogram of 80 stands based on the importance value of the species. EV: Eigen value, *Bro dia:Bromus diandrus* Roth, *Cak mar: Cakile maritima* Scop., *Cal pol: Calligonum polygonoides* L., *Car ten:Carthamus tenuis* (Boiss. & Blanche) Bornm., *Hor mur:Hordeum murinum* L., *Lol per:Lolium perenne* L., *Polmon: Polypogon monspeliensis* (L.) Desf., *Rum pic: Rumex pictus* L. *and Sen gla: Senecio glaucus* L.

Community III is the largest one (contained 35 stands), where it was co-dominated by *Hordeum murinum* and *Senecio glaucus*, in addition to 106 associated plant species such as *Rumex pictus*, *Melilotus indicus* and *Mesembryanthemum crystalinum*. Moreover, the community IV was co-dominated by *Cakile maritima* and *Senecio glaucus* and also contained other accompanying 73 plant species such as *Mesembryanthemum crystalinum*, *Mesembryanthemum nodiflorum*, *Rumex pictus*, *Zygophyllum album* and *Bassia indica* (Table 2).

The ordination of the stands representing the four plant communities is plotted on the biplot of Fig. (5) along the plane of the first and second axes. The plant communities II, III and IV were slightly overlapped in the center of DCA biplot, while *Silybum mariannum* community (Community I) is completely separated.

Plant diversity of the plant communities

The identified plant communities demonstrated differences in species richness and evenness (Table 2 and Fig. 6). The communities II (*Mesembryanthemum crystalinum* community) and IV (*Cakile maritima* and *Senecio glaucus* community) showed more richness, while the community I (*Silybum mariannum* community) was the lowest diverse one, where its Simpson index was 0.94. On the other hand, according to the plant evenness, the communities IV and I attained the highest Shannon–Wienner index of 0.87 and 0.86, respectively (Fig. 5), however, the community III (*Hordeum murinum* and *Senecio glaucus* community) was showed the lowest plant evenness.

Table 2. Plant communities, species diversity, and invasive species in each community along the international coastal highway.

Comm.	Stand No.	Total Species	Species Diversity Indices			Dominant species	Other important species	Invasive species
			Simposn	Shannon –Wienner	Shannon-evenness			
I	5	35	0.94	3.07	0.86	*Silybum mariannum* (31.6±3.3)	*Hordeum murinum* (22.1±4.3) *Malva parviflora* (11.2±7.0) *Chenopodium murale* (11.0±4.5) *Carduus pycnocephalus* (10.3±8.9) *Urtica urens* (10.2±11.0)	*Arundo donax* *Symphyotrichum squamatum*
II	19	97	0.97	3.79	0.84	*Mesembryanthemum crystalinum* (16.4±2.2)	*Melilotus indicus* (11.8±17.7) *Malva parviflora* (10.4±11.7) *Phragmites australis* (9.4±7.8) *Chenopodium murale* (9.7±10.2) *Hordeum murinum* (8.7±7.0)	*Nicotiana glauca* *Atriplex semibaccata* *Cyperus rotundus* *Imperata cylindrical* *Symphyotrichum squamatum* *Bassia indica*
III	35	106	0.96	3.75	0.79	*Hordeum murinum* (15.6±2.1) *Senecio glaucus* (14.3±1.1)	*Rumex pictus* (11.5±8.9) *Melilotus indicus* (8.2±13.9) *Mesembryanthemum crystalinum* (8.1±10.1)	*Acacia saligna* *Nicotiana glauca* *Atriplex semibaccata* *Heliotropium curassavicum* *Bassia indica*
IV	21	73	0.97	3.75	0.87	*Senecio glaucus* (19.9±1.9) *Cakile maritima* (17.7±1.2)	*Mesembryanthemum crystalinum* (12.0±10.8) *Mesembryanthemum nodiflorum* (12.6±13.3) *Rumex pictus* (11.4±10.7) *Zygophyllum album* (11.0±13.5) *Bassia indica* (10.9±10.0)	*Heliotropium curassavicum* *Bassia indica*

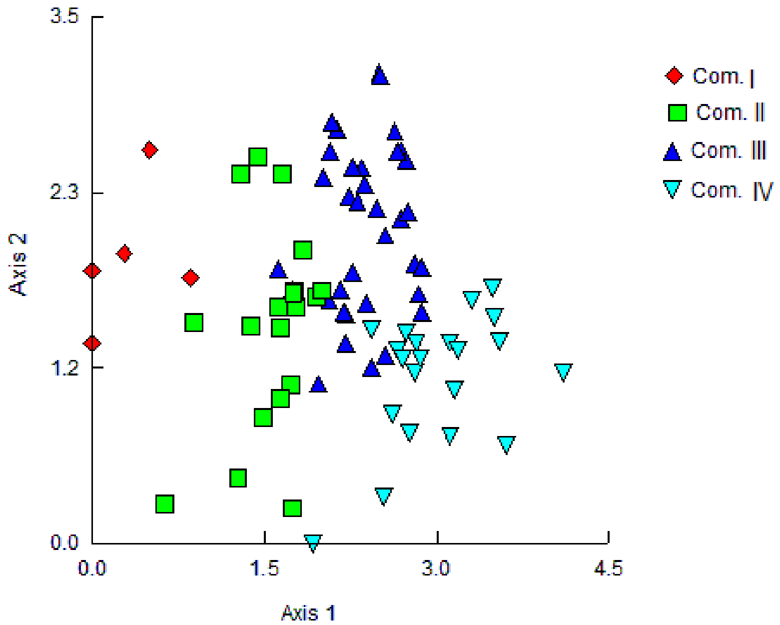

Fig. 5. The biplot ordination of different stands of the four identified plant communities along the international coastal highway, identified from TWINSPAN.

Soil-vegetation relationships

The soil analysis of the represented stands of the four separated plant communities indicated considerable significant variations in soil variables, although others did not show significant variation (Table 3). Electric conductivity, porosity, soil texture, Na^+, Cl^- and bicarbonate showed significant variations ($P < 0.05$) among the identified communities. The soil texture of all communities is mainly composed of coarse sand fraction, while the community co-dominated by *Hordeum murinum* and *Senecio glaucus* showed the highest value of sand fraction. The soil of *Cakile maritima* and *Senecio glaucus* community was more saline (1.78 ms cm^{-1}) compared to other communities, as expected. Moroever, this community showed the highest values of Na^+, Cl^- and bicarbonates. Howevere, the other measured soil variables (pH, WHC, calcium carbonate, organic carbon, sulphate, K^+, C^{2+} and Mg^{2+}) did not showed a significant variation betweeen the identified communities (Table 3).

The application of CCA on the important plant species with environmental (soil) variable showed diferrent correspondene of the different plant species with the soil characteristcs (Fig. 7). The plant species of community I exhibit a close relationship with sulphate and K^+. However, communities II and III were mainly correlated with salinity and organic matter, where they were positively correlated with electric conductivity, organic carbon and Na^+, while Cl^- content was negatively correlated with the both communities (Fig. 7). Community IV showed postive correlation with both Mg^{2+} and Ca^{2+}, while it was negatively correlated with pH and clay content.

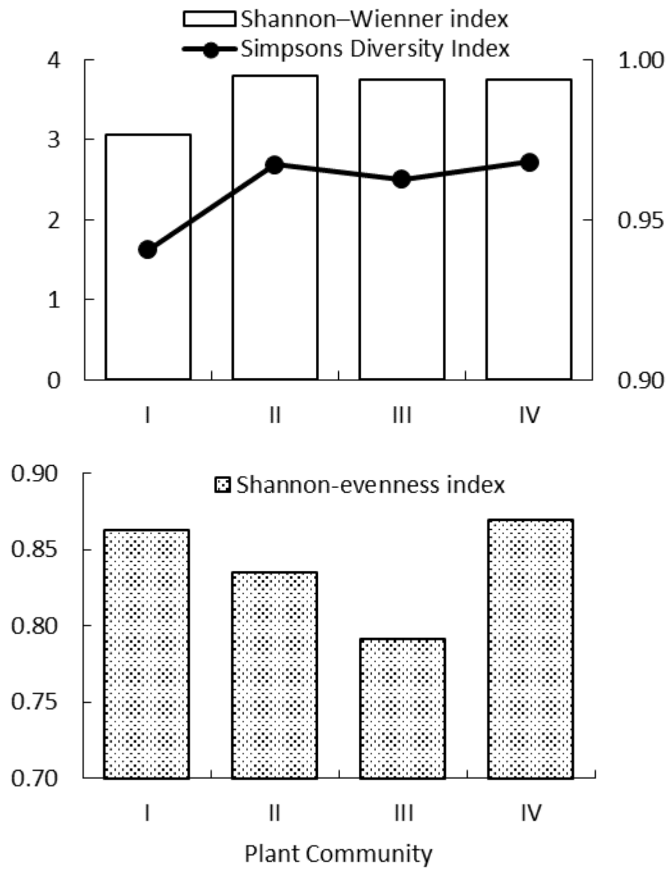

Fig. 6. Species diversity, richness and evenness of different identified plant communities along the international coatsal highway.

Table 3. Soil variables of different plant communities obtained from TWINSPAN.

Soil variables	Plant Community				*F-ratio*
	I	II	III	IV	
pH	7.82±0.06	7.70±0.03	7.79±0.03	7.79±0.04	1.87ns
E.C. (ms cm^{-1})	0.61±0.23	0.93±0.16	0.16±0.01	1.66±0.16	15.33***
Sand (%)	96.20±0.68	95.34±0.85	97.87±0.12	93.72±0.73	6.89**
Silt (%)	3.29±0.65	3.92±0.75	1.82±0.10	5.26±0.66	5.72**
Clay (%)	0.51±0.07	0.74±0.11	0.31±0.06	1.02±0.08	12.91***
Porosity (%)	37.46±2.36	36.66±2.34	34.62±1.42	43.87±1.20	4.39*
W.H.C. (%)	29.16±2.21	26.17±1.38	28.19±1.16	31.42±2.59	1.28ns
$CaCO_3$ (%)	0.216±0.037	0.296±0.077	0.136±0.010	0.160±0.013	2.69ns
O.C. (%)	0.352±0.077	0.304±0.067	0.260±0.065	0.388±0.067	0.65ns
SO_4^{2-}(%)	0.152±0.065	0.038±0.005	0.101±0.047	0.033±0.005	1.93ns
HCO_3^- (%)	0.017±0.002	0.018±0.001	0.019±0.001	0.025±0.003	4.80*
Cl- (%)	0.026±0.017	0.038±0.018	0.009±0.004	0.145±0.026	11.32***
Na^+ (mg/100g)	10.62±3.27	6.94±5.21	8.71±1.02	22.59±3.92	3.69*
K^+ (mg/100g)	1.68±0.57	2.28±0.47	1.50±0.22	2.23±0.45	0.76ns
Ca^{2+} (mg/100g)	13.92±6.17	22.31±4.39	9.57±2.17	8.35±3.24	2.20ns
Mg^{2+} (mg/100g)	7.52±3.27	15.63±6.25	7.52±3.40	5.87±1.67	1.21ns

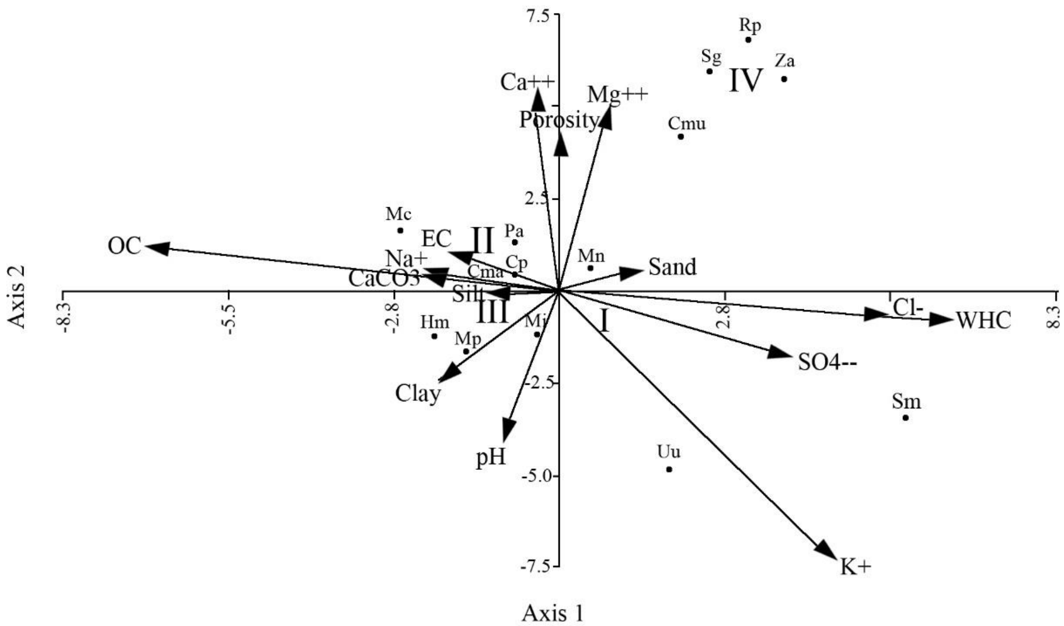

Fig. 7. Canonical Correspondence Analysis (CCA) ordination biplot of species-soil variable. OC: organic carbon, EC: electrical conductivity, WHC: water hloding capacity, *Cma: Cakile maritima, Cp: Carduus pycnocephalus, Cmu: Chenopodium murale, Hm: Hordeum murinum, Mp: Malva parviflora, Mi: Melilotus indicus, Mc: Mesembryanthemum crystalinum, Mn: Mesembryanthemum nodiflorum, Pa: Phragmites australis, Rp: Rumex pictus, Sg: Senecio glaucus, Sm: Silybum mariannum, Uu: Urtica urens and Za: Zygophyllum album.*

Discussion

The international coastal highway is one of the most important roads in Egypt, where it connect the country from east to west. This highway crosses along semi natural areas with different habitats, contained very important natural flora and fauna. The construction of this road resulted in changes in the plant composition as well as increases the human activities along the coastal part of the country.

The floristic analysis of the present study revealed that roadside habitat of the international highway comprises 146 plant species, mainly annuals, where the plants were flourished after the rainfall. This part of the country received the highest amount of the rainfall in the winter season (Zahran and Willis, 2009). Annual plants characterized by high reproductive capacity, as well as ecological, morphological and genetic plasticity (Grime, 1979; Kowarik, 1985).

In harmony with other related studies, Asteraceae, Poaceae, Chenopodiaceae, Fabaceae and Brassicaceae were the major families and also is the most common families in Mediterranean North African flora (Abd El-Gawad and Shehata, 2014; El-Amier et al., 2014). Asteraceae is the largest and most widespread family of the flowering plants in the world (Walters and Keil, 1996).

Nine invasive species were recorded in this study representing 8.33% of the invasive species in the Nile region of Egypt (Shaltout et al., 2016), which corroborated to the increasing human activities along the highway. The transportation is considered as one of the most important way for the invasive plant to spread in new localities. Moreover, soil disturbance and modification of roadside substrates due to road construction result in increased non-native species cover and richness at roadsides (Greenberg et al., 1997).

The life form analysis of the recorded species showed that therophytes are the most represented form, where it may be attributed to their short life cycles that enable them to resist the instability of the environmental condition, the climate of the Mediterranean region, topography variation and biotic influence (Heneidy & Bidak, 2001). Moreover, the relatively high value of hemicryptophytes of the plant species in the present study may be attributed to the ability of these species to resist drought, salinity, sand accumulation and grazing (Danin & Orshan, 1990; Danin, 1996).

The widespread of the Mediterranean chorotype of the surveyed flora in the study area reflects the Mediterranean climate of studied area. This result agrees with most of related studies (Salama et al., 2013; Barakat et al., 2014; El-Amier, 2016). Saharo-Arabian and Mediterranean chorotypes represented 22.6% of the recorded flora. 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 signal to mesic environment (El-Husseini et al., 2008; Abd El-Ghani et al., 2011). The whole country lies within the Saharo-Arabian belt of the Holarctic floristic realm (Abd El-Ghani et al., 2011).

It is worth noting that, a mixture of different floristic elements such as Cosmopoliton, Palaeotropical, Pantropical, Neotropical, Saharo-Sindian, Sudano-Zambezian, Australian and Irano-Turanuian elements are represented by variable number of species in the study area. This may be attributed to human impact, history of agriculture and capability of certain floristic elements to penetrate the study area from several adjacent phytogeographical regions (Zahran & Willis, 2009).

The roadside habitat of the international coastal highway dominated with different plant communities. In the present study we determine four communities, three (communities II, III and IV) were the richest and diverse, while community I is the smallest and less diverse one. In accordance, the ordination of the plant communities showed that these three communities were slightly overlapped, reflecting more similar vegetation structure and environmental variables.

Among the identified communities, community II, dominated with *Mesembryanthemum crystalinum*, was mainly correlated with salinity and organic matter which could be correlated to the habitat structure, salinity and the anthropogenic activities (Abd El-Gawad and Shehata, 2014). Also, this plant is an important species of the community III and community IV. Moreover, other salt tolerant species associated with this community such as *Melilotus indicus* and *Malva parviflora*, *Phragmites australis*, *Chenopodium murale* and *Hordeum murinum*.

The high ecological amplitude of *Mesembryanthemum crystallinum* in this community may be attributed to its adaptation to harsh environmental condition. Moreover, this species is very tolerant to salinity where it survived well in saline soils, salt spray and coastal conditions (Adams et al., 1998; El Shayeb et al., 2002), as well as it can accumulate salt in the top soil, hindering nontolerant species and subsequently increases its abundance (Dassonville et al., 2007). The identified communities in the present study are in harmony with the study of

Abd El-Gawad and Shehata (2014), whom determined also four communities in the deltaic Mediterranean coast, three dominated with *Mesembryanthemum crystallinum*, while one community dominated with *Hordeum murinum*. Nevertheless, the ordination of the plant communities II, III and IV showed that they were slightly overlapped, meaning more or less similar characteristics.

Conclusion

The deltaic areas are sensitive ecosystem toward both natural hazards and human interventions. During the last decades, the Nile Delta coast in Egypt subjected to several threats, mainly anthropogenic impact. The construction of the international coastal highway made the study area accessible to urbanization; therefore, change the natural habitats and the vegetation. The present study revealed that roadside habitat of the international coastal highway dominated with different plant communities which correlated with the habitat structure, salinity and the anthropogenic activities. Furthermore, nine invasive species were recorded in this study representing 8.33% of the invasive species in the Nile region of Egypt, where it could be attributed to the increment of human activities after construction of the highway, especially reclamation practices.

Author contributions

Ahmed Abd El-Gawad and Yasser El-Amier contributed equally for field work, samples analysis, treatment of data and manuscript preparation. Both authors approved the final version of the manuscript for publication.

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