Vegetation and Species Diversity in the Northern Sector of Eastern Desert, Egypt

Y. A. El-Amier* and O. M. AbdulKader
Department of Botany, Faculty of Science, Mansoura University, Mansoura, Egypt
*Corresponding author; E-mail: yasran@mans.edu.eg, elamier76@yahoo.com

Abstract

The study aims to assess the vegetation and plant diversity in relation to edaphic factors at three sites (Cairo- Suez, Ain Sokhnia-Makattam desert roads and Wadi Hagul) in northern sector of Eastern Desert. The results revealed that northern sector of Eastern Desert (The Galalah Desert) harbors had 95 species (36 annuals, two biennial and 57 perennials) with high taxonomic diversity (species/genera = 1.17 and genera/families = 3.12). The largest families were Asteraceae comprising 22 species, followed by Poaceae, 11 species, Brassicaceae and Chenopodiaceae, 7 species each, Fabaceae 6 species, Zygophyllaceae, 5 species. *Zilla spinosa* and *Zygophyllum coccineum* had a wide ecological range of distribution (P = 63.3% and 61.7%, respectively). On the other hand, *Zygophyllum simplex, Matthiola longipetala* and *Senecio glaucus* showed the highest presence estimates among annuals (P = 38.3%, 31.7% and 30%, respectively). Species richness, Shannon-Weiner H and Simpson indices measurements indicated that group D and B are the most diverse group followed by group A and C in the present study. The main dominant species include *Haloxylon salicornicum, Launaea nudicaulis, Zilla spinosa* and *Zygophyllum coccineum*. Soil physical properties in addition to soil salinity and human activities are the main driving factors controlling the distribution of wild plants in the northern sector of Eastern Desert.

Introduction

The Egyptian desert is among the most arid parts of the world characterized by arid and, or extreme arid climate. Vegetation is, thus, continuously exposed to extreme and drastic environmental condition (Batanouny, 1979; Zahran & Willis, 2009). Egyptian deserts, the subject area of this study, comprise the desert east of the Nile which will be referred to as the "Eastern Desert". According to Eig (1931–1932), three floral provinces are represented in Egypt: 1. The Saharo-Sindian province, comprising most of the deserts of Egypt, 2. The Irano-Turanian province, and 3. The Sudano-Deccanian province. The plant life in the Eastern Desert is much richer than that of the Western Desert. The flora of the northern wadis and mountains of the Eastern Desert, west of the Gulf of Suez, have strong relations with that of the Sinai Peninsula (Bolous, 2008).Two major phytogeographical regions are usually recognized within the Eastern Desert: the Red Sea coastal region and the inland desert.

Kassas (1952) classified the desert vegetation into two groups: ephemerals and perennials. The ephemerals are active only in the vernal aspect of the vegetation. The appearance of ephemerals and duration of their life are dependent on the chance occurrence of rainy seasons. The perennials are linked to the stands which they occupy, and are governed by the whole complex of physical and biotic conditions. The perennial plant cover forms the permanent framework of the desert vegetation, and is the best indicator of the habitat conditions.

On the other hand, the desert vegetation in Egypt is by far the most important and characteristic type of natural plant life. It covers about 95% of the total area of the country, and is mainly formed of xerophytic shrubs and sub-shrubs. Monod (1954) recognized two types of desert vegetation, namely contracted and diffuse. Both types refer to permanent vegetation that can be accompanied by ephemeral (or annual) plant growth depending on the amount of precipitation in a given year. Kassas (1966, 1971) added a third type termed "accidental vegetation", where precipitation is so low and falls so irregularly that no permanent vegetation exists. The most critical gradients in abiotic factors may be related to water availability, including annual precipitation, soil properties, and topography (Parker, 1991). Correlation of soils and vegetation are important for most investigations of plant habitats. In the arid regions of the Middle East, Hillel & Tadmor (1962), Kassas & Girgis (1965), Olsvig-Whittaker *et al.* (1983), Stahr *et al.* (1985), Abd El-Ghani (1997, 1998, 2000), Masoud & Koike (2006) and Salama *et al.* (2012, 2013, 2014) worked in this direction. The present study aims to assess the vegetation and plant diversity in relation to edaphic factors at three sites (Cairo-Suez, Ain Sokhnia-Makattam desert roads and Wadi Hagul) in the northern sector of Eastern Desert.

Materials and methods

Study area

The Eastern Desert of Egypt occupies the area extending from the Nile Valley eastward to the Gulf of Suez and the Red Sea, which is about 223,000 km^2, i.e. 21% of the total area of Egypt. On the other hand, Cairo-Suez, Ain Sokhnia-Makattam desert roads and Wadi Hagul are located in the northern part of the Eastern Desert of Egypt (The Isthmic Desert), which extends east of the Nile Delta (Fig. 1). These three localities represent the natural xeric habitat which is mainly inhabited by xerophytic vegetation. The gravel desert is one of the most characteristic features of these roads. While, Wadi Hagul occupies the valley depression between Gebel Ataqa to the north and the Kahaliya ridge to the south. Its main channel extends for about 35 km, collects drainage on both sides and debouch into the Gulf of Suez. It is characterized by local physiographic variations and physiognomic heterogeneity.

The application of several methods suggested for the classification of climate indicates that the Cairo Suez, Ain Sokhnia-Makattam desert roads and Wadi Hagul belong to arid or extreme arid climate (Thornthwaite, 1948; Meig, 1953; Emberger, 1955). Meteorological data of the Cairo and Suez District shows that the climate of this region is obviously hot and dry. The low rainfall and high temperature are the main aspects of its aridity (Table 1).

Vegetation survey

Vegetation survey and assessing the ecological situation of plants were carried out in year 2013 at three sites (Cairo-Suez, Ain Sokhnia-Makattam desert roads and Wadi Hagul) in two governorates of Egypt. Sixty stands (area = 10 m × 10 m) have been selected for sampling vegetation as follows: 30 stands in Cairo-Suez road, 15 stands in Wadi Hagul and 15 stands in Ain Sokhnia-Makattam road. These stands were randomly chosen at locations where considerable vegetation cover was encountered.

The density and cover of each species have been estimated in each selected stand
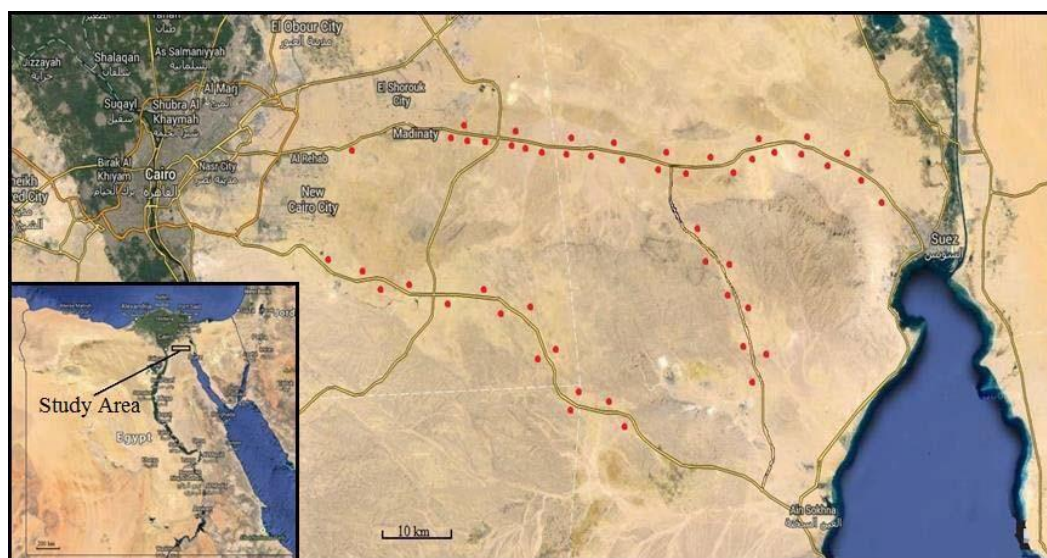
Fig. 1. Map of the Egypt showing different localities (*) in northern part of Eastern Desert of the study area.

TABLE 1

Long-term averages (≥ 20 years) of the climatic records at two stations in northern sector of Eastern Desert (Anonymous, 1980)

Meteorological variable	Cairo 31º 242 N, 30º 252 E		Suez 31º 332 N, 31º 052 E	
	Range	Mean	Range	Mean
Maximum air temperature (ºC)	20.5–34.7	28.0	19.2–34.6	27.6
Minimum air temperature (ºC)	8.8–21.8	15.6	10.4–24.1	17.6
Mean air temperature (ºC)	13.6–27.7	21.4	14.7–28.9	15.8
Relative humidity (%)	42.0–61.0	53.0	42.0-56.0	51.0
Evaporation (mm/day)	7.4-17.0	11.8	7.4–15.4	11.5
Rainfall (mm/month)	0.0–6.6	-	0.0–6.2	-

(Canfield, 1941). Relative values of density and cover were calculated for each plant species and summed up to give an estimate of its important value (IV) in each stand which is out of 200. Nomenclature, identification and floristic categories were carried out according to Zohary (1966, 1972), Tackholm (1974), Feinbrun-Dothan (1978, 1986) and Boulos (1999, 2005). Life forms were identified according to the scheme of Raunkiaer (1937).

Soil analysis

Sixty surface soil samples were collected as a mixture from zero to 25 cm in depth. They were air-dried and sieved through 2- mm sieve to obtain representative sub-samples (fine soil) for physical and chemical analyses. Soil texture, water holding capacity (WHC), soil porosity, organic carbon and sulphate were determined according to Piper (1947). Calcium carbonate content was determined by titration against 1 *N* NaOH

and expressed as a percentage (Jackson, 1962). Determination of electric conductivity and *p*H was determined in soil-water (1:5) extracts by the method adopted by Jackson (1962). Carbonates and bicarbonates were determined by titration using 0.1 *N* HCl (Pierce *et al.*, 1958). Sodium and potassium were determined by flame photometry, while calcium and magnesium were estimated using atomic absorption spectrometer (Allen *et al*., 1974).The sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) were calculated to express the combined effects of different ions in the soil (Mckell & Goodin, 1984).

Data analysis

A floristic data matrix of 60 stands and 95 species was subjected for classification by two way indicator species analysis (TWINSPAN, version 2.3) and Detrended Correspondence Analysis (DCA) into groups (Hill & Smilauer, 2005). The relation between the vegetation and soil gradients was assessed using Canonical Correspondence Analysis (CCA) (ter Braak, 1987). Plant diversity indices included species richness (SR), Shannon-Weiner diversity index (H´) and Simpson index. These diversity indices were estimated for each vegetation group (Whittaker, 1972; Pielou, 1975; Magurran, 1988). Taxonomic diversity including species/ genera and genera/families ratios for studied area as a whole was determined (Wilson & Schmida, 1984). Linear correlations coefficient (*r*) was calculated for assessing the relationship between the estimated soil variables on one hand and the community variables, on the other hand. The obtained data were statistically evaluated using SPSS 16 for Windows.

Results

Floristic analysis

The total number of the recorded plant species surveyed in the present study is 95 species (36 annuals, two biennial and 57 perennials) belonging to 81 genera and related to 26 families. The largest families were Asteraceae comprising 22 species, followed by Poaceae 11 species, Brassicaceae and Chenopodiaceae, seven species each, Fabaceae, six species, Zygophyllaceae comprising five species, Asclepiadaceae and Caryophyllaceae comprising four species each. Other families were represented in different numbers of species.

Taxonomic diversity of study area is 1.17 for species/genera ratio and 3.12 for genera/ families. Generally, the family size is small: 24 families have less than 10 species and only two families have more than 10 species. Obviously, genus with higher number of species included *Launaea* (4 species). Another nine genera were represented by two species, including, amongst others, *Artemisia, Bassia, Cleome* and *Plantago* (Table 2).

According to Raunkiaer (1934) the life-forms of the species recorded are grouped under six types. The majority of the recorded species are therophytes (36 species = 37.89%) followed by chamaephytes (31 species = 32.63%) then hemicryptophytes (14 species = 14.74%), phanerophytes (12 species = 12.63%) and geophytes (4 species = 21.34%). The lowest value of life-forms is recorded as helophytes which attained value of 1.10%.

Two of the recorded species have a wide ecological range of distribution. *Zilla spinosa* and *Zygophyllum coccineum* and had the highest presence values (*P* = 63.3% and

Floristic composition of the recorded species in northern part of Eastern Desert, Egypt. P%, presence of values; Per, perennials; Bi, Biannual; Ann, annuals; Ph, Phanerophytes; H, Hemicryptophyte; Ch, Chemaephytes; Th, Theophytes; G, Geophytes; P, Parasites; COSM, Cosmopolitan; NEO, Neotropical SA-SI, Saharo-Sindian; S-Z, Sudano-Zambezian; IR-TR, Irano-Turanian; ER-SR, Euro-Siberian; ME, Mediterranean.

Species	Duration	Life form	Chorology	P%
Aizoaceae				
Aizoon canariense L.	Ann	Th	SA-SI+S-Z	3.3
Mesembryanthemum forsskaolii Hochst. Ex Boiss.	Ann	Ph	SA-SI	11.7
Amaranthaceae				
Aerva javanica (Burm.F.) Juss. ex. Schult.	Per	Ch	SA-SI + S-Z	1.7
Asciepiadaceae				
Calotropis procera (Willd.) R.Br.	Per	Ph	SA-SI + S-Z	1.7
Cynanchum acutum L.	Per	H	ME+IR-TR	6.7
Leptadenia pyrotechnica (Forrsk.) Decne.	Per	Nph	SA-SI	5.0
Pergularia tomentosa L.	Per	Ch	SA-SI	1.7
Asteraceae				
Achillea fragrantissima (Forssk.)Sch.Bip.	Per	Ch	IR-TR+SA-SI	5.0
Anthemis cotula L.	Ann	Th	ME	8.3
Artemisia judiaca L.	Per	Ch	SA-SI	5.0
Artemisia monosperma Delile.	Per	Ch	ME+SA-SI	1.7
Atractylis carduus (Forssk.) C.Chr.	Per	H	SA-SI+ME	6.7
Centaurea aegyptiaca L.	Bi	Th	SA-SI	23.3
Echinops spinosus L.	Per	H	ME+SA-SI	20.0
Francoeuria crispa (Forssk.) Cass.	Per	Ch	SA-SI+S-Z	3.3
Ifloga spicata (Forssk.) Sch.Bip.	Ann	Th	SA-SI	8.3
Iphiona mucronata (Forssk.) Asch. & Schweinf.	Per	Ch	SA-SI	10.0
Lactuca serriola L	Ann	Th	ME+IR-TR+ER-SR	1.7
Launaea capitata (Spreng) Dandy	Bi	Th	SA-SI + S-Z	5.0
Launaea mucronata (Forssk.) Muschl.	per	H	ME+SA-SI	13.3
Launaea nudicaulis (L.) Hook.f.	Per	H	SA-SI	40.0
Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze.	Per	Ch	SA-SI	16.7
Nauplius graveolens (Forssk.) Wilklund	Per	Ch	SA-SI	3.3
Pluchea dioscoridis (L.)DC.	Per	Nph	SA-SI + S-Z	3.3
Pulicaria undulate (L.) C. A. Mey.	Per	Ch	SA-SI	13.3
Reichardia tingitana (L.) Roth.	Ann	Th	ME+IR-TR	15.0
Senecio glaucus L.	Ann	Th	ME+IR-TR+SA-SI	30.0
Symphyotrichum squamatum (Spreng.) Nesom	Per.	Ch	NEO	3.3
Volutaria lippii	Ann	Th	SA-SI	8.3
Boraginaceae				
Alkanna lehmanii (Tin.) A.DC.	Per	H	ME	5.0
Heliotropium curassavicum L.	Per	Ch	NEO	1.7
Trichodesma africanum (L.) R.Br.	Per	H	SA-SI+S-Z	8.3
Brassicaceae				
Brassica tournefortii Gouan.	Ann	Th	ME+IR-TR+SA-SI	1.7
Diplotaxis harra (Forssk.) Boiss.	Per	Ch	ME+ SA-SI	35.0

Erysimum repandum L.	Ann	Th	ME+IR-TR+ER-SR	3.3
Farsetia aegyptia Turra.	Per	Ch	SA-SI + S-Z	18.3
Lepidium draba L.	Per	H	ME+ IR-TR	3.3
Matthiola longipetala (Vent.)DC.	Ann	Th	ME+IR-TR	31.7
Zilla spinosa (L.)Prantl.	Per	Ch	SA-SI	63.3
Caryophyllaceae				
Gypsophilla capillaris (Forssk.) C.Chr	Per	H	IR-TR+SA-SI	11.7
Polycarpaea repens (Forssk.)Asch.	Per	Ch	SA-SI	3.3
Spergularia media (L.) C. Presl	Per	H	ME+IR-TR+ER-SR	1.7
Herniaria hemistemon J. Gay	Ann	Th	ME+ SA-SI	
Chenopodiaceae				
Anabasis articulata (Forssk.) Moq.	Per	Ch	IR-TR+SA-SI	13.3
Atriplex lindleyi Moq.subsp. *Inflate* (F.Muell.)Wilson.	Ann	Th	ME+IR-TR+ER-SR	3.3
Bassia indica (Wight) Scott.	Ann.	Th	IR-TR+S-Z	10.0
Bassia muricata (L.) Asch.	Ann	Th	IR-TR+SA-SI	16.7
Chenopodium murale L.	Ann	Th	COSM	11.7
Haloxylon salicornicum (Moq.)Bunge ex Boiss.	Per	Ch	SA-SI	15.0
Salsola kali L.	Ann	Th	COSM	1.7
Cleomaceae				
Cleome amblyocarpa Barratte &Murb.	Ann	Th	SA-SI	1.7
Cleome droserifolia (Forssk.) Delile	Per	Ch	IR-TR+SA-SI	1.7
Convolvulaceae				
*Convolvulus lanatus*Vahl.	Per	Ch	SA-SI	3.3
Euphorbiaceae				
Euphorbia retusa Forssk.	Ann	Th	SA-SI	
Fabaceae				
Astragalus bombycinus Boiss.	Ann	H	IR-TR+SA-SI	10.0
Astragalus spinosus (Forssk.) Muschl.	Per	Ch	IR-TR+SA-SI	1.7
Crotalaria aegyptiaca Benth.	Per	Ch	SA-SI	10.0
Lotus glinoides Delile.	Ann	Th	S-Z	11.7
Retama raetam (Forssk.) Webb &Berthel.	Per	Nph	SA-SI	18.3
Trigonella stellata Forssk.	Ann	Th	IR-TR+SA-SI	16.7
Geraniaceae				
Erodium laciniatum (Cav.) Wild.	Ann	Th	ME	28.3
Poaceae				
Cyondon dactylon (L.) Pers.	Per	G	COSM	8.3
Hordeum murinum L.	Ann	Th	ME+IR-TR+ER-SR	3.3
Hordeum spontaneum K. Koch	Ann	Th	ME+IR-TR	5.0
Lasiurus scindicus Henrard.	Per	G	SA-SI+S-Z	13.3
Lolium multiflorum Lam.	Ann	Th	ME+IR-TR+ER-SR	3.3
Panicum coloratum L.	Per	G	SA-SI	5.0
Panicum turgidum Forssk.	Per	H	SA-SI	10.0
Parapholis incurve (L.) C.E.Hubb.	Ann	Th	ME+IR-TR+ER-SR	1.7
Phragmites australis (Cav.) Trin.exSteud.	Per	G, He	COSM	6.7
Poa annua L.	Ann	Th	COSM	8.3
Lamiaceae				
Lavandula coronopifolia Poir.	Per	Ch	SA-SI	6.7
Malvaceae				
Malva parvifolra L.	Ann	Th	ME+IR-TR	15.0

Neuradaceae				
Neurada procumbense L.	Ann	Th	SA-SI + S-Z	3.3
Plantaginaceae				
Plantago lagopus L.	Ann.	Th	ME+IR-TR	3.3
Plantago notate Lag.	Ann.	Th	IR-TR+SA-SI	8.3
Polygonaceae				
Calligonum polygonoides L.	Per	Nph	IR-TR+SA-SI	1.7
Emex spinosa (L.) Campd.	Ann	Th	ME+SA-SI	15.0
Rumex vesicarius L.	Ann	Th	ME+SA-SI+S-Z	26.7
Resedaceae				
Ochradenus baccatus Delile.	Per	Nph	SA-SI	33.3
Reseda decursiva Forssk.	Ann	Th	SA-SI	6.7
Rutaceae				
Haplophyllum tuberculatum (Forssk.) Juss.	Per	H	SA-SI	3.3
Scrophulariaceae				
Kickxia aegyptiaca (L.) NÜbelek.	Per	Ch	ME+SA-SI	3.3
Scophularia deserti Delile	Per	Ch	SA-SI	1.7
Solanaceae				
Hyoscyamus muticus L.	Per	Ch	SA-SI	11.7
Lycium shawii Roem. & Schult.	Per	Nph	SA-SI+S-Z	5.0
Tamaricaceae				
Tamarix aphylla (L.) H. Karst.	Per	Nph	SA-SI+S-Z	5.0
Tamarix nilotica (Ehrenb.) Bunge.	Per	Nph	SA-SI	15.0
Apiaceae				
Deverra tortuosa (Desf.) DC.	Per	Ch	SA-SI	6.7
Urticaceae				
Forsskaolea tenacissima L.	Per	H	SA-SI + S-Z	1.7
Zygophyllaceae				
Fagonia Arabica L.	Per	Ch	SA-SI	13.3
Fagonia mollis Delile.	Per	Ch	SA- SI	13.3
Zygophyllum coccineum L.	Per	Ch	SA-SI	61.7
Zygophyllum decumbens Delile.	Per	Ch	SA- SI	13.3
Zygophyllum simplex L.	Ann	Th	SA-SI	38.3

61.7%, respectively). On the other hand, *Zygophyllum simplex, Matthiola longipetala* and *Senecio glaucus* showed the highest presence estimates among annuals (P = 38.3%, 31.7% and 30%, respectively).

Chorological affinities

Chorological analysis of the surveyed flora (Table 3) revealed that 25 species (26.32% of the total flora) were bi- and pluriregional Mediterranean elements. Monoregional chorotypes extending their distribution all over the Saharo-Sindian, Sudano-Zambezian, and Mediterranean regions amounted to 40% of the recorded flora. On the other hand, Cosmopolitan and Neotropical chorotypes constituted seven species. While Saharo-Sindian chorotype, either pure or penetrated into other regions, was represented by 69 species of the total recorded flora.

Classification of vegetation

The application of TWINSPAN classification on 95 plant species recorded in 60 stands representing the study area yielded four vegetation groups (Fig. 2). Five species were recorded with variable presence values in the four groups. It included three annuals (*Zygophyllum*

simplex, Rumex vesicarius and *Erodium laciniatum*) and two perennials (*Launaea nudicaulis* and *Lasiurus scindicus*).

Group (A): Launaea nudicaulis group

It is the smallest among the separated vegetation groups. It comprised of 24 species recorded from four stands, with the lowest species richness of 1.58 species/stands, Simpson index 0.88 and Shannon-Wiener diversity index of 2.48. Stands of this group inhabited soil rich in its soil texture (clay and silt), SAR, Na$^+$ and *p*H (Table 4). The abundant species include *Cyondon dactylon* (IV = 26.19), *Cynanchum acutum* (IV = 19.04) and *Pluchea*

dioscoridis (IV = 17.67) (Table 5).

Group (B): Haloxylon salicornicum group

The 62 species in this group were recorded from 14 stands, with average species richness of 2.32 species/stand, Simpson index 0.96 and Shannon diversity index of 3.52. The stands of this group inhabited soil with water-holding capacity, bicarbonate and CaCO3 (Table 4). Sixteen sporadic species (or about 25.81% of the recorded species in this group) were recorded which included, amongst others, *Aizoon canariense, Astragalus spinosus, Calligonum polygonoides, Calotropis procera, Fagonia mollis* and *Gypsopila capillaris* (Table 5).

TABLE 3

Number of species and percentage of various floristic categories of the study area. COSM, Cosmopolitan; NEO, Neotropical; SA-SI, Saharo-Sindian; S-Z, Sudano-Zambezian; IR-TR, Irano-Turanian; ER-SR, Euro-Siberian; ME, Mediterranean.

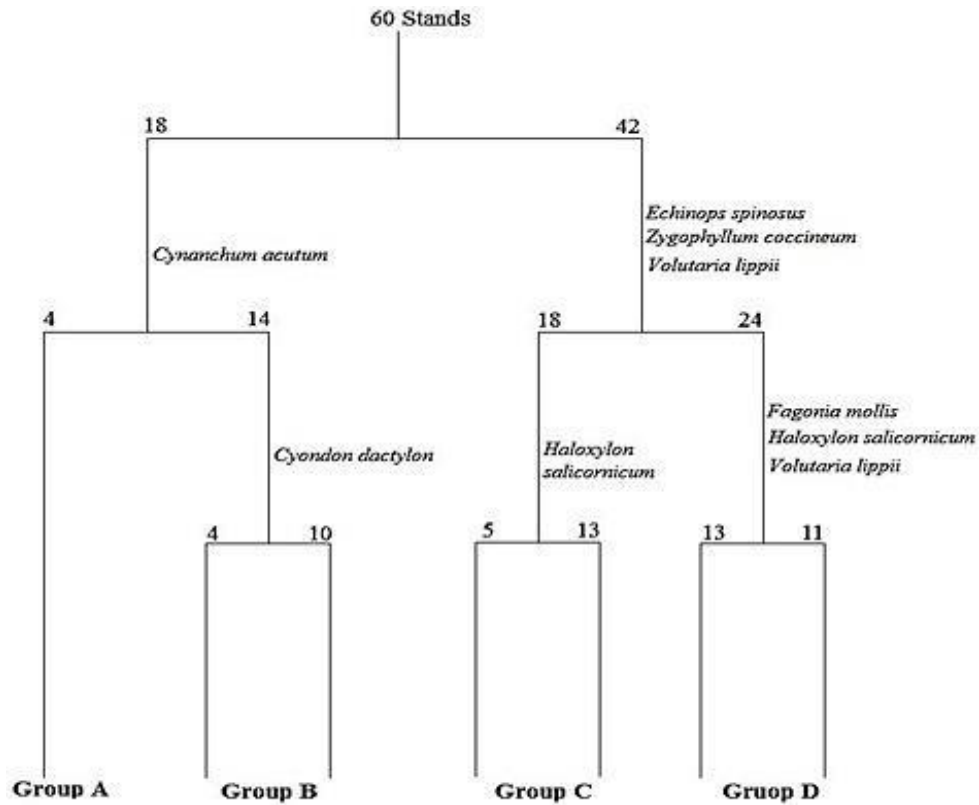| Floristic category	Total number	Percentage	Type
COSM	5	5.26	World wide
NEO	2	2.11	
Sum	7	7.37	
ME	3	3.16	Monoregional
SA-SI	34	35.79	
S-Z	1	1.05	
Sum	38	40.00	
ME+ SA-SI	8	8.42	Biregional
ME+IR-TR	7	7.37	
SA-SI+IR-TR	10	10.53	
S-Z+IR-TR	1	1.05	
S-Z+SA-SI	14	14.74	
Sum	40	42.11	
ME+IR-TR+ER-SR	7	7.37	Pluriregional
ME+IR-TR+SA-SI	2	2.11	
ME+ SA-SI +S-Z	1	1.05	
Sum	10	10.53	
Total	95	100	

Fig. 2. TWINSPAN dendrogram of the 60 sampled stands based on the important values of species

The abundant species include *Diplotaxis harra* (IV = 14.32), *Zygophyllum coccineum* (IV = 13.47), *Senecio glaucus* (IV = 12.44) and *Zygophyllum simplex* (IV = 12.40).

Group (C): Zygophyllum coccineum group

The group size of this group was represented by 18 stands that included 45 species. The average species richness in this group is 1.69 species/stands, Simpson index 0.92 and Shannon-Wiener diversity index of 3.0. The stands of this group inhabited soil with the highest content of sand, porosity and lowest content of sulphates (Table 4). Sporadic species included 17 species, of

which *Aerva javanica*, *Anthemis cotula*, *Cleome amblyocarpa*, *Deverra tortuosa* and *Erodium laciniatum* were included (Table 5). The abundant species include *Haloxylon salicornicum* (IV = 27.27), *Zygophyllum simplex* (IV = 23.05), *Zilla spinosa* (IV = 20.48) and *Ochradenus baccatus* (IV = 16.11).

Group (D): Zilla spinosa group

This group was the most diversified among the recognized groups. It comprised 65 species recorded from 24 stands, with average species richness of 2.43 species/ stands, Simpson index 0.97 and Shannon-Wiener diversity index of 3.76. It inhabited soil with the highest water-holding capacity,
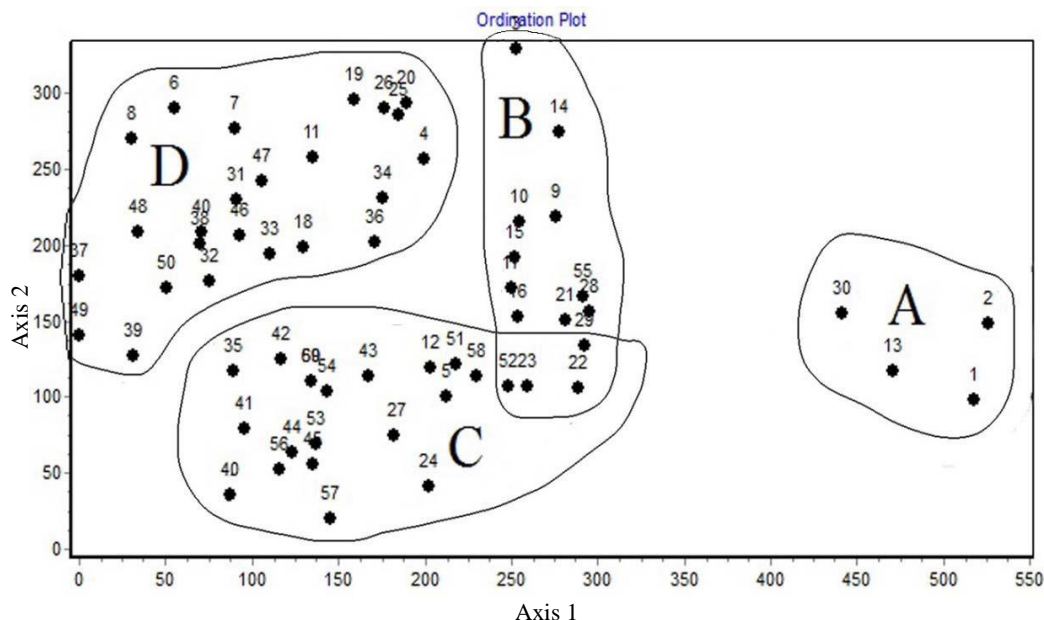
Fig. 3. The detrended correspondence analysis (DCA) ordination diagram of the 60 sampled stands

bicarbonate and $CaCO_3$ (Table 4). Sporadic species comprised 15 species (or about 23% of the recorded species of this group) which included, amongst others, *Alkanna lehmanii, Artemisia monosperma, Astragalus bombycinus, Cleome droserifolia, Convolvulus lanatus, Heliotropium curassavicum* and *Herniaria hemistemon* (Table 5). The abundant species in this group include *Ochradenus baccatus* (IV = 16.69), *Haloxylon salicornicum* (IV = 13.55) and *Retama raetam* (IV = 13.58).

The ordination of sampled stands given by DCA is shown in Fig. 3. It is clear that the vegetation groups obtained by TWINSPAN classification were markedly distinguishable and having a comprehensible pattern of segregation on the ordination plane, where the group A separated at the lower part of the right side of the DCA diagram, Group A is clearly separated from other groups (B, C and D), the group B segregated

at the middle part, while group C and D are separated at the lift side of the DCA diagram.

Soil-vegetation relationships

Significant differences in the examined soil variables within the separated vegetation groups were demonstrated in Table 4. The soil texture in all groups is formed mainly of coarse fraction (sand) and partly of fine fractions (silt and clay). Water-holding capacity, pH, bicarbonate, sodium, potassium, calcium, magnesium, sodium and potassium adsorption ratio 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), porosity, calcium carbonate, organic carbon, EC, chloride and sulphate.

The correlation coefficient (r) between the different soil variables in the sampled stands are shown in Table 6. It has been

TABLE 4

Mean values and standard error of the different soil variables in the stands representing the different vegetation groups (A–D) obtained by TWINSPAN classification in the study area.

Soil variable		Vegetation group				Mean	F-ratio	LSD$_{0.05}$
		A	B	C	D			
Sand	(%)	$88.43^a \pm 5.87$	$91.84^a \pm 1.70$	$88.07^a \pm 1.34$	$90.67^a \pm 1.31$	89.75	0.24^{ns}	11.47
Silt		$10.42^a \pm 5.50$	$6.95^a \pm 1.53$	$10.40^a \pm 1.25$	$8.07^a \pm 1.25$	8.96	0.21^{ns}	10.81
Clay		$1.15^a \pm 0.43$	$1.21^a \pm 0.21$	$1.53^a \pm 0.17$	$1.29^a \pm 0.20$	1.30	1.1^{ns}	0.81
Porosity		$33.10^a \pm 3.54$	$32.14^{ab} \pm 1.35$	$29.84^b \pm 1.23$	$31.62^{ab} \pm 0.99$	31.68	3.34^{ns}	4.64
WHC		$29.25^a \pm 1.60$	$28.01^c \pm 1.29$	$27.41^c \pm 1.34$	$28.81^b \pm 1.28$	28.37	56.89^{***}	0.64
CaCO$_3$		$13.39^b \pm 6.01$	$14.62^b \pm 2.29$	$28.87^a \pm 2.67$	$18.89^{ab} \pm 2.72$	18.94	2.76^{ns}	13.85
OC		$0.29^a \pm 0.09$	$0.22^{ab} \pm 0.04$	$0.12^b \pm 0.01$	$0.18^{ab} \pm 0.02$	0.20	2.65^{ns}	0.18
pH		$8.12^a \pm 0.08$	$7.98^b \pm 0.05$	$7.97^b \pm 0.06$	$8.10^{ab} \pm 0.05$	8.04	4.50^*	0.15
EC (µmhos/cm)		$626.15^a \pm 301.75$	$503.25^a \pm 113.64$	$471.86^a \pm 63.35$	$441.29^a \pm 69.10$	510.64	$0.47ns$	305.86
Cl$^-$	(%)	$0.45^a \pm 0.24$	$0.35^a \pm 0.15$	$0.06^a \pm 0.03$	$0.17^a \pm 0.05$	0.26	$1.91ns$	0.51
SO$_4^{--}$		$0.56^a \pm 0.28$	$0.32^a \pm 0.09$	$0.21^a \pm 0.05$	$0.22^a \pm 0.04$	0.33	$1.93ns$	0.55
CO$_3^{--}$		$0.65^a \pm 0.38$	$0.40^a \pm 0.15$	$0.49^a \pm 0.15$	$0.40^a \pm 0.13$	0.48	$0.10ns$	0.58
HCO$_3^-$		$0.81^b \pm 0.27$	$0.83^b \pm 0.15$	$1.33^a \pm 0.21$	$0.89^b \pm 0.09$	0.97	9.55^{**}	0.33
Na$^+$	mg /100g	$272.70^c \pm 248.70$	$195.55^{ab} \pm 77.69$	$178.08^b \pm 37.71$	$202.54^a \pm 51.23$	212.22	139.49^{***}	23.38
K$^+$	dry soil	$30.32^c \pm 25.89$	$21.82^b \pm 7.92$	$20.02^b \pm 3.50$	$26.58^a \pm 5.59$	24.69	105.16^{***}	3.05
Ca^{++}		$77.86^c \pm 71.37$	$57.16^b \pm 22.69$	$53.94^b \pm 11.03$	$74.02^a \pm 16.45$	65.74	180.5^{***}	7.03
Mg^{++}		$37.79^d \pm 34.51$	$26.01^b \pm 10.70$	$23.18^c \pm 3.97$	$32.72^a \pm 7.31$	29.93	359.63^{***}	2.18
SAR		$24.73^b \pm 15.00$	$24.70^a \pm 4.90$	$25.61^a \pm 3.23$	$23.73^a \pm 3.79$	24.69	20.73^{***}	5.32
PAR		$3.38^b \pm 1.34$	$3.13^a \pm 0.42$	$3.15^a \pm 0.22$	$3.36^a \pm 0.34$	3.26	13.22^{**}	0.53
Species richness		$1.58^d \pm 0.6$	$2.32^b \pm 0.8$	$1.69^c \pm 0.4$	$2.43^a \pm 0.9$	2.01	2.02^{***}	9.92
Simpson index		$0.88^d \pm 0.21$	$0.96^b \pm 0.11$	$0.92^c \pm 0.22$	$0.97^a \pm 0.31$	0.93	4.68^{***}	6.12
Shannon-Wiener index		$2.48^d \pm 0.64$	$3.52^b \pm 0.72$	$3.01^c \pm 0.51$	$3.76^a \pm 0.32$	3.19	1.17^{***}	1.72

ns = not significant at $P \leq 0.05$. *: Values are significant at $P \leq 0.05$, **: values are significant at $P < 0.01$, ***: values are significant at $P \leq 0.01$. Different superscript letters indicate a significant difference at $P \leq 0.05$.

TABLE 5

Floristic composition in the vegetation groups in the study area. Values in bold are species with highest presence values.

Vegetation groups	A	B	C	D
Total numbers of stands	4	14	18	24
Total numbers of species	24	62	45	65
Achillea fragrantissima (Forssk.) Sch.Bip.	-	-	-	0.85
Aerva javanica (Burm.F.) Juss. ex Schult.	-	-	0.34	-
Aizoon canariense L.	-	2.11	-	0.14
Alkanna lehmanii (Tin.) A.DC.	-	0.69	-	0.20
Anabasis articulata (Forssk.) Moq.	-	3.16	3.16	3.76
Anthemis cotula L.	1.82	1.07	0.30	-
Artemisia monosperma Delile.	-	-	-	0.29
Artemisia judiaca L.	-	-	-	1.29
Astragalus bombycinus Boiss.	3.69	0.95	-	0.56
Astragalus spinosus (Forssk.) Muschl.	-	1.41	-	-
Atractylis carduus (Forssk.) C.Chr.	-	-	-	1.38
Atriplex lindleyi Moq.subsp. *inflata* (F.Muell.) Wilson.	-	1.30	-	0.00
Bassia indica (Wight) Scott.	8.88	-	1.50	1.50
Bassia muricata (L.)Asch.	-	11.97	-	-
Brassica tournefortii Gouan.	7.93	-	-	-
Calligonum polygonoides L. subsp. *comosum* (L. Hér.) Soskov	-	1.46	-	-
Calotropis procera (Willd.) R.Br.	13.53	1.29	2.66	-
Centaurea aegyptiaca L.	-	0.68	4.02	3.31
Chenopodium murale L.	2.06	3.70	0.00	0.00
Cleome amblyocarpa Barratte & Murb.	-	-	0.57	-
Cleorne droserifolia (Forssk.) Delile	-	-	-	0.38
Convolvulus lanatus Vahl.	5.03	-	-	0.60
Crotalaria aegyptiaca Benth.	-	-	-	5.38
Cynanchum acutum L.	19.04	-	-	-
***Cyondon dactylon* (L.) Pers.**	26.19	2.13	-	-
Deverra tortuosa (Desf.)DC.	-	-	0.52	5.43
Diplotaxis harra (Forssk.) Boiss.	-	14.32	3.41	3.12
Echinops spinosus L.	-	-	-	8.15
Emex spinosa (L.) Campd.	5.39	2.32	1.20	0.00
Erodium laciniatum (Cav.) Wild.	1.87	6.99	0.62	2.34
Erysimum repandum L.	-	0.81	-	-
Euphorbia retusa Forssk.	-	3.24	2.59	1.01
Fagonia arabica L.	-	1.52	6.77	0.68
Fagonia mollis Delile.	-	2.57	-	6.71
Farsetia aegyptia Turra.	-	2.32	4.70	2.57
Forsskaolea tenacissima L.	-	-	-	1.94
Gypsopila capillaris (Forssk.) C.Chr	-	0.68	0.80	2.02
***Haloxylon salicornicum* (Moq.) Bunge ex Boiss.**	-	19.21	27.27	13.55
Haplophyllum tuberculatum (Forssk.) Juss.	-	-	-	0.67
Heliotropium curassavicum L.	-	-	-	0.26
Herniaria hemistemon J. Gay	-	-	-	0.08

Hordeum murinum L.	-	0.48	0.43	-
Hordeum spontaneum K. Koch	-	1.35	-	0.42
Hyoscyamus muticus L.	-	1.29	0.54	2.99
Ifloga spicata (Forssk.) Sch.Bip.	-	0.42	0.22	0.80
Iphiona mucronata (Forssk.) Asch. & Schweinf.	-	-	-	3.16
Kickxia aegyptiaca (L.) NÜbelek.	-	-	0.23	0.44
Lactuca serriola L	-	0.29	-	-
Lasiurus scindicus Henrard.	3.18	1.74	1.62	1.02
Launaea capitata (Spreng) Dandy	-	-	1.00	0.80
Launaea mucronata (Forssk.) Muschl.	-	3.21	0.83	-
***Launaea nudicaulis* (L.) Hook.f.**	34.21	4.50	4.97	7.47
Launaea spinosa (Forssk.)Sch. Bip. ex Kuntze.	-	-	4.04	6.58
Lavandula coronopifolia Poir.	-	-	-	2.48
Lepidium draba L.	0.98	0.19	-	-
Leptadenia pyrotechnica (Forrsk.) Decne.	-	-	-	5.05
Lolium multiflorum Lam.	-	1.10	-	-
Lotus glinoides Delile.	-	1.57	0.66	0.80
Lycium shawii Roem. & schult.	-	-	-	0.99
Malva parvifolra L.	8.40	4.81	2.00	-
Matthiola longipetala (Vent.) DC.	-	7.71	5.86	1.42
Mesembryanthemum forsskaolii Hochst. Ex Boiss.	-	6.87	-	0.74
Nauplius graveolens (Forssk.)Wilklund	-	-	-	0.54
Neurada procumbense L.	-	0.73	-	-
Ochradenus baccatus Delile.	-	2.59	16.11	16.69
Panicum coloratum L.	6.92	-	-	-
Panicum turgidum Forssk.	-	-	-	6.02
Parapholis incurva (L.) C.E. Hubb.	-	0.86	-	-
Pergularia tomentosa L.	-	-	-	1.80
Phragmites australis (Cav.) Trin. ex Steud.	4.01	1.92	0.29	-
Plantago lagopus L.	12.27	-	-	-
Plantago notata Lag.	-	1.19	0.35	0.40
Pluchea dioscoridis (L.) DC.	17.67	-	-	-
Poa annua L.	-	2.20	-	0.50
Polycarpaea repens (Forssk.) Asch.	-	0.56	-	0.08
Pulicaria incisa (Lam.) DC., Prodr.	-	-	-	2.05
Pulicaria undulata (L.) C.A. Mey.	-	1.19	-	4.72
Reichardia tingitana (L.) Roth.	5.95	2.71	-	-
Reseda decursiva Forssk.	-	1.11	0.52	0.18
Retama raetam (Forssk.) Webb & Berthel.	-	1.42	1.01	13.58
Rumex vesicarius L.	6.77	8.00	2.11	0.95
Salsola kali L.	-	0.56	-	-
Scophularia de serti Delile	-	-	-	0.14
Senecio glaucus L.	-	12.44	3.83	0.15
Spergularia media (L.) C. Presl	-	0.38	-	-
Symphyotrichum squamatum (Spreng.) Nesom	2.16	-	-	0.19
Tamarix aphylla (L.) H. Karst.	-	-	0.92	1.38
Tamarix nilotica (Ehrenb.) Bunge.	-	1.27	0.65	4.82
Trichodesma africanum (L.) R.Br.	-	-	-	1.51
Trigonella stellata Forssk.	-	2.24	4.74	0.98

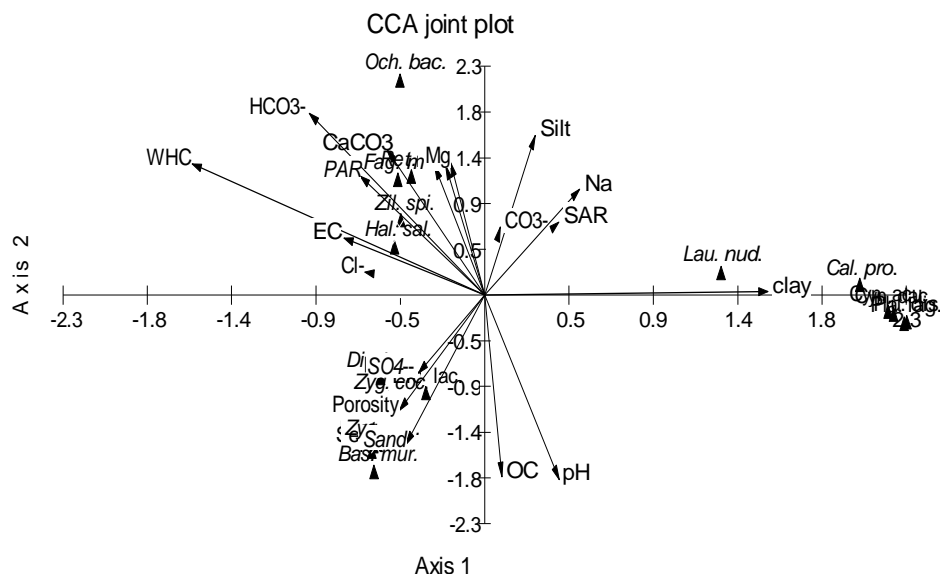|				
Volutaria lippii (L.) Cass. Ex Maire.	-	-	2.70	1.71
***Zilla spinosa* (L.) Prantl.**	-	11.35	20.48	23.36
***Zygophyllum coccineum* L.**	-	13.47	40.39	9.28
Zygophyllum decumbens Delile.	-	-	-	5.39
***Zygophyllum simplex* L.**	2.04	12.40	23.05	0.26

Fig. 4. Canonical Correspondence Analysis (CCA) ordination diagram of plant species with soil variables. The indicator and preferential species are abbreviated to the first three letters of the genus and species, respectively. For plant species abbreviations, see Table 1.

found that some soil variables are significant positively correlated with other soil variables such as silt with clay and calcium carbonate, while clay fraction is significantly correlated with bicarbonate. Calcium carbonate showed high significant correlations with carbonate and bicarbonate, while organic carbon exhibited significant correlations with pH and Mg^{++}. The electrical conductivity showed high significant correlations with Na^+, K^+, Ca^{++}, SAR and PAR. Chloride and carbonate ions showed high significant correlations with sulphates and bicarbonate, respectively. Cations exhibited high significant correlations with each. On the other hand, some other variables have significant negative correlation or none with soil variables such as sand, WHC, porosity, sulphates, bicarbonate and pH.

Correlations of edaphic variables with the important values of the dominant and abundant species are shown in Table 7. Silt and porosity correlated significantly with *Zygophyllum coccineum* ($r = 0.267$) and *Zilla spinosa* ($r = 0.258$), respectively. Calcium carbonate exhibited significant correlations with *Haloxylon salicornicum* ($r = 0.260$), *Zygophyllum coccineum* ($r = 0.440$) and *Zygophyllum simplex* ($r = 0.358$). CO_3 showed significant correlations with

TABLE 6

Correlation matrix between the soil variables in the stands surveyed in the study area.

Soil variables	Sand	Silt	Clay	Por.	WHC	CaCO$_3$	OC	pH	EC
Sand	1								
Silt	-0.994**	1							
Clay	-0.624**	0.532**	1						
Por.	0.308**	-0.334**	0.029	1					
WHC	0.028	-0.031	0.005	0.253*	1				
CaCO$_3$	-0.565**	0.580**	0.220*	-0.137	0.073	1			
OC	0.478**	-0.450**	-0.479**	-0.302**	-0.216*	-0.465**	1		
pH	0.417**	-0.379**	-0.510**	-0.355**	-0.238*	-0.340**	0.753**	1	
EC	0.04	-0.036	-0.018	0.119	0.065	0.109	-0.199*	-0.289**	1
Cl$^-$	0.274**	-0.305**	0.049	0.594**	0.295**	-0.360**	-0.169	-0.204*	-0.037
SO$_4^{--}$	0.300**	-0.314**	-0.092	0.281**	0.16	-0.304**	0.206*	0.005	-0.029
CO$_3^{--}$	-0.550**	0.548**	0.329**	-0.061	0.072	0.481**	-0.371**	-0.283**	0.072
HCO$_3^-$	-0.513**	0.498**	0.406**	0.052	0.035	0.597**	-0.569**	-0.595**	0.233*
Na$^+$	0.169	-0.158	-0.144	-0.252*	-0.376**	-0.206*	0.288**	0.126	0.529**
K$^+$	0.173	-0.164	-0.132	-0.225*	-0.228*	-0.195	0.281**	0.099	0.481**
Ca^{++}	0.165	-0.153	-0.153	-0.269**	-0.250*	-0.156	0.291**	0.11	0.533**
Mg^{++}	0.314**	-0.309**	-0.210*	-0.253*	-0.235*	-0.345**	0.480**	0.255*	0.313**
SAR	-0.349**	0.355**	0.193	-0.081	-0.302**	0.336**	-0.402*	-0.375**	0.562**
PAR	0.087	-0.081	-0.067	-0.222*	-0.242*	-0.098	0.179	0.041	0.506**

TABLE 6 cont'd

Correlation matrix between the soil variables in the stands surveyed in the study area

Soil variables	Cl$^-$	SO$_4^{--}$	CO$_3^{--}$	HCO$_3^-$	Na$^+$	K+	Ca^{++}	Mg^{++}	SAR	PAR
Sand										
Silt										
Clay										
Por.										
WHC										
CaCO$_3$										
OC										
pH										
EC										
Cl$^-$	1									
SO$_4^{--}$	0.474**	1								
CO$_3^{--}$	-0.196	-0.125	1							
HCO$_3^-$	-0.05	-0.159	0.474**	1						
Na$^+$	-0.280**	-0.044	-0.185	-0.149	1					
K$^+$	-0.261**	-0.049	-0.202*	-0.151	0.927**	1				
Ca^{++}	-0.296**	-0.07	-0.228*	-0.134	0.958**	0.973**	1			
Mg^{++}	-0.218*	0.101	-0.282**	-0.294**	0.865**	0.923**	0.905**	1		
SAR	-0.243*	-0.302**	0.136	0.382**	0.543**	0.402**	0.450**	0.105	1	
PAR	-0.277**	-0.125	-0.178	-0.067	0.885**	0.967**	0.933**	0.830**	0.509**	1

Por. = Porosity	OC = Organic carbon	* = Significant at $P < 0.05$
EC = Electrical conductivity	SAR = Sodium adsorption ratio	** = Significant at $P < 0.01$
WHC = Water holding capacity	PAR = Potassium adsorption ratio	

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

Species	Edaphic variable									
	Sand	Silt	Caly	Por.	WHC	CaCO₃	OC	pH	EC	Cl⁻
Cynodon dactylon	0.084	-0.072	-0.132	0.138	-0.018	-0.169	0.297*	0.081	0.259*	0.196
Diplotaxis harra	0.142	-0.151	-0.016	-0.038	0.053	-0.149	0.183	-0.057	-0.074	0.186
Fagonia mollis	-0.04	0.046	0.005	-0.042	0.025	-0.161	0.164	0.047	-0.096	0.007
Haloxylon salicornicum	0.028	-0.016	-0.084	0.031	0.188	0.260*	-0.13	0.081	0.05	-0.004
Launaea nudicaulis	-0.07	0.088	-0.054	0.121	-0.129	-0.035	0.055	0.186	0.166	0.027
Launaea spinosa	0.101	-0.102	-0.050	0.049	-0.030	0.146	-0.219	-0.079	0.043	-0.174
Matthiola longipetala	-0.143	0.139	0.095	-0.257*	-0.039	0.052	-0.034	-0.042	0.042	-0.121
Ochradenus baccatus	0.046	-0.066	0.111	-0.032	-0.03	0.232	-0.205	-0.058	0.118	-0.158
Retama reatam	0.113	-0.106	-0.118	0.07	-0.089	-0.046	-0.001	-0.056	-0.013	-0.026
Zilla spinosa	0.18	-0.167	-0.164	0.258*	-0.012	-0.046	-0.022	0.074	0.021	-0.105
Zygophyllum coccineum	-0.266*	0.267*	0.119	-0.162	-0.223	0.440**	-0.421**	-0.095	-0.153	-0.307*
Zygophyllum simplex	-0.133	0.119	0.162	-0.187	0.072	0.358**	-0.089	-0.049	0.091	0.04

TABLE 7 cont'd
Linear correlation coefficients (r) between edaphic factors and the importance values of the dominant and abundant species

Species	SO₄⁻⁻	CO₃⁻⁻	HCO₃⁻⁻	Na⁺	K⁺	Ca⁺⁺	Mg⁺⁺	SAR	PAR
Cynodon dactylon	0.388**	0.099	-0.096	0.230	0.219	0.190	0.224	0.128	0.153
Diplotaxis harra	0.107	-0.171	-0.096	-0.089	-0.141	-0.137	-0.136	-0.061	-0.132
Fagonia mollis	-0.082	-0.085	-0.072	0.032	0.00	-0.002	0.016	0.00	-0.109
Haloxylon salicornicum	-0.109	0.013	0.148	0.013	0.028	0.033	0.046	0.009	0.032
Launaea nudicaulis	0.153	0.057	-0.061	0.365**	0.277*	0.248	0.287*	0.264*	0.251
Launaea spinosa	-0.022	0.007	0.00	0.089	0.114	0.132	0.067	0.129	0.162
Matthiola longipetala	0.026	0.390**	0.001	-0.012	-0.028	-0.058	-0.019	-0.041	-0.025
Ochradenus baccatus	-0.193	0.114	0.195	0.113	0.109	0.119	0.086	0.12	0.121
Retama reatam	0.133	-0.103	-0.013	0.069	0.092	0.093	0.084	0.104	0.128
Zilla spinosa	-0.282*	-0.145	-0.143	-0.124	-0.106	-0.107	-0.113	-0.126	-0.096
Zygophyllum coccineum	-0.275*	0.051	0.379**	-0.091	-0.097	-0.092	-0.07	0.027	-0.051
Zygophyllum simplex	0.018	0.133	0.275*	-0.120	-0.136	-0.156	-0.13	-0.085	-0.083

Por. = Porosity   SAR = Sodium adsorption ratio   * = Significant at *P* < 0.05
EC = Electrical conductivity   PAR = Potassium adsorption ratio   ** = Significant at *P* < 0.01
WHC = Water holding capacity   OC = Organic carbon

Matthiola longipetala ($r = 0.390$) while, HCO_3 correlated significantly with *Zygophyllum coccineum* ($r = 0.379$) and *Zygophyllum simplex* ($r = 0.275$). *Cynodon dactylon* exhibited significant correlations with sulphates ($r = 0.388$), organic carbon ($r = 0.297$) and electrical conductivity ($r = 0.259$) while, *Launaea nudicaulis* correlated significantly with sodium ($r = 0.365$), potassium ($r = 0.277$), magnesium ($r = 0.287$) and SAR ($r = 0.264$).

The correlation between the identified vegetation groups 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 soil texture (sand, silt and clay), water-holding capacity, *p*H, bicarbonate and organic carbon are the most effective soil variables. The dominant and abundant species of group A (*Launaea nudicaulis, Cyondon dactylon, Cynanchum acutum* and *Pluchea dioscoridis*) are separated at the right side of CCA-biplot diagram. These species in group A showed a close relationship with soil texture (clay and silt), SAR, Na$^+$ and *p*H. *Haloxylon salicornicum* and *Zilla spinosa* as the dominant species in two groups (B and D), and abundant species (*Ochradenus baccatus* and *Fagonia mollis*) are separated at the upper left side of CCA biplot diagram and exhibited a distinct relationship with water-holding capacity, bicarbonate and $CaCO_3$. While the dominant species of group C (*Zygophyllum coccineum*) and abundant species (*Diplotaxis harra, Senecio glaucus* and *Zygophyllum simplex*) of groups B and C are segregated at the lower right side of the diagram. These species exhibited a clear relationship with magnesium, porosity, calcium carbonate, silt, clay and organic carbon in the surface layer, as well as water-holding capacity in subsurface layer.

Discussion

Cairo-Suez, Ain Sokhnia- Makattam desert roads and Wadi Hagul are located in the northern part of the Eastern Desert of Egypt (The Galalah Desert) which extends east of the Nile Delta. These three localities represent the natural xeric habitat which is mainly inhabited by xerophytic vegetation. The natural plant in the present study is composed of 95 species belonging to 81 genera and related to 26 families. The major families were Asteraceae, Poaceae, Brassicaceae and Chenopodiaceae, which contributed collectively about 49.47% of the total recorded plant species. This indicated that these four families are leading taxa and constitute the major bulk of the flora of the study area. Similar results were also reported by other researchers (Abd El-Ghani, 2000; El-Amier *et al*., 2014; Salama *et al*., 2014). Pielou (1975) and Magurran (1988) point out that taxonomic diversity will be higher in an area in which the species are divided among many genera as opposed to one in which most species belong to the same genus, and still higher as these genera are divided among many families as opposed to few. Taxonomic diversity in terms of species/ genera and genera/families ratios indicates that the study area is more diverse as compared with Sinai Peninsula as a whole (Ayyad *et al*., 2000; Barakat *et al.*, 2014).

The dominance of perennials (60% of total recorded species) 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 (Harper,

1977; Grime, 1979).The high contribution of annuals (37.91% of total recorded species) can be attributed to time of study (March – May 2014) and short life cycle that enables them to resist the instability of the agro-ecosystem (Harper, 1977).

The life form spectra provide information which may help in assessing the response of vegetation to variations in environmental factors (Ayyad & El-Ghareeb, 1982). The present study demonstrated that therophytes was represented by 37.89% of the total recorded species, 32.63% chamaephytes, 22.44% cryptophytes, 14.74% hemicryptophytes and 12.63% phanerophytes. The above results agree with those of other reports (Abd EL-Ghani *et al.*, 2013; Salama *et al.*, 2013; El-Amier *et al.*, 2014). The dominance of therophytes over the other life-forms seems to be a response to Mediterranean climate, topography variation and biotic influence (Heneidy & Bidak, 2001). The highest values of hemicryptophytes and chamaephytes may be attributed to the ability of species to resist drought, salinity, sand accumulation and grazing (Danin & Orshan, 1990; Danin, 1996).

Chorological analysis of the floristic data revealed that the Saharo-Sindian chorotype forms the major component of the floristic structure where it was represented by 72.63%. This is in accordance with the results obtained by Danin & Plitman (1987) on the phytogeographical analysis of the flora of Israel and Sinai, and Salama *et al.* (2013) on vegetation analysis and species diversity in the desert of coastal wadis of South Sinai. The high percentage of Saharo-Sindian chorotype may be attributed to the fact that plants of the Saharo-Sindian species are good indicators for desert environmental conditions. It is worth noting that the species composition of the studied area varied considerably from those of the Mediterranean coast. This may be attributed mainly to the differences in the nature of soil sediments. The floristic elements of the Mediterranean coastal belt enjoy better climatic conditions than those of the other parts of Egypt (Zahran & Willis, 1992).

The present study revealed that stands of group A have the highest salinity soil dominated by *Launaea nudicaulis,* and the lowest species richness (1.58 ± 0.6 species stands⁻¹). Group B, dominated by *Haloxylon salicornicum,* has the average species richness (2.32 ± 0.8 species stands⁻¹) and exhibited a distinct relationship with water-holding capacity, bicarbonate and $CaCO_3$. The dominant species of group C (*Zygophyllum coccineum*) has the average species richness (1.69 ± 0.4 species stands⁻¹). This group exhibited a clear relationship with porosity and sulphates. Group D dominated by *Zilla spinosa* and the most diversified among the recognized groups with highest species richness (2.43±0.9 species stands⁻¹), this may explains the high contribution of annuals in this group. It inhabited soil with the highest water-holding capacity, bicarbonate and $CaCO_3$.These results are in line with those of Abd El-Ghani and Amer (2003) in El-Qaa plain of South Sinai, Abd El-Wahab *et al.* (2006) in Gebel Serbal of South Sinai, Abd El-Ghani *et al.* (2013) in the reclaimed lands along the northern sector of the Nile Valley and El-Amier *et al.* (2014) in costal sand formation. These groups were separated markedly along DCA ordination axes. It is of interest to note that interspecific relationships between the above mentioned vegetation groups may be due to the close similarities of their floristic composition and natural habitats.

The gravel desert is one of the most characteristic features of these roads. While, Wadi Hagul occupies the valley depression between Gebel Ataqa to the north and the Kahaliya ridge to the south, its main channel extends for about 35 km, collects drainage on both sides and debouch into the Gulf of Suez. It is characterized by local physiographic variations and physiognomic heterogeneity.

Soil texture, salinity and organic carbon can affect phytodiversity of wild communities (El-Sheikh, 1989; Andersson & Skovgaard, 2009; Pinke *et al*., 2010). In the present study linear correlation of soil variables with the important values of some dominant species indicates significant associations between the floristic composition of the study area and the edaphic factors such as soil texture, organic carbon, carbonate, bicarbonate, sulphates and sodium. Moreover, silt, clay, organic carbon, $CaCO_3$, SO_4^-, magnesium and potassium exhibited significant differences between vegetation groups (A–D). These results suggest the effective role of these soil parameters in the study area community structure and diversity. The present findings agree with those of Al-Sodany (1992), Mashaly (2001), El-Halawany (2003) and Zahran *et al.* (2014). Soil texture may affect soil or productivity *via* influence on the soil water holding capacity, infiltration rate, moisture availability for plants and, consequently, plant nutrition (Sperry & Hacke, 2002; El-Sheikh, 2013).

Conclusion

The present study provided an assessment of the vegetation and plant diversity in northern part of Eastern Desert to help in management and conservation of these natural resources. Different types of human impacts, including urbanization, agriculture, mining and quarrying, over collection and over cutting of woody species threaten biodiversity of Eastern Desert. Therefore, the conservation of natural habitats of this desert is of vital importance. The recorded 95 plant species can play a vital role in the economic and medicinal purposes. Hence, for the Egyptian desert, especially the inland desert, there is the need for judicious utilization and sustainable development.

References

Abd El-Ghani M. M. (1997). Vegetation analysis and species diversity along an altitudinal gradient in the central Higaz Mountains in Saudia Arabia. *Arab Gulf J. Sci. Res.* **15**: 399-414.

Abd El-Ghani M. M. (1998). Environmental correlates of species distribution in arid desert ecosystems of Eastern Egypt. *J. Arid Envir.* **38**: 297–313.

Abd El-Ghani M. M. (2000). Floristics and environmental relations in two extreme desert zones of western Egypt. *Global Ecology & Biogeography* **9**: 499–516.

Abd El-Ghani M. M. and **Amer** W. (2003). Soil-vegetation relationships in a coastal desert plain of Southern Sinai, Egypt. *J. Arid Envir.* **55**: 607-628.

Abd El–Ghani M. M., Soliman A., Hamdy R. and **Bennoba E.** (2013). Weed flora in the reclaimed lands along the northern sector of the Nile Valley in Egypt. *Turk. J. Bot.* **37**(3): 464-488.

Allen S. E., Grimshaw H. M., Parkinson J. A., Quarmby C. and **Roberts J. D.** (1974). *Chemical Analysis of Ecological Materials*. Blackwell Scientific Publications. Osney, Oxford, London.

Al-Sodany Y. M. (1992). *Vegetation analysis of the northern part of Nile Delta Region*. (M.Sc. Thesis.) Fac. Sci., Tanta Univ., Egypt.

Andersson T. N. and **Skovgaard I. M.** (2009). Crop and soil factors of importance for the distribution of plant species on arable fields in Denmark. *Agr. Ecosystems Envir.* **133**: 61-67.

Ayyad M. A. and **El-Ghareeb R. E. M.** (1982). Saltmarsh vegetation of the western Mediterranean desert of Egypt. *Vegetatio* **49**: 3–19.

Ayyad M. A., Fakhry A. M. and **Moustafa A. A.**

(2000). Plant biodiversity in the Saint Catherine area of the Sinai peninsula, Egypt. *Biodiversity and Conserv.* **9**: 265-281.

Barakat N. A. M., El-Gawad A. M. A., Laudadio V. H. F., Kabiel H. K., Tufarelli V. and **Cazzato E.** (2014). A contribution to the ecology and floristic markers of plant associations in different habitats of Sinai Peninsula, Egypt. *Rend. Fis. Acc. Lincei.* **25**: 479–490.

Batanouny K. H. (1979). Vegetation along Jeddah–Mecca road: pattern and processes as affected by human impact. *J. Arid Envir.* **2**: 21–30.

Boulos L. (1999, 2001, 2002, 2005). *Flora of Egypt* Vol. 1–4. Al Hadara Publishing, Cairo, Egypt.

Boulos L. (2008). Flora and vegetation of the deserts of Egypt. *Flora Mediterran.* **1**(8): 341–359.

Canfield R. (1941). Application of the line interception method in sampling range vegetation. *J. Forestry* **39**: 288–394.

Danin A. (1996). *Plants of desert dunes*. Springer-Verlag.

Danin A. and **Orshan G.** (1990).The distribution of Raunkiaer life forms in Israel in relation to the environment. *J. Veg. Sci.* **1**(1): 41-48.

Danin A. and **Plitman U.** (1987). Revision of the plant geographical territories of Israel and Sinai. *Pl. Syst. Evol.* **156**: 43–53.

Eig A. (1931–1932). Les elements et les groupes phytogeographiques auxiliares dans la flore palestinienne. *Beih. Repert. Spec. Nov. Regni. Veg.* 63 (1, texte): 1–201 (1931); (2, Tabl. analyt.), 1–120 (1932).

El-Amier Y. A., El-Halawany E. F. and **Abdullah T. J.** (2014).Composition and diversity of plant communities in sand formations along the northern coast of the Nile Delta in Egypt. *Res. J. Pharmaceut. Biol. Chem. Sci.* **5**(4): 826–847.

El-Halawany E. F. (2003). Vegetation changes in north Nile Delta within two decades, *J. Envir. Sci. Mansoura Univ* **26**(2): 153–180.

El-Sheikh M. A. (1989). *A Study of the Vegetation-Environmental Relationships of the Canal Banks of Middle Delta Region*. (MSc. Thesis.) Fac. Sci., Tanta Univ., Egypt.

El-Sheikh M. A. (2013). Population structure of woody plants in the arid cloud forests of Dhofar. Southern Oman. *Acta Bot. Croat.* **72**: 97–111.

Emberger L. (1955). Une Classification Biogeographiques des Climates. Recueil des Travaux de Laboratoires de Botanique, Geologie et Zoologie de la Faculte de Science dl'Universite de Montpellier, *Fascicule*. **7**: 3–43.

Feinbrun-Dothan N. (1986). *Flora Palaestina:* Alismataceae to orchidaceae. Israel Academy of sciences and humanities.

Grime J. P. (1979).Competition and the struggle for existence. Population dynamics. *20th Symposium of the British Ecological Society*. Blackwell Scientific Publication, London.

Harper J. (1977). *Population Biology of Plants*. Academic Press.

Heneidy S. Z. and **Bidak L. M.** (2001). Multipurpose plant species in Bisha, Asir region, southwestern Saudi Arabia. *J. King Saud Univ. Sci.* **13**: 11–26.

Hillel D. and **Tadmor N.** (1962). Water regime and vegetation in the central Negev highlands of Israel. *Ecol*. 33–41.

Jackson M. L. (1962). *Soil chemical analysis*. Constable and Co. Ltd. London.

Kassas M. (1952). Habitat and plant communities in the Egyptian deserts. *J. Ecol*. **40**: 342–351.

Kassas M. (1966). Plant life in deserts. In *Arid Lands*. (E. S. Hills, ed.), pp. 145–80. UNESCO, London, Mathuen/Paris.

Kassas M. (1971). Die Pflanzenwelt. 2. Teil. Pflanzenleben in der Östlichen Sahara. In *Die Sahara und ihre Randgebiete*. (*I. Physiogeographie*. (H. Sciffers, ed.), pp. 477–497. Afrika–Studien, München: Weltforum–Verlag.

Kassas M. and **Girgis W. A.** (1965). Habitat and plant communities in the Egyptian desert: VI. The units of a desert ecosystem. *J. Ecol*. 715–728.

Magurran A. E. (1988). *Ecological diversity and its measurement,* Vol. 168. Princeton: Princeton University Press.

Mashaly I. A. (2001). Contribution to the ecology of Deltaic Mediterranean coast, Egypt. *Online J. Biol. Sci.* **1**: 628–635.

Masoud A. A. and Koike K. (2006). Arid land salinization detected by remotely-sensed land cover changes: A case study in the Siwa region, NW Egypt. *J. Arid Envir.* **66**. 151–167.

Mckell C. M. and **Goodin J. K.** (1984). A brief over–view of the saline lands of the United States. *Research and development seminar on forage and fuel production from salt affected wasteland. Western Australia, Dept. Agric. May 19–27.*

Meigs P. (1953). *World distribution of arid and semi-arid homoclimates*. Arid Zone Hydrology, UNESCO, Paris.

Monod T. H. (1954). Mode contracté et diffuse de la vegetation Saharienne. In *Biology of desert.* (J. L. Cloudsley-Thompson, ed.), pp. 35–44. London.

Olsvig-Whittaker L., Shachak M. and **Yair A.** (1983). Vegetation patterns related to environmental factors in a Negev Desert watershed. *Vegetatio.* **54**(3): 153-165.

Parker K. (1991). Topography, substrate, and vegetation patterns in the northern Sonoran Desert. *J. Biogeogr.* **18**: 151–163.

Pielou E. C. (1975). *Ecological diversity.* Wiley, New York.

Pierce W. C., Haenisch E. L. and **Sawyer D. T.** (1958). *Quantitative Analysis*. Wiley Toppen, Tokyo.

Pinke G., Pal R. and **Botta-Dukat Z.** (2010). Effects of environmental factors on weed species composition of cereal and stubble fields in western Hungary. *Cent. Eur. J. Bio.* **5**: 283–292.

Piper C. S. (1947). *Soil and plant analysis.* Intersience Publishers. Inc. New York.

Raunkiaer C. (1934). *The Life Forms of Plants and Statistical Plant Geography.* Translated by Carter Fausboll and Tansley, Oxford Univ. Press, London.

Raunkiaer C. (1937). *Plant Life Forms*. Clarendon, Oxford.

Salama F. M., Ahmed M. K., El-Tayeh N. A. and **Hammad S. A.** (2012). Vegetation analysis, phenological patterns and chorological affinities in Wadi Qena, Eastern Desert, Egypt. *African Journal of Ecology* **50**(2): 193–204.

Salama F., Abd El–Ghani M. M. and **El-Tayeh N.** (2013). Vegetation and soil relationships in the inland wadi ecosystem of central Eastern Desert, Egypt. *Turk. J. Bot.* **37**(3): 489–498.

Salama F. M., Sayed S. A. and **Abd El-Gelil** (2014). Plant Communities and Floristic Composition of the Vegetation of Wadi Al-Assiuty and Wadi Habib in the Eastern Desert, Egypt. *Not. Sci. Biol.* **6**(2):196–206.

Sperry J. S. and **Hacke U. G.** (2002). Desert shrub water relations with respect to soil characteristics and plant functional type. *Funct. Ecol.* **16**: 367–378.

Stahr K., Bornkamm R., Gauer A. and **Kehl H.** (1985). V*eränderung von Boden und Vegetation am Übergang von Halbwüste zur Vollwüste.*

Tackholm V. (1974). *Students' flora of Egypt*, 2nd edn. Cairo Univ. Press.

ter Braak C. J. (1987). The analysis of vegetation-environment relationship by canonical correspondence analysis. *Vegetatio* **69**: 69–77.

Whittaker R. H. (1972). Evolution and measurement of species diversity. *Taxon*. 213–251.

Wilson M. V. and **Schmida A.** (1984). Measuring beta diversity with presence absence data. *J. Ecol.* **72**: 1055–1064.

Zahran M. A. and **Willis A. J.** (1992). *The Vegetation of Egypt.* Chapman & Hall, London, U.K.

Zahran M. A. and **Willis A. J.** (2009). *The Vegetation of Egypt,* 2nd edn. Springer. Netherlands.

Zahran M. A., El-Ameir Y. A. and **Hammad M. E.** (2014). Contribution to the eco-palynological studies of the Mediterranean coastal desert of Egypt. *J. Envir. Sci. Mansoura Univ.* **43**(1): 1–22.

Zohary M. (1966, 1972). *Flora Palaestina.* Vol. 1 & 2. The Israel Academy of Science and Humanities. Jerusalem.