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Ecological Study on *Zygophyllum coccineum* L. in Coastal and Inland Desert of 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

Zygophyllum coccineum is very common plant in the limestone wadies and plains of the Eastern (Arabian) desert of Egypt and shows wide soil range. The present study provides an analysis of floristic composition and vegetation types of *Z. coccineum* at 60 sites in coastal and inland desert of Egypt, emphasizing the environmental factors that affect species distribution. A total of 79 species of the vascular plants (39 perennials, one biennial and 39 annuals) belonging to 63 genera and related to 24 families. Asteraceae, Chenopodiaceae, Poaceae, Cruciferae and Zygophyllaceae are the largest families. Therophytes and chmaephytes are the most frequent, indicating a typical desert life-form spectrum. Chorological analysis of the study area revealed that 40.51% of the total species are Mediterranean taxa and 30.38% is Monoregional Saharo-Sindian. After application of the TWINSPAN and DCA, four groups (A-D) were identified and they were named after the characteristic species. Each group occupied a distinct type of habitats. *Z. coccineum* is assigned as dominant species in groups A and B or indicator species in groups C and D. Sodium, magnesium, SAR, PAR, EC and pH were the most effective soil factors on the spatial distribution of plants

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which showed high significant correlations with the first and second axes of CCA ordination diagram.

Keywords: Zygophyllum coccineum; xerophytes; edaphic factor; multivariate analysis.

1. INTRODUCTION

Zygophyllaceae (Caltrop family) is a family with approximately 25 genera and 240 species adapted to semi desert and Mediterranean climates [1]. Species belonging to this genus represent a group of succulent plants that are drought resistant and/or salt tolerant, living under severe, dry climatic conditions. The abundance of species related to this genus could be attributed to their high tolerance to environmental stresses in addition to their unpalatability. The growth and distribution of *Zygophyllum* species are attributed to their dependence on the chemical nature of the soil of their habitats [2].

Zygophyllum coccineum is the most widespread *Zygophyllum* species in Egypt and Saudi Arabia, where it occupies diverse habitats and shows wide soil range. The plant is very common in the limestone wadies and plains of the Eastern (Arabian) desert and tolerant of saline soils. It is a small perennial herb with fleshy leaves and somewhat whitish flowers of saline and sandy habitats near the sea. Its flowering time is starting from October to November [3].

The Egyptian deserts are classified ecologically into: coastal and inland deserts. The coastal deserts are associated with and affected by the Mediterranean, Red Sea and the two Gulfs of Sinai. The inland deserts are those far from the effects of the seas including the oases [4]. The Deltaic Mediterranean coast of Egypt comprises four main habitats: salt marshes, sand formations, reed swamps and fertile non-cultivated lands [5].

The desert vegetation in Egypt is the most important and characteristic type of natural plant life. It is mainly formed of xerophytic shrubs and sub-shrubs. The Egyptian desert is one of the most arid parts of the world characterized by arid and/or extreme arid climate. The perennial plant cover forms the permanent framework of the desert vegetation and is the best indicator of the habitat conditions [4].

The different habitats and plant communities in the Deltaic Mediterranean coastal desert were studied by many authors such as Zahran et al. [6], El-Demerdash et al. [7], El-Kady and Sharaf El-Din [8], Shaltout et al. [9], El-Halawany [10], El-Amier et al. [11]. The xero-halophytes of the Nile Delta coastal desert were also studied by many workers such as Zahran et al. [12], Serag [13], Zahran and El-Amier [14], El-Amier et al. [15]. However, the natural plant communities in the Eastern desert of Egypt were studied by several workers e.g. Zahran and Willis [4], Abd El-Ghani et al. [16], Salama et al. [17], El-Amier and Abdulkader [18] and Abd El-Ghani et al. [19]. Thus, the main objective of the present investigation was to study the abundance and distributional behavior of *Z. coccineum* and to evaluate the various edaphic factors supporting its growth.

2. MATERIALS AND METHODS

2.1 Studied Areas

The Deltaic Mediterranean coastal land of Egypt extends from Abu-Quir (in the west, Long. 32°19' E) to Port-Said (in the east Long.31°19' E) with a length of about 180 km, and with a width in a N-S direction for about 15 km from the coast [20,4]. On the other hand, Cairo-Suez desert road is located in the northern part of the Eastern Desert of Egypt (Galalah Desert) extends for about 130 Km long. This locality represents the natural xeric habitat which is mainly inhabited by xerophytic vegetation. The gravel desert is one of the most characteristic features of this road.

According to the map of the world distribution of arid regions, the climate of the whole stretch of the Mediterranean coastal desert is, generally, less arid than the remaining southern parts of Egypt [21]. The climatic conditions are warm summers (20–31°C) and mild winters (10–20°C). Relative humidity ranges from 76% to 74% in January and 83% to 75% in July. On the other hand, the climate of the Red Sea coastal land of Egypt is arid. Temperature is high and ranges between 14 and 21.7°C in winter and 23.1–46.1°C in summer. Relative humidity ranges from 43% in summer to 65% in winter. The mean annual rainfall ranges from 25 mm in Suez to 3.4 mm in Qusseir [4].

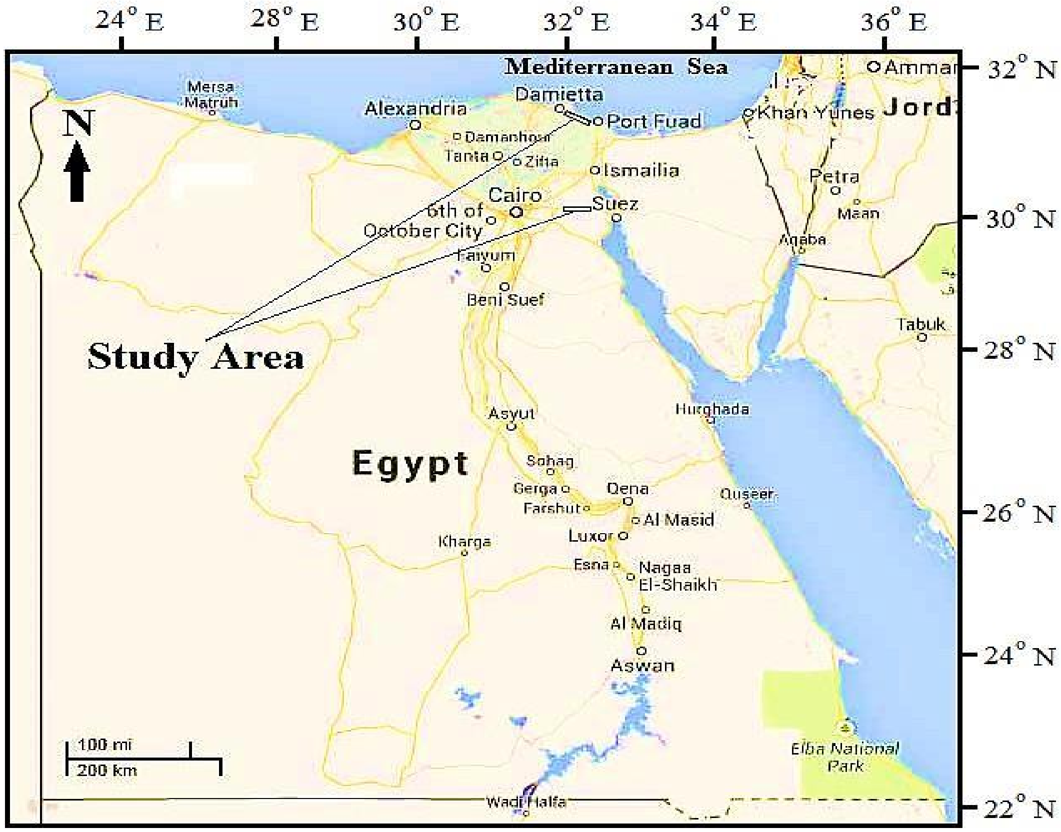

Fig. 1. Map of Egypt showing the studied areas

2.2 Estimation of Species Abundance

Sixty stands (10×10 m) were selected in coastal (Deltaic Mediterranean coast) and inlands desert (Cairo-Suez desert road) of Egypt. These stands were chosen to cover different habitat types supporting the growth of *Z. coccineum*. The density of each plant species was measured by counting the number of individuals of the species within randomly stands [22]. The plant cover of each species in the surveyed stands was measured by using the line intercept method [23]. Relative values of density and cover were calculated and estimate of its importance value (IV=200) for each plant species in each stand. The description and classification of life-forms in the present study were carried out according to Raunkiaer [24]. The nomenclature and identification of the recorded species were done according to Boulos [25].

2.3 Laboratory Analysis

For physical and chemical analysis, one composite soil sample was collected from each stand (profile 0-50 cm). Soil texture, soil porosity, water-holding capacity, oxidizable organic carbon, calcium carbonates, chlorides, sulphats, carbonates and bicarbonates were determined according to Piper [26], Jackson [27] and Pierce et al. [28]. Electrical – pH meter with glass electrode was used to determine the soil reaction. Conductivity was expressed as µmhos/cm and measured by YSI Incorporated Model 33 conductivity meter. Concentrations of the cations Na^+ and K^+ was estimated using Flame photometer [29]. Ca^{++} and Mg^{++} were determined by using atomic absorption spectrophotometer (A Perkin-Elemer, Model 2380, USA). Sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) were calculated according to McKell and Goodin [30].

2.4 Multivariate Analysis

Two trends of multivariate analysis were applied in the present study namely classification and ordination. The classification technique was the Two Way Indicator Species Analysis (TWINSPAN) described by Hill et al. [31], while the ordination technique was the Canonical

Correspondence Analysis (CCA) described by ter Braak [32].

2.5 Statistical Analyses

One-way analysis of variance (ANOVA) was applied to assess the significance of variation in the environmental variables with equal replication using the COSTAT program.

3. RESULTS AND DISCUSSION

3.1 Floristic Composition

The vegetation structure in the study area is relatively simple, in which the species have to withstand the harsh environmental conditions. This it can be reflected by the presence of several highly adapted and drought-resistant species. The floristic diversity of the study area included 79 species of the vascular plants (39 perennials, one biennial and 39 annuals) belonging to 63 genera and related to 24 families indicating the predominance of perennials. The highest number of species (60 species; 29 perennials, one biennial and 30 annuals) is recorded in the inland desert habitat which is represented by about 75.94% of the total recorded species, while the costal desert habitat is represented by 35 species or about 44.30% (18 perennials and 17 annuals).

The percentage of the life span in the current study varied in two locations of the study area. In the Deltaic Mediterranean coast and North Galalah desert, 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 [33,34]. On the other hand, the predominance of annuals can be attributed to time of study (March – May 2014) and short life cycle that enables them to resist the instability of the harsh condition [33,35].

The largest families were Asteraceae and Chenopodiaceae (13 species = 16.45% each) of the total recorded species, followed by Poaceae (10 species = 12.65%) then Cruciferae (7 species = 8.86%), Fabaceae (6 species = 7.59%) and Zygophyllaceae (5 species = 6.32%). These leading families were reported to be the most frequent in the desert of the Deltaic Mediterranean [5,36,11] and Eastern Desert [17,18]. Moreover, these families represent the most common in the Mediterranean North African flora [37].

The species composition of the studied area in the Nile Delta coast and Galalah desert 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 [4].

According to Raunkiaer [24], the life-forms of the wild species of the present study are grouped under five types (Table 1). The majority of the recorded species are therophytes (38 species = 46.83%) followed by chmaephytes (22 species = 27.84%), hemicryptophytes (9 species = 11.39%), cryptophytes (6 species=7.59) then nanophanerophytes attained value of 6.32% (5 species). It is evident that, the relative percentage of the life-form spectra varied from one habitat to the other (Fig. 2). Coastal and inland desert habitat can be grouped into five types of life forms therophytes (44.44 and 50.00%), chmaephytes (27.78 and 28.33%), hemicryptophytes (8.33 and 13.33%), cryptophytes (13.89 and 1.67%), nanophanerophytes (5.56 and 6.67%), respectively. The above results agree with those of other studies such as El-Demerdash et al. [7], Abd EL-Ghani et al. [38] and El-Amier et al. [15,39].

The dominance of therophytes over the other life forms seems to be a response to Mediterranean climate, topography variation and biotic influence [40]. The highest values of hemicryptophytes and chamaephytes may be attributed to the ability of species to resist sand accumulation, grazing, drought and salinity [41].

Chorological analysis of the study area revealed that 32 species (about 40.51% of the total species) are Mediterranean taxa (11 Pluriregional, 16 Biregional and 5 Monoregional species), while Monoregional Saharo-Sindian is represented by 24 species (30.38%). On the other hand, Cosmopolitan and S-Z+SA-SI are represented by 6 species each, while the other floristic categories are poorly represented. Fig. 3 indicated that the floristic categories are varied from one habitat to another. The highest number of Mediterranean taxa is 18 species (51.43%) is recorded in coastal desert habitat, this element includes Pluriregional and Biregional (8 species = 22.86%, each) and Monoregional (2 species = 2.5%) species. In the inland desert habitat, the number of

Mediterranean element is 24 species (40.0%). It classified into 6 species (10%) Pluriregional, 13 species (21.67%) Biregional and 5 species (8.33%) Monoregional.

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 [42]. In addition to, the dominance of Saharo-Sindian chorotypes, either pure or penetrated into other regions reflect the effect of both Mediterranean and Saharo-Sindian chorotypes in the vegetation of the study area. Similar results were reported in other studies e.g. Galal and Fawzy [36]; Abd EL-Ghani et al. [38] and El-Amier et al. [11,39].

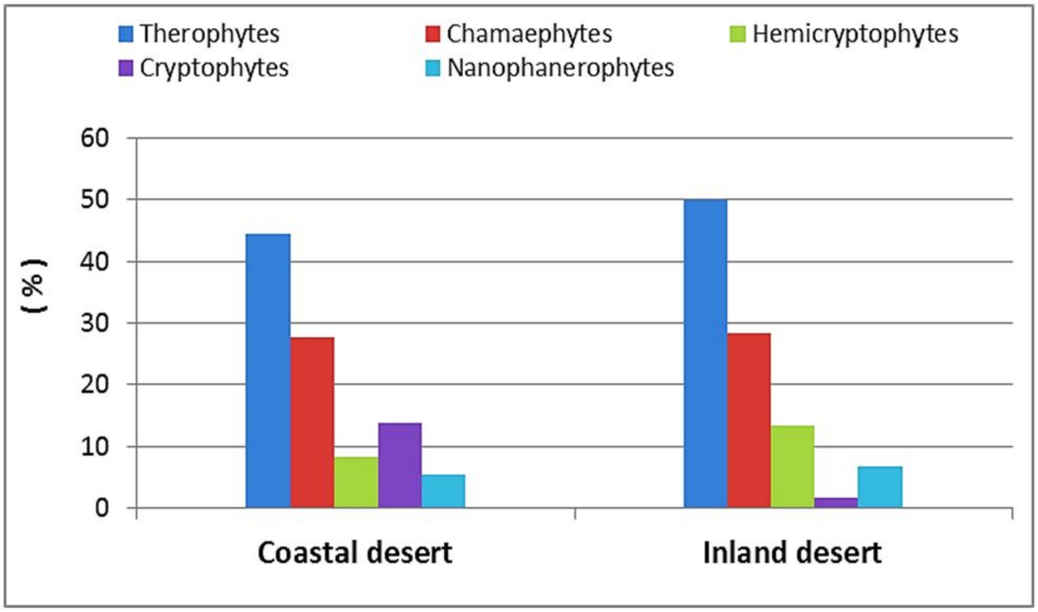

Fig. 2. Plant life form spectra in the coastal and inland desert

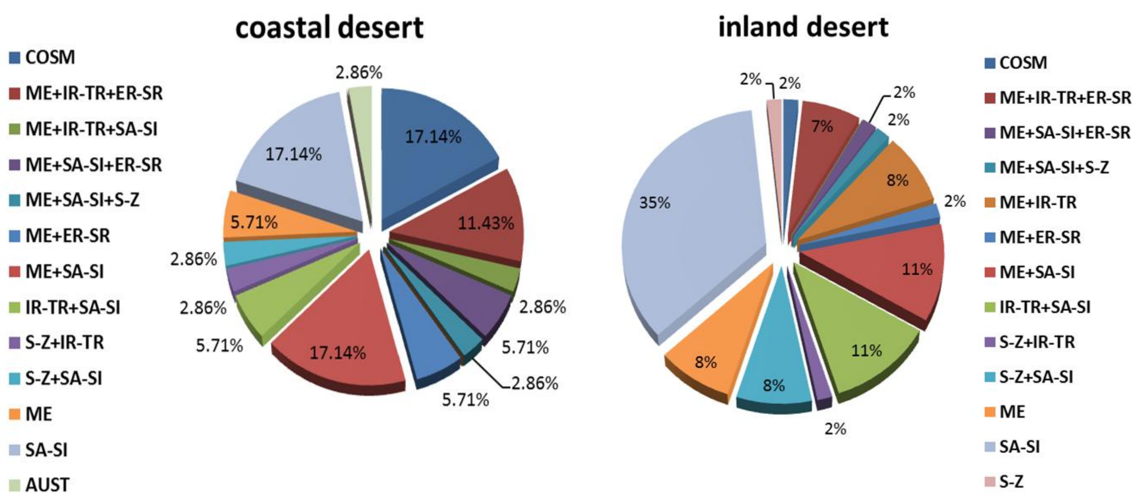

Fig. 3. Chorotype spectrum diagram of the coastal and inland desert

Table 1. Floristic composition, life forms and chorotype of the recorded plant species in the different habitats of the study area

Species	Duration	Life form	Chorotypes	Phytogeographical regions		P%
				Coastal desert	Inland desert	
Aizoaceae						
Mesembryanthemum crystallinum L.	Ann	Th	ME+ER-SR	+	+	13.33
Mesembryanthemum forsskaolii Hochst. ex Boiss.	Ann	Ph	SA-SI	-	+	6.67
Mesembryanthemum nodiflorum L.	Ann	Th	ME+SA-SI+ER-SR	+	+	33.33
Amaranthaceae						
Aerva javanica (Burm.f.) Juss. ex Schult.	Per	Ch	SA-SI + S-Z	-	+	1.67
Asclepiadaceae						
Cynanchum acutum L.	Per	H	ME+IR-TR	-	+	3.33
Asteraceae						
Anthemis cotula L.	Ann	Th	ME	-	+	3.33
Centaurea aegyptiaca L.	Bi	Th	SA-SI	-	+	5.00
Echinops spinosus L.	Per	H	ME+SA-SI	-	+	3.33
Ifloga spicata (Forssk.) Sch.Bip.	Ann	Th	SA-SI	+	+	10.00
Launaea mucronata (Forssk.) Muschl.	Per	H	ME+SA-SI	+	+	5.00
Launaea nudicaulis (L.) Hook.f.	Per	H	SA-SI	+	+	11.67
Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze	Per	Ch	SA-SI	-	+	1.67
Limbarda crithmoides (L.) Dumort.	Per	Ch	ME+ER-SR+SA-SI	+	-	1.67
Pluchea dioscoridis (L.) DC.	Per	Nph	SA-SI + S-Z	+	-	1.67
Pulicaria undulata (L.) C. A. Mey.	Per	Ch	SA-SI	-	+	5.00
Reichardia tingitana (L.) Roth	Ann	Th	ME+IR-TR	-	+	5.00
Senecio glaucus L.	Ann	Th	ME+IR-TR+ER-SR	+	+	45.00
Volutaria lippii (L.) Cass. ex Maire	Ann	Th	SA-SI	-	+	3.33
Boraginaceae						
Alkanna lehmanii (L.) Boiss.	Per	H	ME	-	+	3.33
Brassicaceae						
Cakile maritima Scop.	Ann	Th	ME+ER-SR	+	-	26.67
Diplotaxis acris (Forssk.) Boiss.	Ann	Th	SA-SI	-	+	3.33

Species	Duration	Life form	Chorotypes	Phytogeographical regions		P%
				Coastal desert	Inland desert	
Diplotaxis harra (Forssk.) Boiss.	Per	Ch	ME+SA-SI	-	+	8.33
Erysimum repandum L.	Ann.	Th	ME+IR-TR+ER-SR	-	+	1.67
Farsetia aegyptia Turra	Per	Ch	SA-SI + S-Z	-	+	13.33
Matthiola longipetala (Vent.) DC.	Ann.	Th	ME+IR-TR	-	+	10.00
Zilla spinosa (L.) prantl	per	Ch	SA-SI	-	+	38.33
Caryophyllaceae						
Gypsophila capillaris (Forssk.) C. Chr.	Per	H	IR-TR+SA-SI	-	+	5.00
Herniaria hemistemon J. Gay	Ann.	Th	ME+ SA-SI	-	+	1.67
Chenopodiaceae						
Anabasis articulata (Forssk.) Moq.	Per	Ch	IR-TR+SA-SI	+	+	15.00
Arthrocnemum macrostachyum (Moric.) K. Koch	Per.	Ch	ME+ SA-SI	+	+	6.67
Atriplex lindleyi Moq.	Ann	Th	ME+IR-TR+ER-SR	+	+	6.67
Atriplex prostrata Boucher ex DC.	Ann.	Th	ME+IR-TR+ER-SR	+	-	1.67
Atriplex semibaccata R. Br.	Per	H	AUST	+	-	1.67
Bassia indica (Wight) A.J.Scott	Ann	Th	IR-TR+S-Z	+	+	43.33
Bassia muricata (L.) Asch.	Ann	Th	IR-TR+SA-SI	-	+	16.67
Chenopodium murale L.	Ann.	Th	COSM	+	+	25.00
Halocnemum strobilaceum (Pall.) M. Bieb.	Per	Ch	ME+IR-TR+SA-SI	+	-	18.33
Haloxylon salicornicum (Moq.)	Per	Ch	SA-SI	-	+	36.67
Salsola kali L.	Ann	Ch	COSM	+	-	10.00
Suaeda maritima (L.) Dumort.	Ann	Th	COSM	+	-	3.33
Suaeda pruinosa Lange	Per	Ch	ME	+	+	5.00
Cleomaceae						
Cleome amblyocarpa Barratte & Murb.	Ann.	Th	SA-SI	-	+	5.00
Convolvulaceae						
Convolvulus lanatus Vahl	Per	Ch	SA-SI	+	-	3.33
Euphorbiaceae						
Euphorbia retusa Forssk.	Ann.	Th	SA-SI	-	+	13.33

Species	Duration	Life form	Chorotypes	Phytogeographical regions		P%
				Coastal desert	Inland desert	
Fabaceae						
Astragalus bombycinus Boiss.	Ann	H	IR-TR+SA-SI	-	+	5.00
Astragalus spinosus (Forssk.) Muschl.	Per	Ch	IR-TR+SA-SI	-	+	1.67
Lotus halophilus Boiss. & Spruner	Ann	Th	ME+SA-SI	+	-	3.33
Lotus glinoides Delile	Ann	Th	S-Z	-	+	5.00
Retama raetam (Forssk.) Webb & Berthel.	Per	Nph	SA-SI		+	6.67
Trigonella stellata Forssk.	Ann	Th	IR-TR+SA-SI	-	+	3.33
Geraniaceae						
Erodium laciniatum (Cav.) Willd.	Ann	Th	ME	-	+	6.67
Lamiaceae						
Lavandula coronopifolia Poir.	Per	Ch	SA-SI	-	+	1.67
Malvaceae						
Malva parviflora L.	Ann	Th	ME+IR-TR	-	+	6.67
Neuradaceae						
Neurada procumbens L.	Ann	Th	SA-SI + S-Z	-	+	1.67
Plantaginaceae						
Plantago notata Lag.	Ann	Th	IR-TR+SA-SI	-	+	6.67
Poaceae						
Aegilops kotschyi Boiss.	Ann	Th	IR-TR+SA-SI	+	-	5.00
Cynodon dactylon (L.) Pers.	Per	G	COSM	+	-	1.67
Hordium murinum L.	Ann	Th	ME+IR-TR+ER-SR	+		6.67
Lasiurus scindicus Henrard	Per	G	SA-SI+S-Z	-	+	1.67
Parapholis incurva (L.) C.E. Hubb	Ann	Th	ME+IR-TR+ER-SR	-	+	1.67
Panicum turgidum Forssk.	Per	H	SA-SI	-	+	6.67
Phragmites australis (Cav.) Trin.ex Steud.	Per	G, He	COSM	+	-	11.67
Poa annua L.	Ann	Th	COSM	+	-	10.00
Sporobolus spicatus (Vahl) Kunth	Per	G	S-Z-SA-SI-ME	+	-	1.67
Stipagrostis lanata (Forssk.) De Winter	Per	G	SA-SI	+	-	1.67

Species	Duration	Life form	Chorotypes	Phytogeographical regions		P%
				Coastal desert	Inland desert	
Polygonaceae						
Emex spinosa (L.) Campd.	Ann	Th	ME+SA-SI	+	+	13.33
Rumex pictus Forssk.	Ann	Th	ME+SA-SI	+	-	10.00
Rumex vesicarius L.	Ann	Th	ME+SA-SI+S-Z	-	+	15.00
Resedaceae						
Ochradenus baccatus Delile	Per	Nph	SA-SI	-	+	8.33
Reseda decursiva Forssk.	Ann	Th	SA-SI	-	+	3.33
Scrophulariaceae						
Kichxia aegyptiaca (L.) Nabelek	Per	Ch	ME+SA-SI	-	+	1.67
Solanaceae						
Hyoscyamus muticus L.	Per	Ch	SA-SI	-	+	6.67
Tamaricaceae						
Tamarix aphylla (L.) H. Karst.	Per	NPH	SA-SI+S-Z	-	+	3.33
Tamarix nilotica (Ehrenb.) Bunge	Per	NPH	SA-SI	+	+	8.33
Zygophyllaceae						
Zygophyllum aegptium Hosny	Per	Ch	ME	+	+	13.33
Zygophyllum coccinum L.	Per	Ch	SA-SI	+	+	100.00
Fagonia mollis Delile	Per	Ch	SA-SI	-	+	18.33
Zygophyllum album L.F.	Per	Ch	SA-SI+ME	+	-	13.33
Zygophyllum simplex L.	Ann	Th	SA-SI	-	+	35.00

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

3.2 Classification of Vegetation

Application of TWINSPAN classification based on the importance values of 79 plant species recorded in 60 sampled stands representing the costal desert and inland desert habitat led to the recognition of four vegetation groups (Fig. 2), the vegetational composition of these groups are presented in Table 2.

3.2.1 Group (A): *Zygophyllum coccinum* group

This group was the least diversified (24 species) among the recognized groups with 7 stands dominated by *Z. coccinum*. Stands of this group were found on soil rich in its sand, organic carbon and sulphates and lowest levels of silt, calcium carbonate, EC and cations (Table 2). The other importance species are *Ifloga spicata, Mesembryanthemum nodiflorium, Poa annua, Senecio glaucus* and *Z. album*. Six sporadic species were *Aegilops kotschyi, Convolvulus lanatus, Cynodon dactylon, Lotus halophilus, Sporobolus spicatus* and *Stipagrostis lanata* recorded in this group (Table 3).

3.2.2 Group (B): *Zygophyllum coccinum* group

This is the largest group (22 stands) of the studied communities. Thirty three species were recorded in this group. The soil of this group was characterized by the highest electrical conductivity, anions and cations (Table 3). Sporadic species included six species, *Arthrocnemum macrostachyum, Atriplex prostrata, Limbarda cvithmoides, Pluchea dioscoridis, Suaeda maritima* and *S. pruinosa*. The other importance species are *Bassia indica, M. nodiflorum*, *Senecio glaucus*, *Z. aegptium, Z. album* (indicator species) (Table 2). The other indicator species in this group is *Anabasis articulata*.

3.2.3 Group (C): *Haloxylon salicornicum* and *Zygophyllum coccinum* group

It is the most diversified group (50 species) among the separated vegetation groups, consists of 14 stands. This group attained the highest level of sand, silt, electrical conductivity, calcium carbonate and cations (Table 3). Twenty sporadic species were included, amongst others *Aerva javanica*, *Alkanna lehmanii, Diplotaxis acris, Erodium laciniatum, Erysimum repandum,* and *Euphorbia retusa.* The other important species in this group are *Ochradenus baccatus*, *Senecio glaucus, Zilla spinosa* and *Zygophyllum simplex* (Table 2). The indicator species in this group are *Chenopodium murale* and *Launaea nudicaulis*.

3.2.4 Group (D): *Haloxylon salicornicum* group

This group comprised 32 species recorded from 17 stands. The stands of this group characterized by soil with the highest levels of sand and silt fractions, porosity, calcium carbonate and moderates levels of electrical conductivity, chlorides, sulphates and cations (Table 3). Sporadic species included six species, *Echinops spinosus, Herniaria hemistemon, Kichxia aegyptiaca, Lasiurus scindicus, Panicum turgidum* and *Pulicaria undulata.* The other common important species is *Fagonia mollis, Retama raetam, Zilla spinosa, Z. coccinum* and *Z. simplex*.

The desert vegetation in Egypt is the most important and characteristic type of natural plant life. The perennial plant cover forms the permanent framework of the desert vegetation and is the best indicator of the habitat conditions. The identified vegetation groups in the current study were more or less similar with those investigated by Zahran et al. [6], Abd El-Ghani [45], Abd El-Ghani et al. [38], Salama et al. [17,43] and El-Amier et al. [11, 39,44].

3.3 Ordination of Sampled Stands

It is clearly that the vegetation groups yielded by TWINSPAN classification are markedly distinguishable and having obvious pattern of segregation on the ordination planes. All the vegetation groups in two different habitats are located on the positive sides of the first and second axes.

As shown in Fig. 3, groups A and B dominated by *Z. coccinum* that separated at left side of the DCA, where group A at the lower part and group B at the upper part. In addition these two groups are superimposed. On the other hand and group C is co-dominated also by *Haloxylon salicornicum* and *Z. coccinum* separated at upper part of right side of DCA. Finally, group D is dominated by *Haloxylon salicornicum* separated at lower part of right side the DCA diagram. The obtained results concerning the DCA ordination in the present investigation were in agreement with the studies carried out by Deweeb [46], Khorshied [47] and Ramez [48].

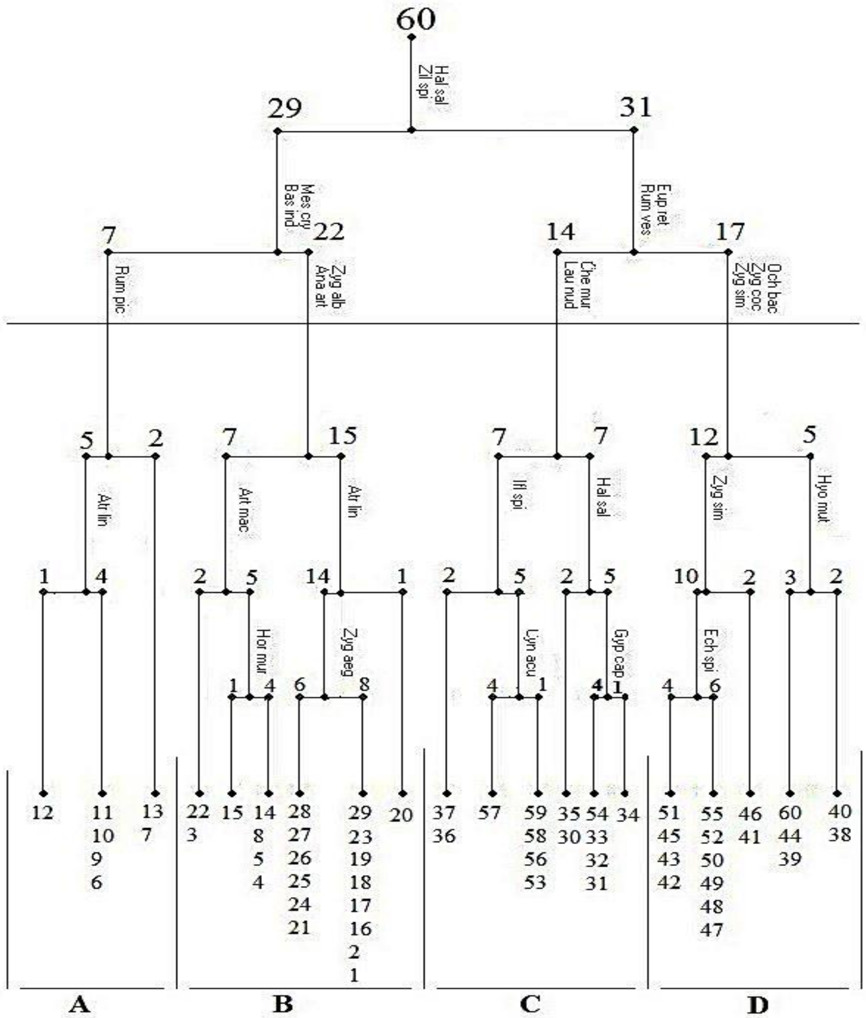

Fig. 4. Two Way Indicator Species Analysis (TWINSPAN) dendrogram of the 60 sampled stands based on the importance values of the 79 species. The indicator species are abbreviated by the first three letters of genus and species respectively

3.4 Soil-vegetation Relationships

The relationship between vegetation and soil variables is indicated on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot of species-soil factors Fig. 6. It is clear that, sodium, magnesium, SAR, PAR, EC and pH were the most effective soil factors which showed high significant correlations with the first and second axes of CCA ordination diagram.

The important species (*Z. aegyptium, Z. album* and *Bassia indica*) in group B, *Z. album* is important in group A, *Z. Simplex* is important in each groups C and D. The indicator species (*Launia nudicaulis, Z. album* and *Z. simplex*) in groups C, B and D, respectively were separated at the upper right side of CCA-biplot diagram. These species showed a close relationship with calcium carbonate. While, *Haloxylon salicornicum* is dominant species in groups C and D, *Mesembryanthemum nodiflorium* is important species in groups A and B groups and *Fagonia mollis* is important in group D are segregated at the upper left side of the diagram. These species exhibited a clear relationship with organic carbon and clay.

Table 2. Mean values of the importance value of indicator and preferential species in the different vegetation groups resulting from TWINSPAN classification of the study area

Species	Vegetation groups			
	A	B	C	D
No. of stands	**7**	**22**	**14**	**17**
No. of species	**24**	**33**	**50**	**32**
Aegilops kotschyi Boiss.	5.14	-	-	-
Aerva javanica (Burm.f.) Juss. ex Schult.	-	-	0.51	-
Alkanna lehmanii (L.) Boiss.	-	-	0.74	-
Anabasis articulata (Forssk.) Moq.	0.80	5.98	3.91	1.24
Anthemis cotula L.	-		0.57	-
Arthrocnemum macrostachyum (Moric.) K. Koch	-	3.63	-	-
Astragalus bombycinus Boiss.	-	-	1.86	-
Astragalus spinosus (Forssk.) Muschl.	-	-	0.16	-
Atriplex lindleyi Moq.	0.57	1.05	0.39	1.80
Atriplex prostrata Boucher ex DC.	-	0.61	-	-
Atriplex semibaccata R. Br.	-	-	-	-
Bassia indica (Wight) A.J.Scott	4.55	22.30	2.74	2.59
Bassia muricata (L.) Asch.	-	0.47	7.21	1.85
Cakile maritima Scop.	8.09	5.65	-	-
Centaurea aegyptiaca L.	-	-	0.30	0.70
Chenopodium murale L.	-	3.39	3.46	2.43
Cleome amblyocarpa Barratte & Murb.	-	-	1.55	0.72
Convolvulus lanatus V ahl	3.82	-	-	-
Cynanchum acutum L.	-	-	1.94	1.07
Cynodon dactylon (L.) Pers.	1.10	-	-	-
Diplotaxis acris (Forssk.) Boiss.	-	-	3.43	-
Diplotaxis harra (Forssk.) Boiss.	-	0.77	3.87	1.19
Echinops spinosus L.	-	-	-	2.83
Emex spinosa (L.) Campd.	1.95	2.67	1.53	-
Erodium laciniatum (Cav.) Willd.	-	-	2.46	-
Erysimum repandum L.	-	-	0.29	-
Euphorbia retusa Forssk.	-	-	5.32	-
Fagonia mollis Delile	-	0.58	3.79	8.63
Farsetia aegyptia Turra	-	-	2.29	5.35
Gypsophila capillaris (Forssk.) C. Chr.	-	-	2.77	-
Halocnemum strobilaceum (Pall.) M. Bieb.	-	5.83	4.00	-
Haloxylon salicornicum (Moq.)	-	1.52	22.85	37.28
Herniaria hemistemon J. Gay	-	-	-	0.58
Hordium murinum L.	5.98	1.08	-	-
Hyoscyamus muticus L.	-	-	2.04	1.42
Ifloga spicata (Forssk.) Sch.Bip.	12.27	-	0.51	-
Kichxia aegyptiaca (L.) Nabelek	-	-	-	0.58
Lasiurus scindicus Henrard	-	-	-	0.62
Launaea mucronata (Forssk.) Muschl.	-	-	1.09	-
Launaea nudicaulis (L.) Hook.f.	1.34	0.83	7.00	-
Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze	-	-	1.58	-
Lavandula coronopifolia Poir.	-	-	0.68	-
Limbarda cvithmoides (L.) Dumort.	-	0.37	-	-
Lotus glinoides Delile	-	-	1.89	-
Lotus halophilus Boiss.& Spruner	2.33	-	-	-
Malva parviflora L.	-	0.48	4.43	-
Matthiola longipetala (Vent.) DC.	-	0.32	5.48	3.13
Mesembryanthemum crystallinum L.	8.03	0.94	-	-
Mesembryanthemum forsskaolii Hochst.ex Boiss.	-	-	3.23	-
Mesembryanthemum nodiflorum L.	9.78	21.69		

Species	Vegetation groups			
	A	B	C	D
Neurada procumbens L.	-	-	0.38	-
Ochradenus baccatus Delile	-	-	8.52	7.10
Panicum turgidum Forssk.	-	-	-	4.45
Parapholis incurva (L.) C.E. Hubb	-	-	0.89	-
Phragmites australis (Cav.) Trin.ex Steud.	1.27	5.76	0.38	-
Plantago notata Lag.	-	-	3.19	-
Pluchea dioscoridis (L.) DC.	-	1.05	-	-
Poa annua L.	15.97	-	-	2.19
Pulicaria undulata (L.) C. A. Mey.	-	-	-	3.67
Reichardia tingitana (L.) Roth	-	-	1.72	0.56
Reseda decursiva Forssk.	-	-	1.37	-
Retama raetam (Forssk.) Webb & Berthel.	-	-	-	10.58
Rumex pictus Forssk.	6.63	-	-	0.31
Rumex vesicarius L.	-	0.42	5.55	0.72
Salsola kali L.	0.31	1.83	-	
Senecio glaucus L.	16.91	16.45	7.70	1.50
Sporobolus spicatus (Vahl) Kunth	3.20	-	-	-
Stipagrostis lanata (Forssk.) De Winter	1.65	-	-	-
Suaeda maritima (L.) Dumort.	-	1.83	-	-
Suaeda pruinosa Lange	-	3.35	-	-
Tamarix aphylla (L.) H. Karst.	-	-	3.54	1.38
Tamarix nilotica (Ehrenb.) Bunge	-	5.06	0.90	-
Trigonella stellata Forssk.	-	-	1.92	-
Volutaria lippii (L.) Cass. ex Maire	-	-	2.24	0.47
Zilla spinosa (L.) prantl	-	0.52	18.23	25.34
Zygophyllum aegptium Hosny	3.95	8.70	-	-
Zygophyllum album L.F.	11.23	6.61	-	-
Zygophyllum coccinum L.	73.15	67.76	20.75	35.87
Zygophyllum simplex L.	-	0.52	15.23	31.55

Table 3. 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 groups				*P-value*
		A	B	C	D	
pH		8.65±0.12	8.50±0.10	8.17±0.05	8.12±0.04	0.50^{ns}
EC (µmhos/cm)		276.81±8.23	2132.02±47.46	553.86±11.63	373.53±8.32	850.37*
Sand	%	90.20±1.32	86.92±1.30	85.57±1.69	87.82±1.23	6.11^{ns}
Silt	%	7.66±1.53	10.60±1.05	12.84±1.56	10.64±1.10	5.65^{ns}
Clay	%	1.76±0.29	2.49±0.38	1.59±0.17	1.59±0.18	1.10^{ns}
Porosity	%	28.68±1.62	29.32±1.06	27.94±0.80	30.71±1.21	5.60^{ns}
WHC	%	24.65±1.81	25.69±1.09	23.10±1.04	26.13±1.50	4.74^{ns}
$CaCO_3$	%	4.24±0.81	17.79±3.25	24.94±2.99	24.89±2.79	11.77**
OC	%	0.18±0.02	0.23±0.02	0.14±0.01	0.15±0.01	0.07^{ns}
Cl^-	%	0.06±0.01	0.55±0.15	0.06±0.01	0.05±0.01	0.15^{ns}
HCO_3	%	1.33±0.09	1.35±0.08	1.23±0.09	1.30±0.09	0.41^{ns}
SO_4^{--}	%	0.22±0.06	0.20±0.03	0.20±0.05	0.18±0.04	0.21^{ns}
Na^+	mg/100g air dry soil	197.44±61.19	1769.14±427.89	387.89±84.35	239.58±55.18	643.59*
K^+	mg/100g air dry soil	21.97±6.57	198.86±44.24	41.69±8.72	28.40±5.99	60.17**
Ca^{++}	mg/100g air dry soil	57.09±17.01	531.22±114.74	114.74±24.16	77.16±16.53	171.14*
Mg^{++}	mg/100g air dry soil	28.27±8.51	262.56±58.76	54.01±11.44	36.49±7.81	80.16*
SAR		28.47±4.15	78.04±10.53	38.82±4.64	30.20±3.21	27.14*
PAR		3.19±0.43	8.61±1.02	4.26±0.44	3.54±0.32	2.21^{ns}

*WHC= Water-holding capacity, OC= Organic carbon, EC= Electrical conductivity, SAR= sodium adsorption ratio, PAR= Potassium adsorption ratio, ns= non-significance, * P < 0.05, ** P < 0.01*

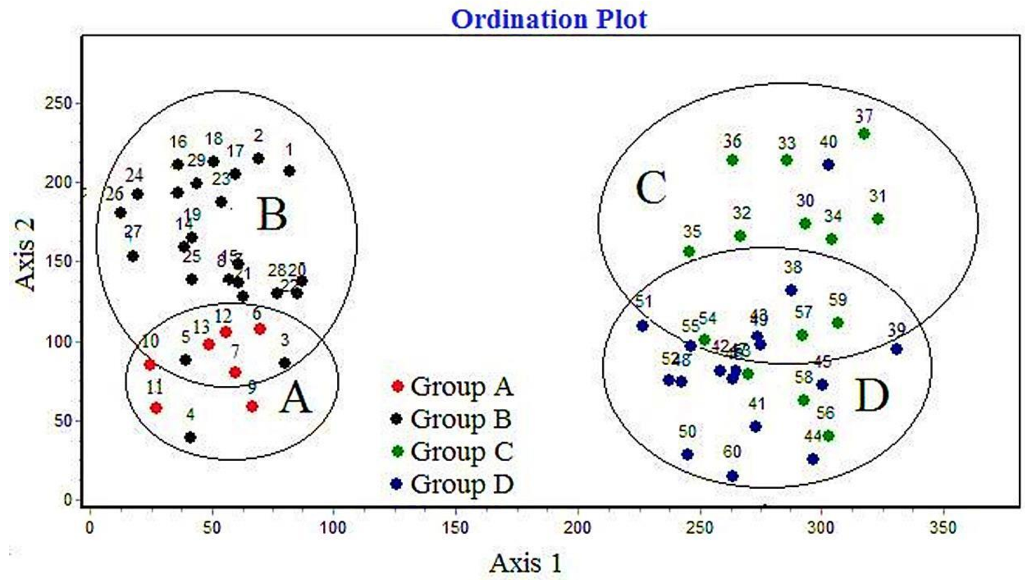

Fig. 5. Detrended Correspondence Analysis (DCA) ordination of the 60 stands with vegetation groups of the study areas in North Nile Delta and North Galalah Desert

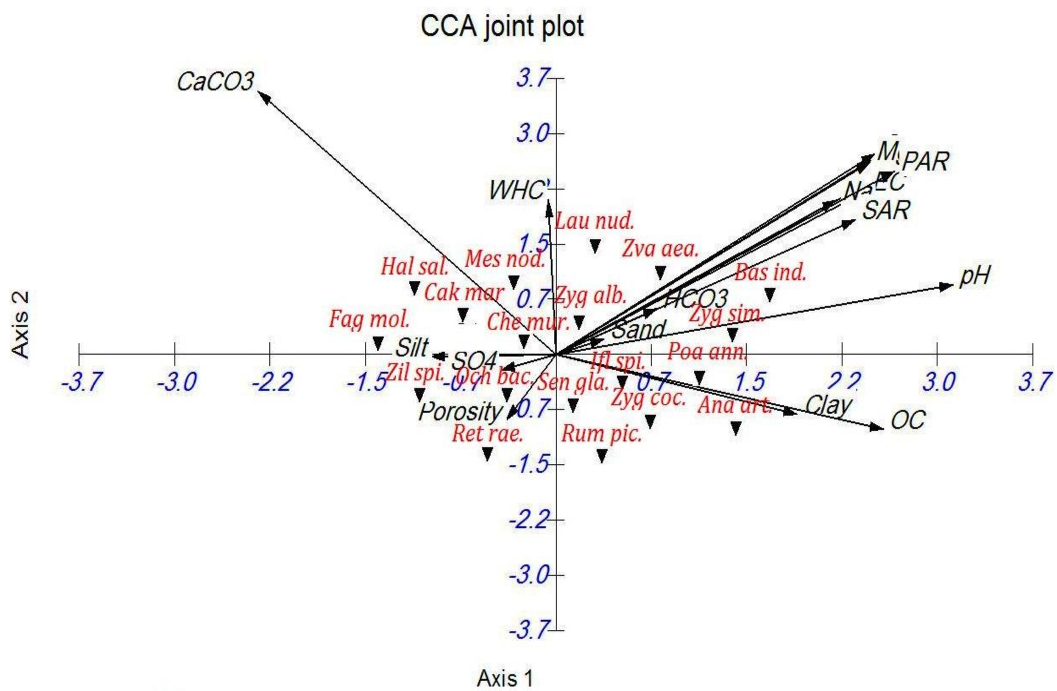

Fig. 6. Canonical Correspondence Analysis (CCA) ordination diagram of plant species with soil variables represented by arrows in the study area. The indicator and preferential species are abbreviated to the first four letters of the genus and species respectively

On the other hand, *Z. coccineum* is dominant in A and B, and codominant in group C, the important species (*Ifloga spicata, Senecio glaucus* and *Poa annua*) of group A, *Senecio glaucus* important species of groups B and C, *Anabasis articulata* is indicator in group B and *Rumex pictus* is indicator in group A are separated at lower right side of CCA biplot diagram. These species showed a close relationship with clay and organic carbon. The important species (*Zilla spinosa* and *Ochradenus baccatus*) in groups C and D as well as *Retama raetam* is important species in group D were separated at the lower left side of the diagram. These species showed a close relationship with silt, porosity and SO_4^{--}. Similar results are more or less comparable with those recorded in some other habitats [6,45,49,18].

4. CONCLUSION

The present study provides an analysis of floristic composition and vegetation structure of *Z. coccineum* community in coastal and inland desert of Egypt to help in management and conservation of these natural resources. *Z. coccineum* is the most famous *Zygophyllum* species in Egypt and Saudi Arabia. It shows wide soil range and occupies diverse habitats. Therefore, the conservation of natural habitats of this desert is vital importance. The recorded 79 plant species in the present study can play a vital role in the economic and medicinal purposes. Hence, the Egyptian desert need for judicious utilization and sustainable development.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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