JJBS

Volume 12, Number 4,September 2019
ISSN 1995-6673
Pages 421 - 434

Jordan Journal of Biological Sciences

Assessing the Role of Environmental Gradients on the Phytodiversity in Kharga Oasis of Western Desert, Egypt

Fawzy M. Salama[1,*] , Monier M. Abd El-Ghani[2], Noha A. El-Tayeh[3], Ahmed M. Amro[1], Ali Al-Saied Gaafar[4] and Ayat Abd El-Monem Abd El- Galil[4]

[1] Department of Botany and Microbiology, Faculty of Science, Assiut University, Assiut; [2] The Department of Botany and Microbiology, Faculty of Science, Cairo University, Giza 12613; [3] Department of Botany, Faculty of Science, South Valley University; [4] Department of Botany, Faculty of Science in New Valley University, New Valley, Egypt.

Received October 30, 2018; Revised December 18, 2018; Accepted December 25, 2018

Abstract

The vegetation-soil relationships in the four major habitats of Kharga Oasis (farmlands, date- palm orchards, salinized lands and the surrounding desert) in the Western Desert of Egypt are examined in this study. Altogether, 122 vascular plants species distributed in 102 genera and thirty-five families were recorded. Poaceae (25.2 %), Asteraceae (11.9 %), Brassicaceae (6.5 %), Cyperaceae (6.5 %), Amaranthaceae (5.4 %) and Euphorbiaceae (5.4 %) were the largest families. With respect to the floristic composition, habitats varied from one to another: eighty-six species in farmlands, seventy-nine species in date-palm orchards, seventy-three species in salinized lands and thirty-nine species in the surrounding desert lands. About 22 % of the total flora was represented in the four habitats, while 37.7 % was found in one habitat. The vegetation classificatory method of Two-Way Indicator Species Analysis yielded fourteen vegetation groups: four in both farmlands and date-palm orchards, and three for both salinized lands and the surrounding desert habitats. The results of the Canonical Correspondence Analysis (CCA) showed that water content, soil texture, organic matter and bicarbonates were most related to the species distribution in the studied habitats. Other related variables included sulfates and phosphates in the date-palm orchards and salinized lands, and electric conductivity in the surrounding desert. Farmlands had the highest species richness, followed by the date-palm orchards and the salinized lands, whereas the desert outskirts were the lowest in terms of species richness. The linear correlations (r) between the farmlands and palm orchards were highly significant (r = 0.703), and also occurred between salinized lands and the surrounding deserts (r = 0.764). These high correlations may be attributed to the effect of concentric zonation of the habitat as each pair of the aforementioned habitats is adjacent to each other.

Keywords: Species diversity, Kharga Oasis, Vegetation analysis, Flora, Soil factors, CCA, Egypt.

1. Introduction

Among the arid deserts of the globe is the African Sahara (*c.* 9 million km^2) which extends from Morocco in the west of the continent to Eritrea and Somalia in the east. Such regions are characterized by scarce rainfall and unique local and regional topography and soil conditions acting as the major environmental factors which control plant species distribution and floristic diversity. In recent decades, such fragile desert ecosystems are subjected to severe human activities (e.g., establishment of new urban settlements, construction of roads, building summer resorts along coasts, and uncontrolled grazing) which significantly contributed to land degradation, destruction of natural vegetation, loss of special habitats and biodiversity. In desert ecosystems with heterogeneous habitats, soil among other environmental variables plays a key role in the distribution of plant communities and species diversity (Titus *et al.*, 2002; Abd El-Ghani *et al.*, 2017).

Generally speaking, the vegetation structure and floristic composition of desert ecosystem are simple with low species diversity. They are dominated by xerophytic and/or halophytic shrubs of different sizes, and perennial herbs that are adapted to survive under the harsh environmental conditions of high temperatures and low precipitation. Generally, the Egyptian deserts are considered among the hyper-arid environments of the world. The Western Desert is characterized by its oases, with sufficient underground artesian water flowing from naturally flowing springs to support plant growth. Due to long periods of droughts and erratic precipitation in this region since the Late Pleistocene and Early Holocene times when a more humid climate prevailed in the region, the underground water reservoir has not been recharged (Hermina, 1990). Such decline in the groundwater resources can result in remarkable land degradation within the oases.

Like many other oases in the Sahara Desert, agricultural practices are the most important process in the Egyptian oases. Buckley and Roughgarden (2004)

[*] Corresponding author e-mail: fawzysalama2020@yahoo.com.

indicated that changes in land use will have significant impacts on global biodiversity by the year 2100. Over the past few decades, the oases were subjected to considerable environmental changes which extensively modified them through the implementation of ambitious desert reclamation schemes. Since the 60's of the last century, a pioneer desert reclamation project was initiated in Kharga and Dakhla oases known as the "New Valley Project". Agriculture in the five major oases of Siwa, Bahariya, Farafra, Dakhla, and Kharga follows the general pattern of Egyptian agriculture of summer and winter crops. Vast areas of the agricultural lands are cultivated with date-palms (*Phoenix dactylifera*) and olives (*Olea europaea*) which represent the main orchard trees and the principal source of income for the oases. Large areas of the natural landscape are dominated by dom-palms (*Hyphaene thebaica*).

In general, Abd El-Ghani *et al.*, (2017) recognized three main ecosystems as major components of the plant life in the oases of Egypt: (1) the surrounding desert, (2) the farmlands (including croplands and orchards), and (3) the salt marshes. As a result of uncontrolled use of the artesian water, several new deep wells (250-850m) were drilled, and hence many old wells were overwhelmed by drifted sand and/or decreased water output. Usually, no good drainage system is found. Similar to many other oases of the Western Desert, the lack of efficient drainage system in the Kharga Oasis transformed large areas of the arable lands into salt marshes with salinized soil.

Studying the relationships between vegetation characteristics and environmental variables is commonly applied using gradient analysis techniques which have been widely used as a quantitative analytical approach to correlate environmental gradients with floristic variation (Kent, 2012). In Egypt, the application of multivariate analysis approach has been widely used in both natural and man-made habitats including the arable lands (Salama *et al.*, 2017), desert vegetation (Sheded *et al.*, 2014), salt marshes, urbanized areas (Abd El-Ghani, 2017), water bodies and lakes (Shaltout and Al-Sodany, 2008).

Since the documentary account of Abd El-Ghani *et al.* (1992) which portrayed the species distribution in different habitats around the old wells of Kharga Oasis, little attention has been paid to studying the impact of recent environmental conditions on the floristic diversity, vegetation heterogeneity, and patterns of species distribution in the landscape of Kharga Oasis. Most of the documented old wells are now either dried up or overwhelmed by sand and had become inactive. Recently, these special habitats in the Kharga Oasis are completely altered and in danger of threat which, therefore, deserve urgent management and conservation, and sustainable utilization of natural resources.

The present study hypothesizes that floristic composition and plant species distribution should exhibit significant differences in contrasting habitats, with different vegetation structures in relation to their variations in soil nutrients, water availability, and surface sediments. For this reason, this detailed study was the first to be conducted in Kharga Oasis focusing at: (1) describing the floristic composition and vegetation structure in different habitats, (2) identifying the vegetation structure dominating each habitat, and (3) assessing the role of soil factors in species distribution within and between different habitats.

2. Material and Methods

2.1. Description of the Study Area

Kharga Oasis is one of the main oases of the Nubian Desert of Egypt (El-Hadidi, 2000). It lies between 24° 30’- 26° N and 30° 07’ - 30° 47’ E (Figure 1), with a total area of about 7200 km^2. The depression floor is between 300-400m below the surrounding plateau, and formed of non-fossiliferous brown sandstone that cover large tracts of the lower-lying parts of the floor with Aridisol soil type (Hermina, 1990). The floor of the depression is composed of Nubian Sandstone, but much of it is covered with blown sand. The lowest point of the depression floor is almost at the sea level, while the highest point is at 115m above sea level (ASL). The wells of the oasis obtain their water from two distinct water-bearing sandstone strata separated by a band of impermeable grey shale.

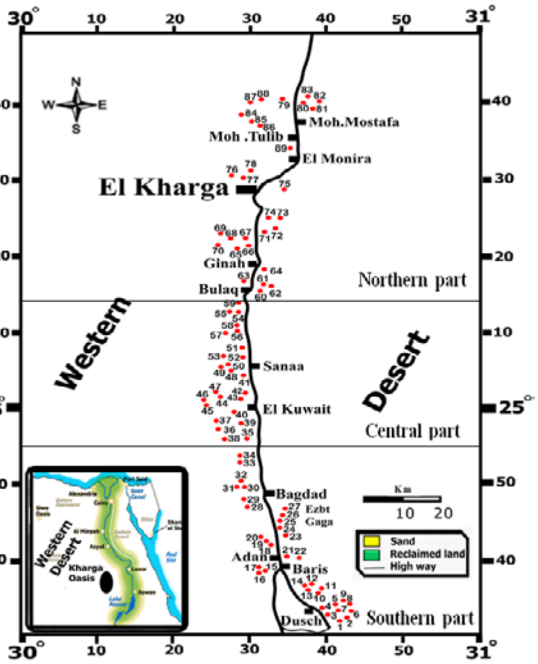


Figure 1. Map of Kharga Oasis showing the studied sampling plots (numbers).

Rainfall is erratic; almost zero (mm year^{-1}), whereas the mean annual relative humidity is lower in summer (26-32 %) than in winter (53-60 %). Temperature is moderate in winter: absolute minimum 6.0-4.8 °C and maximum 22.1-21.5 °C, but becomes very high in summer: absolute minimum 23.4-23.1°C and maximum 39.2-39.5°C. According to the meteorological data obtained for this study over the last five years (2012-2016), the mean temperature ranged between 43°C (June 2016 and August 2015) and 5°C in January, 2012. In the meantime, the relative humidity (RH) varied markedly according to the latitude, longitude and the different seasons of the year. It ranged between 66 % during December, 2015 and 7 % in June and April, 2016 (personal communications, Meteorological Authority of Egypt).

2.2. Field Work and Data Collection

During the winter and summer seasons of 2015 and 2016, vegetation was sampled from eighty-nine permanently visited stands in twelve sites situated along N-S line transect across the Kharga Oasis, and extending for about 185 km (Figure 1) to cover as much as possible the physiognomic variation in these habitats. Physiographically, the floor of the oasis can be clearly distinguished into three main parts: northern (sites 1-3, 15 stands), middle (sites 4-8, 43 stands), and southern (sites 9-12, 31 stands). A stratified random sampling method was employed within each of the twelve studied sites. The area of each stand was about 20 m × 100 m which approximates the minimal area of species associations in the study area. Four habitats were recognized in this study from inner to outer zones: farmlands and date-palm orchards represented the inner zone, the salinized lands (not salt marshes) in the middle, and the surrounding desert represented the outer zone. The farmlands included major field crops such as wheat (*Triticum aestivum*) as the winter crop, millet (*Sorghum bicolor*) as a summer crop and alfa-alfa *(Medicago sativa*) as the perennial crop. In each of the examined habitats, the presence or absence of plant species was recorded using a number of permanent stands randomly positioned and representing the variation in the floristic composition of these habitats. Each of the recorded species was assigned to one of the eight categories of growth forms that were used in this study; these included: trees, perennial shrubs, perennial herbs, annual herbs, annual forbs, annual grass, perennial grass, sedges, and parasites. The studied stands covered the four recognized habitats, and were distributed as follows: thirty-eight in the farmlands, seventeen in the date-palm orchards, twenty-three in the salinized lands and eleven in the surrounding deserts. Absolute frequency (f %) of each species in each habitat was calculated as the total number of stands where species were recorded divided by the total number of monitored stands inside the habitat. Specimens of each species were collected, and were then identified at the Herbarium of Cairo University (CAI), and duplicates were deposited at Assiut University Herbarium (AST). Taxonomic nomenclature was according to Täckholm (1974) and updated by Boulos (1999 - 2005, 2009).

2.3. Physico-chemical Properties of Soil

At each of the eighty-nine stands, three soil samples (0 - 50 cm) were collected from each stand. They were mixed to form one composite sample, air-dried, thoroughly mixed and passed through a 2 mm sieve to remove large gravels, plant remains and debris. Finally, they were packed in plastic bags ready for physical and chemical analysis. The soil texture was determined by the sieving method, and soil water content was determined by Kapur and Govil (2000). The soil pH and electrical conductivity were measured in a soil-water extract (1:5 w/v). Soil reaction (pH) was determined using an electric pH-meter (Model Hanna pH 211), and the electrical conductance (EC) was measured by means of conductivity meter (model 4310 JEN WAY). The sodium and potassium contents were determined by the Flame photometer (Model Carl-Zeiss DR LANGE M7D), and the calcium and magnesium contents were determined volumetrically by the titration method using 0.01 N EDTA (Upadhyay and Sharma 2005). The chloride contents were volumetrically determined as AgCl, and the soluble bicarbonate contents were estimated by titration using the method described by Jackson (1967). Contents of sulfates were estimated by turbidimetry with $BaSO_4$, and phosphate contents were determined calorimetrically as phospho-molybdate. The organic matter content was determined in the soil by the dichromate oxidation method (Pansu and Gautheyrou, 2007).

2.4. Data Analysis

For generating floristic classification of the sampled stands in each habitat, the default settings of Two-Way Indicator Species Analysis (TWINSPAN) of the computer program CAP for Windows version 1.2 (Henderson and Seaby, 1999) was used. After elimination of the species with frequencies less than 5 % in each habitat, four floristic presence/absence data matrices were used: eighty-six species × thirty-eight stands in the farmlands, seventy-nine species × seventeen stands in the date-palm orchards, seventy-three species × twenty-three stands in the salinized lands, and thirty-nine species × eleven stands in the surrounding desert. Classification was stopped at the third level to get interpretable results. Multivariate analyses were performed using Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) of the computer program CANOCO software version 4.5 (ter Braak, 2003). Before analyses, soil variables shown in percentages (gravels, CS, FS, silt, clay, WC and OM) were transformed to their arcsines, and appropriate transformations for other soil variables were applied (Zar, 1999). Detrended Correspondence Analysis (DCA) was used to check the magnitude of change in the species composition along the first axis. DCA estimated the gradient lengths (in standard deviation units) for the first axis in each habitat as follows: 4.841 for the desert, 3.827 for the farmlands, 3.097 for the date-palm orchards, 4.102 for the salinized lands). Therefore, canonical correspondence analysis (CCA) was selected to establish the relationships between floristic data and the soil parameters (Legendre and Legendre, 1998).

To avoid problems of multicollinearity among the soil variables and to provide the best set of soil variables, their number was reduced using CCA with a forward selection procedure (ter Braak and Šmilauer, 2002) using unrestricted Monte Carlo permutation under the reduced model to test each variable for significance (with 499 random permutations). All variables with the significance level of P>0.05 were removed. The forward selection test for significant soil variables in each habitat revealed that gravels, coarse sand, fine sand, silt, K, and HCO_3 contents were the best fit for the surrounding desert habitat, while clay, WC, EC, OM, PO_4, and SO_4 were significantly high in the salinized lands (Table 4). Farmlands showed significant variations in FS, clay, EC, OM, Ca and HCO_3 contents, whereas the date-palm orchards showed significant variations in gravels, silt, clay, WC, OM, Na, and HCO_3 contents. Therefore, fourteen explanatory variables (Table 4) were included in the CCA analysis: gravels, coarse sand (CS), fine sand (FS), silt, clay, water content (WC), electrical conductivity (EC), organic matter (OM), sodium (Na), potassium (K), calcium (Ca), bicarbonates (HCO_3), phosphates (PO_4), and sulfates (SO_4). The interset correlations from the CCA's were used to assess the importance of the soil variables for each habitat (Jongman *et al.*, 1987). A Monte Carlo permutation test based on 499 random permutations was conducted to test the significance of the eigenvalues of the first canonical axis (ter Braak and Šmilauer, 2002). Based on the means of soil variables of the resulted TWINSPAN groups in each habitat, the significant differences were analyzed by Analysis of Variance (ANOVA) test using SPSS version 10.0.

2.5. Species Diversity

Species diversity within each habitat was assessed using two different indices. Species richness was calculated as the average number of species per stand, and Shannon-Wiener index: $H = -\sum_{i=1}^{S} Pi\ Log_2 Pi$ where *S* is the total number of species, and *P*i is the frequency (f%) of the species (Pielou, 1975).

3. Results

3.1. Floristic Composition and Species Diversity

A total of 122 species of the vascular plants belonged to 102 genera and thirty-five families were recorded from the studied areas. Poaceae (twenty-five species) was the most species-rich family, followed by Asteraceae (eleven species), Brassicaceae, Cyperaceae (six species for each) and Amaranthaceae, Euphorbiaceae (five species for each). Annual herbs were the dominant growth form, and were represented by forty-two species (34.43 %), followed by grasses (annuals twelve species, 10 %, perennials eleven species, 9 %), trees (fifteen species, 12 %), perennial herbs and perennial shrubs (twelve species, 10 %), and forbs (annuals six species, 5 %, perennials two species, 2 %). Sedges and parasites included ten species; nine for the former and one for the latter.

3.2. Spatial Distribution Patterns of Species within Habitats

The variations in the spatial distribution patterns of the 122 species recorded in the eighty-nine stands from the four studied habitats were indicated (Table 1). The highest number of species (eighty-six) was recorded in the farmlands, followed by seventy-nine in the date-palm orchards, seventy-three in the salinized lands, and the lowest (thirty-nine) was in the surrounding desert. The species richness of the farmlands showed significant differences between the date-palm orchards (*P*=0.003) and the salinized lands habitats (*P*=0.0003). On the other hand, Shannon Wiener index for the date-palm orchards was the highest (4.04), while the surrounding desert had the lowest value (3.42). The differences in Shannon Wiener index between the habitats were highly significant (F-3.815; *P*-value=0.001).

Twenty-seven species (22.1 % of the total flora) were represented in all of the habitats. These species differ in their habits according to the habitat. For instance *Cynodon dactylon, Sonchus oleraceus, Chenopodium murale, Malva parviflora*, and *Dichanthium annulatum* are far better (f=41-88 %) in the farmlands and the date-palm orchards. On the other hand, psamoxerophytes (e.g., *Tamarix nilotica, Phragmites australis, Brassica tournefortii, Bassia indica, Calotropis procera,* and *Launaea mucronata* attained their highest frequency values in the salinized lands and the surrounding desert. Twenty-five species (20.5 % of the total flora) were recorded in three habitats. *Hyphaene thebaica* and *Juncus rigidus* were absent in the farmlands, but are represented better in the salinized lands and the surrounding desert.

Species confined to a single habitat were represented by forty-six species (37.7 % of the total) of which nine salt-tolerant species were confined to the salinized lands (e.g., *Sporobolus spicatus*, *Centaurium pulchellum*, *Aeluropus lagopoides*, and *Scirpus maritimus)*, seventeen species were confined to the date-palm orchards (e.g., *Oxalis corniculata*, *Setaria verticillata*, *Mentha longifolia, Plantago lagopus*, *Pseudognaphalium luteo-album)*, and eighteen species to the farmlands (e.g., *Trianthema portulacastrum*, *Asphodelus tenuifolius*, *Dinebra retroflexa*., *Euphorbia forsskaolii)*, Moreover, two species were confined to the surrounding desert (*Verbesina encelioides*, *Ricinus communis*).

Table 1. Floristic composition of the studied habitats.

Species	GF	Farmlands (F)		Date-palm orchards(P)		Salinized lands(S)		Surrounding desert(D)	
Total number of stands		38		17		23		11	
Species richness		86		79		73		39	
Number of annuals		48		40		30		12	
Shannon H'		3.95		4.04		3.85		3.42	
		N	f	N	f	N	f	N	f
I. Species present in all habitats									
(Cd) Cyondon dactylon (L.) Pers.	PG	31	82	15	88	13	57	2	18
(Ag) Alhagi graecorum Boiss.	PS	16	42	7	41	20	87	9	82
(So) Sonchus oleraceus L.	AH	27	71	13	76	4	17	1	9
(Cm) Chenopodium murale L.	AH	26	68	10	59	4	17	1	9
(Mp) Malva parviflora L.	AH	30	79	7	41	3	13	1	9
(Pd) Phoenix dactylifera L.	T	12	32	13	76	10	43	5	45
(Tn) Tamarix nilotica (L.) H. Karst.	T	8	21	5	29	20	87	6	55
(Ic) Imperata cylindrica (L.) Raeusch.	PG	12	32	9	53	10	43	5	45
(Dan) Dichanthium annulatum (Forssk.) Stapf	PG	17	45	9	53	6	26	2	18
(Sh) Sorghum halepense (L.) Pers.	PG	18	47	6	35	5	22	1	9
(Cb) Conyza bonariensis (L.) Cronquist.	PH	8	21	11	65	6	26	1	9
(Pa) Phragmites australis (Cav.) Trin. ex. Steud.	PG	5	13	5	29	13	57	3	27
(Bt) Brassica tournefortii Gouan	AH	16	42	3	18	4	17	1	9
(Bi) Bassia indica (Wight) A.J. Scott	AH	6	16	3	18	11	48	2	18

Sesbania sesban (L.) Merr.	T	5	13	3	18	8	35	2	18
(Zs) Ziziphus spina-christi (L.) Desf.	T	4	11	3	18	3	13	3	27
Cuscuta campestris Yunck	PAR	3	8	2	12	5	22	1	9
(Taf) Trichodesma africanum (L.) R. Br.	AH	4	11	2	12	2	9	3	27
Eruca sativa Mill.	AH	5	13	2	12	1	4	1	9
Pluchea dioscoridis (L.) DC.	PS	3	8	2	12	3	13	1	9
Ambrosia maritima L.	AH	1	3	4	24	2	9	1	9
Tamarix aphylla (L.) H. Karst	T	1	3	1	6	4	17	2	18
Acacia nilotica (L.) Delile	T	1	3	2	12	3	13	1	9
Pulicaria undulata (L.) C. A. Mey.	PS	2	5	2	12	2	9	1	9
Typha domingensis (Pers.) Poir. ex. Steud.	SD	1	3	1	6	1	4	2	18
II. Species present in three habitats									
(Hth) Hyphaene thebaica (L.) Mart.	T			1	6	4	17	3	27
Juncus rigidus Desf.	SD			1	6	3	13	1	9
Brassica nigra (L.) Koch	AH	8	21			3	13	1	9
(Hm) Hyoscyamus muticus L.	PS	2	5			5	22	4	36
Balanites aegyptiaca (L.) Delile	T	1	3			2	9	1	9
Fagonia arabica L.	PS	1	3			1	4	1	9
Cenchrus ciliaris L.	PG	1	3	3	18			1	9
(Dsa) Digitaria sanguinalis (L.) Scop.	AG	16	42	11	65	3	13		
(Da) Dactyloctenium aegyptium (L.) Willd.	AG	16	42	10	59	3	13		
(Car) Convolvulus arvensis L.	PH	17	45	7	41	1	4		
(Ct) Corchorus trilocularis L.	AH	16	42	5	29	2	9		
(Mm) Melilotus messanensis (L.) All.	AF	15	39	7	41	1	4		
Solanum nigrum L.	PH	11	29	3	18	2	9		
Portulaca oleracea L.	AH	10	26	3	18	1	4		
Anagallis arvensis L. subsp. *arvensis*	AH	6	16	4	24	2	9		
Emex spinosa (L.) Campd.	AH	6	16	5	29	1	4		
Cyperus rotundus L. var. *rotundus*	SD	7	18	2	12	2	9		
Vicia monantha Retz.	AF	5	13	3	18	2	9		
Pennisetum divisum (Forssk. ex J.F. Gmel.) Henrard	PG	5	13	2	12	2	9		
Amaranthus graecizans L.	AH	4	11	2	12	2	9		
Polygonum bellardii All.	AH	3	8	2	12	2	9		
Lathyrus hirsutus L.	AF	3	8	1	6	1	4		
Cressa cretica L.	PH	2	5	1	6	1	4		
Leptochloa fusca (L.) Kunth	PG	1	3	2	12	1	4		
Olea europaea L.	T	1	3	2	12	1	4		
III. Species present in two habitats									
Citrullus colocynthis (L.) Schrad.	PH			1	6	3	13		
Cordia myxa L.	T			2	12	1	4		
Plantago amplexicaulis Cav.	AH			1	6	1	4		
Beta vulgaris L.	AH	11	29			1	4		
Avena fatua L.	AG	3	8			1	4		
Boerhavia repens L. subsp. *viscosa* (Choisy) Maire	PH	3	8			1	4		
Sinapis arvensis L.	AH	3	8			1	4		
Suaeda fruticosa (L.) Dumort.	PS	2	5			2	9		
Cenchrus echinatus L.	AG	2	5			1	4		
Convolvulus fatmensis Kunze	PH	2	5			1	4		
Gossypium herbaceum L.	PS	1	3			1	4		
(Cen) Cichorium endivia L. subsp. *divaricatum* (Schousb) P.D. Sell	AH	20	53	3	18				
(Ec) Echinochloa colona (L.) Link	AG	20	53	1	6				
Hibiscus trionum L.	AH	12	32	2	12				
Chenopodium album L.	AH	5	13	3	18				
Amaranthus viridis L.	AH	3	8	3	18				
Ammi majus L.	AH	3	8	2	12				
Bidens pilosa L.	AH	1	3	3	18				
Euphorbia peplus L.	AH	1	3	3	18				
Phalaris minor Retz.	AG	2	5	2	12				
Calendula arvensis L.	AH	1	3	1	6				
(Zc) Zygophyllum coccineum L.	PS					3	13	3	27
(Si) Salsola imbricata Forssk. subsp. *Imbricate*	PS					9	39	3	27
Schoenoplectus litoralis (Schrad.) Palla	SD			1	6			1	9
IV. Species present in one habitat									
Ricinus communis L.	T							1	9
Verbesina encelioides (Cav.) Benth.	AH							1	9
Sporobolus spicatus (Vahl) Kunth	SD					3	13		
Aeluropus lagopoides (L.) Trin. ex Thwaites	PG					1	4		
Centaurium pulchellum (Swatz) Druce	AH					1	4		
Dalbergia sissoo Roxb.	T					1	4		
Euphorbia hirta L.	AH					1	4		

Medicago sativa L.	PF					1	4
Scirpus maritimus L.	SD					1	4
Senna italica Mill.	PS					1	4
Stipa capensis Thunb	AG					1	4
Setaria verticillata (L.) P. Beauv.	AG			6	35		
Cyperus laevigatus L.	SD			4	24		
Cyperus difformis L.	SD			3	18		
Oxalis corniculata L.	PH			3	18		
Paspalum distichum L.	PG			3	18		
Chloris virgata Sw.	AG			1	6		
Cordia sinensis Lam.	T			1	6		
Cyperus rotundus var. *fenzelianus* (Steud.) Habashy	SD			1	6		
Desmostachya bipinnata (L.) Stapf	PG			1	6		
Medicago polymorpha L.	AF			1	6		
Mentha longifolia (L.) Huds.	PH			1	6		
Panicum repens L.	PG			1	6		
Plantago lagopus L.	AH			1	6		
Plantago major L.	PH			1	6		
Pseudognaphalium luteo-album (L.) Hilliard & B. L. Burtt	AH			1	6		
Sisymbrium irio L.	AH			1	6		
Trigonella hamosa L.	AF			1	6		
(Tae) Triticum aestivum L.	AG	20	53				
Trianthema portulacastrum L.	AH	4	11				
Tribulus pentandrus Forssk.	AH	4	11				
Paspalidium geminatum (Frossk.) Stapf	PG	3	8				
Asphodelus tenuifolius Cav.	AH	2	5				
Dinebra retroflexa (Vahl) Panz.	AG	2	5				
Polygonum equisetiforme Sm.	PH	2	5				
Acacia farnesiana (L.) Willd.	T	1	3				
Brassica rapa L.	AH	1	3				
Coriandrum sativum L.	AH	1	3				
Euphorbia forsskaolii J. Gay	AH	1	3				
Euphorbia helioscopia L.	AH	1	3				
Lactuca serriola L.	AH	1	3				
Pisum sativum L.	AH	1	3				
Rhynchosia minima (L.) DC. var. *memnonia* (Delile) Cooke	PF	1	3				
Spergularia marina (L.) Griseb.	PH	1	3				
Suaeda aegyptiaca (Hasselq.) Zohary	PS	1	3				
Trifolium alexandrinum L.	AF	1	3				

N= numbers of fields where species was recorded, f= Frequency (%), GF= Growth form, AH= Annual Herb, PH= Perennial Herb, AF= Annual Forb, PF= Perennial Forb, AG=Annual Grass, PG= Perennial Grass, PS= Perennial shrub, T= Tree, SD= Sedge and rush and PAR= Parasite. Species abbreviations used in Figure 4 are given in parentheses.

Table 2. Means ± standard deviation of soil variables of the four studied habitats in Kharga Oasis.

Soil factors		Farmlands (F)	Date-palm orchards(P)	Salinized lands(S)	Surrounding desert(D)	*P* value
Gravels	(%)	4.29 ± 8.94	3.75 ± 9.74	4.70 ± 6.55	7.16 ± 15.70	0.814
Coarse sand (CS)	(%)	16.22 ± 8.79	12.94 ± 8.03	15.91 ± 13.73	12.03 ± 9.39	0.509
Fine sand (FS)	(%)	15.83 ± 6.65	13.71 ± 6.84	10.26 ± 5.49	10.01 ± 6.97	0.005**
Silt	(%)	47.65 ± 10.29	53.68 ± 13.86	51.72 ± 17.95	50.43 ± 17.16	0.473
Clay	(%)	16.01 ± 5.09	15.92 ± 4.14	17.42 ± 5.74	20.38 ± 7.18	0.103
Water content (WC)	(%)	12.33 ± 7.34	7.73 ± 5.42	4.14 ± 4.41	6.04 ± 14.11	0.001**
Organic matter (OM)	(%)	0.62 ± 0.34	0.66 ± 0.44	0.44 ± 0.36	0.44 ± 0.45	0.151
pH		7.87 ± 0.25	7.93 ± 0.28	7.91 ± 0.42	7.84 ± 0.37	0.855
Electrical conductivity (EC) (mS cm^{-1})		0.87 ± 1.08	0.64 ± 0.61	3.50 ± 5.58	2.22 ± 2.66	0.007**
Na^+	($mg.g^{-1}$ dry soil)	1.16 ± 1.38	0.86 ± 1.11	4.94 ± 6.85	3.12 ± 3.56	0.001**
K^+	($mg.g^{-1}$ dry soil)	0.24 ± 0.26	0.26 ± 0.24	0.60 ± 1.19	0.30 ± 0.21	0.181
Ca^{+2}	($mg.g^{-1}$ dry soil)	0.75 ± 0.91	0.45 ± 0.28	1.69 ± 1.97	1.87 ± 2.15	0.005**
Mg^{+2}	($mg.g^{-1}$ dry soil)	0.38 ± 0.28	0.31 ± 0.09	0.89 ± 1.25	0.60 ± 0.76	0.031*
Cl^-	($mg.g^{-1}$ dry soil)	1.46 ± 2.19	0.90 ± 1.02	9.53 ± 16.96	4.61 ± 8.31	0.006**
HCO_3^-	($mg.g^{-1}$ dry soil)	0.74 ± 0.42	0.69 ± 0.36	0.75 ± 0.45	0.71 ± 0.48	0.967
PO_4^{-2}	($\mu g.g^{-1}$ dry soil)	5.79 ± 6.85	6.25 ± 6.90	4.48 ± 7.96	3.12 ± 4.18	0.595
SO_4^{-2}	($\mu g.g^{-1}$ dry soil)	13.11 ± 12.75	9.37 ± 9.57	26.63 ± 27.44	22.54 ± 19.77	0.009**

Significance level: ** at 0.01 and * at 0.05 level.

3.3. Variations in Soil Properties between Habitats

Significant differences in the examined soil variables among the four habitats are shown in (Table 2). The contents of soil moisture, total soluble salts, Na, Ca, Mg, Cl, SO_4, and fine sand showed clear significant differences at $P<0.05$ and $P<0.01$. Salinized lands are characterized by maximum contents of electrical conductivity (EC) and most of the estimated soil ions. The stands of date-palm orchards showed the minima for most soil variables except their contents of silt, PO_4, and organic matter. Notably, the highest moisture content, coarse and fine sand percentages occurred in the farmlands.

3.4. Correlations between Vegetation and Soil within Habitats

The linear correlations (*r*) between the four habitats (Table 3) showed high significant positive correlations between farmlands and date-palm orchards (r = 0.703), and between salinized lands and the surrounding deserts (r = 0.764). Weak correlations occurred between the surrounding desert habitat and both of the farmlands and date-palm orchards on one hand, and between the farmlands and salinized lands on the other.

Table 3. Results of CCA for the different habitats along the first two axes, and linear correlation coefficients (*r*) between habitats.

Habitats	D		F		P		S	
	CCA axes							
	1	2	1	2	1	2	1	2
CCA results								
Eigenvalues	0.325	0.28	0.21	0.18	0.18	0.08	0.13	0.078
Species-environment correlations	0.82	0.88	0.89	0.87	0.88	0.78	0.79	0.73
Cumulative percentage variance of Species-environment relations	37.4	69.8	23.7	44.3	43.1	63	46.6	74.2
Monte Carlo test (499 permutations) of first CCA axis (P value)	0.02*		0.01**		0.04*		0.03*	
Linear correlation coefficients (*r*)								
Surrounding desert (D)								
Farmlands (F)	0.036							
Date-palm orchards (P)	0.208		0.703**					
Salinized lands (S)	0.764**		0.285*		0.401**			

**=P<0.01, *= P<0.05.

3.4.1. Farmlands

At the first TWINSPAN level (Figure 2), the thirty-eight farmlands were classified into two major groups characterized by *Brassica tournefortii* and *Dichanthium annulatum*. The second level was dominated by *Calotropis procera*, located in the northern part of the study area (Groups A and B), while the remaining stands were characterized by *Eruca sativa* representing Groups C (middle part) and D (southern part). Eleven species (e.g., *Cynodon dactylon, Malva parviflora, Chenopodium murale*, *Triticum aestivum,* and *Alhagi graecorum*) were represented in all groups. The stands of Group A were characterized by *Cynodon dactylon*, *Launaea mucronata* and *Calotropis procera* (f=100%), while stands of Group B were characterized by *Cynodon dactylon, Brassica tournefortii, Digitaria sanguinalis* and *Sonchus oleraceus* (f= 85-100%). Stands of Group C (middle part) were characterized by *Ammi majus*, *Lathyrus hirsutus, Dinebra retroflexa*, *Euphorbia helioscopia* and *Spergularia marina*, and stands of Group D (southern part) were characterized by thirteen species (e.g., *Avena fatua, Paspalidium geminatum*, *Calendula arvensis* and *Asphodelus tenuifolius*.

The application of Detrended Correspondence Analysis (DCA; Figure 3) revealed the segregation of the four vegetation groups along DCA axis 1 (Eigenvalue = 0.361) and DCA axis 2 (Eigenvalue=0.271). Stands of Groups A and B separated toward the positive side of DCA axis 1, while those of Group D separated toward its negative side. Meanwhile, the position of Group C was transitional between the other groups.

Results of Canonical Correspondence Analysis (CCA; Table 3) showed that the first two axes explained 44.3 % of cumulative variance in species-environment relations, and the species-environment correlation was high (0.89 and 0.87 for CCA axes 1 and 2, respectively) suggesting strong correlations between the species composition and the measured explanatory variables. From the results in Table (4), CCA axis 1 was highly positively correlated with organic matter (OM), and negatively correlated with HCO_3. This axis can be defined as a gradient of OM-HCO_3. CCA axis 2 showed a high positive correlation with HCO_3 and was negatively correlated with clay. Thus, it can be referred to as a gradient of HCO_3-clay.

Regarding the species distribution and their relation with explanatory variables (Figure 4), the dominant species with the highest frequencies (f%) in both Groups B and C (e.g., *Cichorium endivia* subsp. *divaricatum, Cynodon dactylon, Malva parviflora, Chenopodium murale, Convolvulus arvensis, Sonchus oleraceus* and *Echinochloa colona*) were affected by fine sand (FS), clay, organic matter (OM), calcium, and electrical conductivity (EC). On the other hand, species of Group D (e.g., *Sorghum halepense*) were attributed to contents of HCO_3. The distribution of the obtained TWINSPAN groups of this habitat in Kharga Oasis (Figure 5) revealed that stands of Group D located in the southern part showed correlations with HCO_3 and gravels, whereas, the stands of Groups B and C in the northern part were correlated to fine and coarse soil sediments.

3.4.2. Date-Palm Orchards

The seventeen date-palm orchards were classified into two major groups indicated by *Setaria verticillata* at the first level of classification (Figure 2). The second level was indicated by *Calotropis procera* from eleven stands in the southern (Group A) and middle (Group B) parts. Sixteen species were represented all over the study area, and characterized these groups (f=83-100%) including

Cynodon dactylon, Sonchus oleraceus, Convolvulus arvensis, and *Tamarix nilotica*.

The four vegetation groups of date-palm orchards (Figure 3) were segregated along the first two DCA axes (Eigenvalues= 0.43 and 0.331, respectively). Stands of Groups A and B positioned toward the negative side of axis 1, and the stands of Groups C and D occupied the positive side.

The first two CCA axes (Table 3) accounted for 63.0 % of the cumulative percentage variance, and the species-environment correlations were 0.88 and 0.78 for axis 1 and 2, respectively. The results in Table 4 also showed that axis 1 was strongly positively correlated with HCO_3, and negatively correlated with clay. Thus, this axis can be interpreted as HCO_3-clay gradient. The most important parameters along the second axis were WC and OM (negative correlations), and Na (positive correlation). This axis can be suggested as OM-Na gradient.

The distribution of Imperata cylindrica, Cynodon dactylon, Alhagi graecorum and Dichanthium annulatum were affected by contents of Na and HCO_3 (Figure 4), while Conyza bonariensis, Dactyloctenium aegyptium, Digitaria sanguinalis, Chenopodium murale, Malva parviflora and Sochus oleraceus were affected by soil contents of clay, silt, gravels, water content (WC) and organic matter (OM). Contents of HCO_3 and soil fractions were the most important gradients for stands of the middle (Group B) and southern (Group A) parts of Kharga Oasis (Figure 5).

3.4.3. Salinized Lands

Boerhavia repens subsp. *viscosa* was the indicator species that separated stands of Group A from other stands at the first level (Figure 2). Stands of Group A were characterized by *Boerhavia repens, Convolvulus fatmensis, Euphorbia hirta* and *Senna italica*, and stands of Groups B (northern and southern parts) and C (northern part) were characterized by *Bassia indica, Brassica tournefortii* and *Hyphaene thebaica*. The fifteen stands of Group B were characterized by *Alhagi graecorum* and *Tamarix nilotica* (P=93-100%). The eight stands (Group C) of the northern part were characterized by *Alhagi graecorum, Tamarix nilotica* and *Phoenix dactylifera*. Among the consistent species to this group, some salt-tolerant plants were recorded such as *Juncus rigidus, Cressa cretica, Scirpus maritimus* and *Typha domingensis*.

Along the first DCA axis, stands of Group A were clearly separated along the negative end, and stands of Groups B and C on the other end (Figure 3). The stands of the latter two groups were also separated along the second axis. The Eigenvalues decreased from 0.576 in the first axis to 0.373 in the second one.

The CCA results indicated that the cumulative percentage variance of species-environment relation was 74.2 % for the first two axes, and the species-environment correlations were 0.79 and 0.73 for axes 1 and 2, respectively (Table 3). The CCA analysis showed a positive correlation between the first CCA axis and clay content, and a negative correlation with OM, which can be interpreted as clay-OM gradient (Table 4). Meanwhile axis 2 was positively correlated with contents of PO_4, and negatively correlated with SO_4, which can be interpreted as PO_4-SO_4 gradient.

It can be noted from figure 4 that the distribution of some salt-tolerant species such as *Tamarix nilotica, Salsola imbricata* subsp. *imbricata, Phragmites australis* and *Bassia indica* were related to electrical conductivity (EC), clay and water content, whereas other species such as *Imperata cylindrica*, *Phoenix dactylifera* and *Alhagi graecorum* were related to organic matter and phosphates. The stands of Group C in the northern part of Kharga Oasis were significantly related to organic matter and Mg, while stands of Group B were highly correlated to WC and soil anions and cations. Stands of Group B were clearly distributed all over the study area (Figure 5).

3.4.4. The Surrounding Desert

The thirty-nine species which constituted the desert flora were classified by TWINSPAN into three main groups characterized by *Brassica nigra* at the first level, and *Calotropis procera* at the second level (Figure 2). Stands of Group A were characterized by eleven species; few were consistent to it such as *Brassica nigra, B. tournefortii, Chenopodium murale* and *Malva parviflora*. Twenty-one species of Group B included *Alhagi graecorum, Tamarix nilotica, Imperata cylindrica, Phoenix dactylifera* and *Phragmites australis* as the characteristic species (f=50-100%). The stands of Group C (middle part) were characterized by some desert trees and shrubs such as *Tamarix nilotica, Hyphaene thebaica,* and *Ziziphus spina-christi* (f=75-100%).

The DCA results revealed that the Eigenvalues were 0.724 and 0.459 for the first and second axes, respectively. Stands of Group A were separated along the positive portion of the first axis, while the other two Groups B and C separated along the other end. The species composition of Group A was completely different from Groups B and C (Figure 3).

Data of CCA analysis showed that the cumulative percentage variance of the species-environment relation was 69.8 % for the first two axes (Table 3), and the species-environment correlations were 0.82 and 0.88 for axes 1 and 2, respectively. Along the first axis of CCA biplot, a negative correlation of gravels and a high positive correlation of fine sand (FS) were detected, which can be considered as gravels-FS gradient (Table 4). A high negative correlation of silt and positive correlations of coarse sand (CS), bicarbonates (HCO_3) and potassium (K) were estimated, and therefore this axis can be defined as a gradient of CS and silt.

The effect of the examined explanatory variables on the distribution of the dominant species in this habitat (Figure 4) showed that *Ziziphus spina-christi, Calotropis procera, Trichodesma africanum* and *Hyphaene thebaica* were related to silt contents, while *Phragmites australis, Tamarix nilotica* and *Imperata cylindrica* were related to contents of bicarbonates, fine sand (FS), and coarse sand (CS). Groups A and C occupied the middle part of the oasis, while Group B occurred in the northern and southern parts (Figure 5).

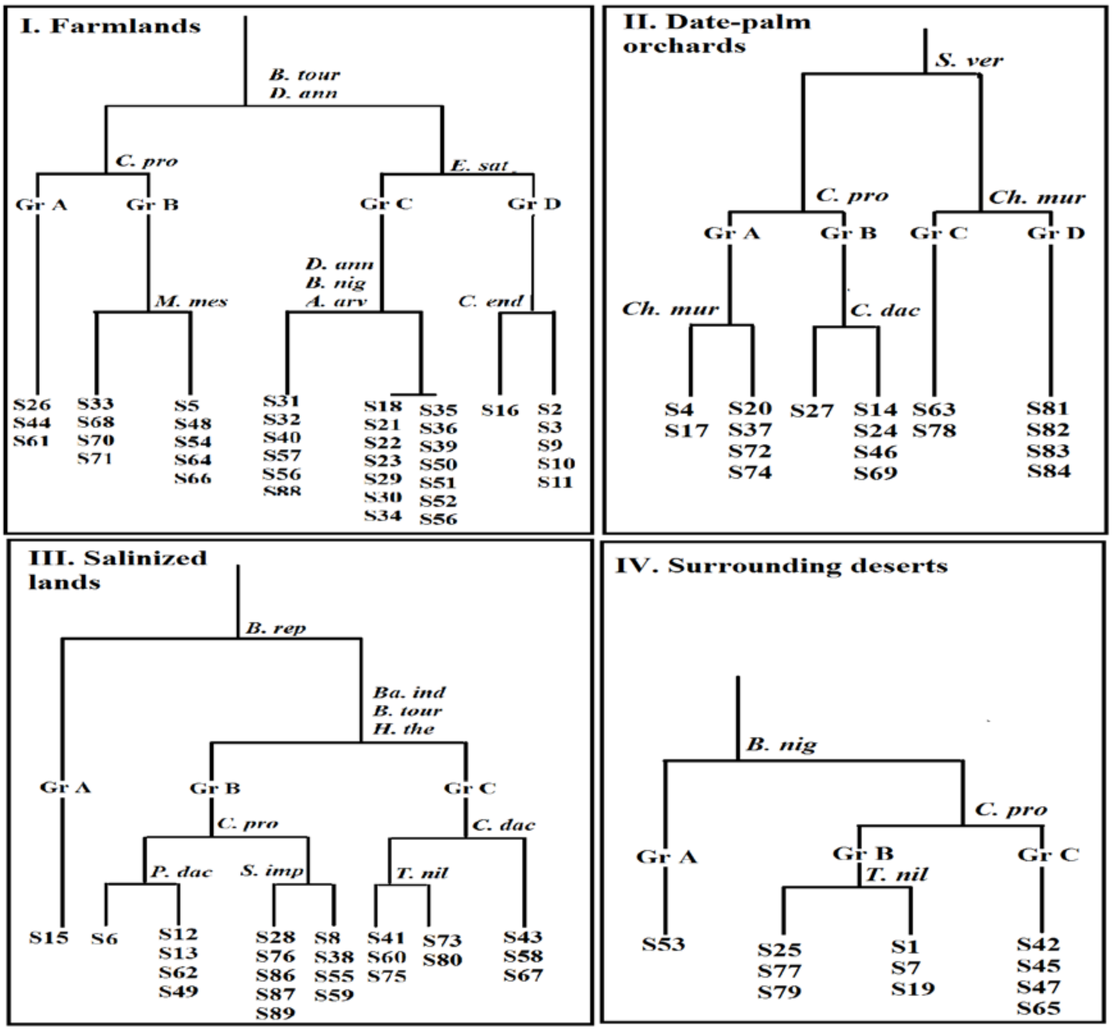


Figure 2. TWINSPAN dendrograms of the studied habitats, showing the distribution of stands within each vegetation group, (S=Stand).

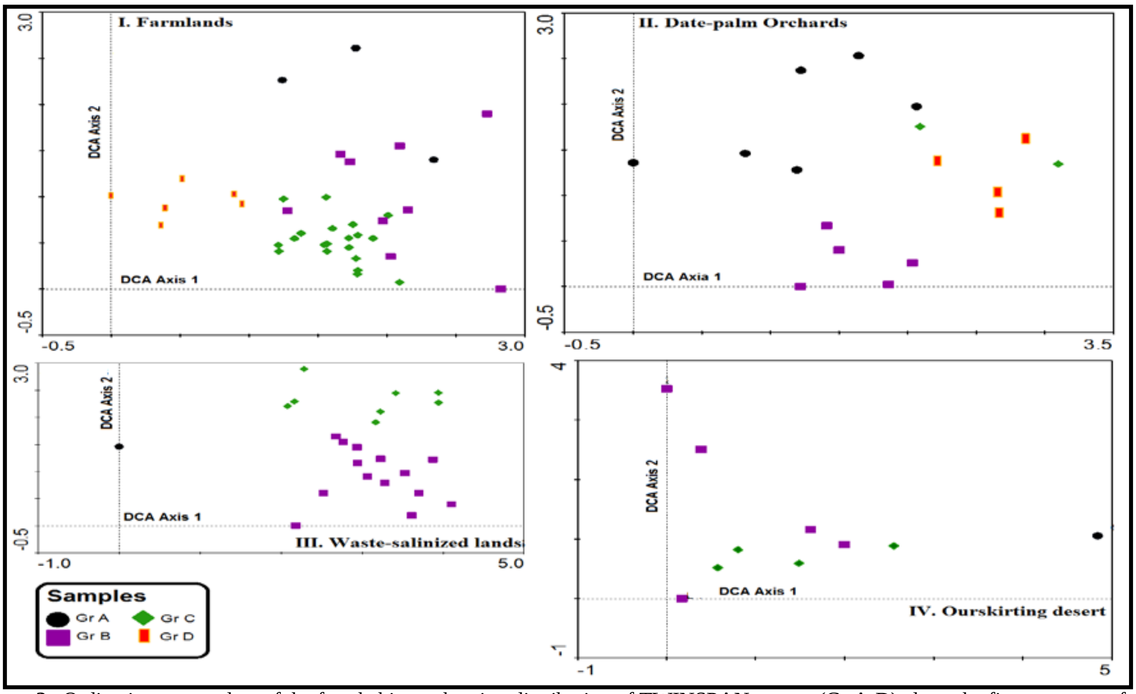
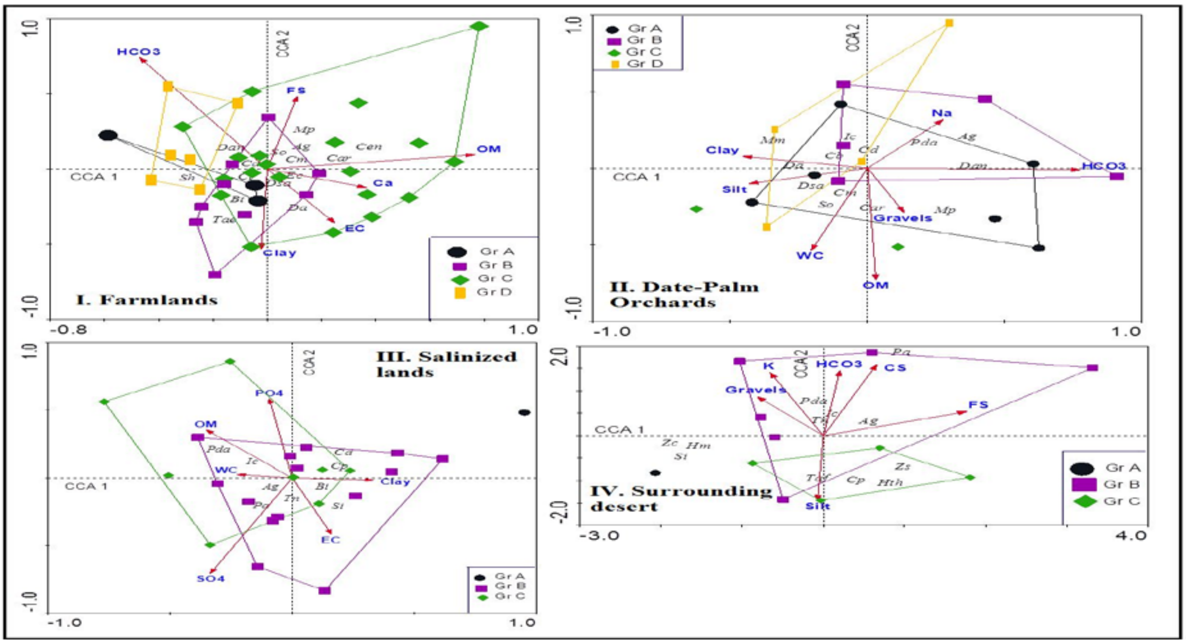


Figure 3. Ordination scatterplots of the four habitats, showing distribution of TWINSPAN groups (Gr A-D) along the first two axes of DCA.



**

Figure 4. CCA ordination diagrams of the four habitats with their dominant species within the TWINSPAN groups and examined soil variables. For species abbreviations, see

Table 4. Summary of forward selection and interest correlations of soil variables in CCA. For units, see Table 2. Figures in **bold** are significant correlations.

	Inter-set correlations with CCA axes								Forward selection (P values)			
Habitats	D		F		P		S		D	F	P	S
Axes	AX1	AX2	AX1	AX2	AX1	AX2	AX1	AX2				
Gravels	**-0.34***	0.39	─	─	0.12	0.22	─	─	0.01	NS	0.03	NS
Coarse sand (CS)	0.27	**0.67****	─	─	─	─	─	─	0.01	NS	NS	NS
Fine sand (FS)	**0.74****	0.23	-0.09	**0.42***	─	─	─	─	0.04	0.03	NS	NS
Silt	-0.03	**-0.61****	─	─	-0.38	-0.08	─	─	0.03	NS	0.02	NS
Clay	─	─	-0.01	**-0.46****	**-0.40***	-0.06	**0.26***	-0.01	NS	0.04	0.01	0.03
Water Content (WC)	─	─	─	─	-0.16	**-0.42***	-0.18	0.019	NS	NS	0.01	0.04
pH	─	─	─	─	─	─	─	─	NS	NS	NS	NS
Electrical conductivity (EC)	─	─	0.22	─	─	─	0.13	-0.30	NS	0.02	NS	0.03
Organic matter(OM)	─	─	**0.68****	-0.08	0.03	**-0.57****	**-0.28***	0.26	NS	0.01	0.05	0.01
Na^+	─	─	─	─	0.24	**0.25***	─	─	NS	NS	0.03	NS
K^+	-0.27	**0.59****	─	─	─	─	─	─	0.03	NS	NS	NS
Ca^{+2}	─	─	0.33	-0.11	─	─	─	─	NS	0.05	NS	NS
Mg^{+2}	─	─	─	─	─	─	─	─	NS	NS	NS	NS
Cl^-	─	─	─	─	─	─	─	─	NS	NS	NS	NS
HCO_3^-	0.08	**0.61****	**-0.42***	**0.68****	**0.69****	-0.07	─	─	0.04	0.01	0.05	NS
PO_4^{-2}	─	─	─	─	─	─	-0.07	**0.43***	NS	NS	NS	0.05
SO_4^{-2}	─	─	─	─	─	─	-0.26	**-0.52****	NS	NS	NS	0.04

**=P<0.01, *= P<0.05. NS=N=not significant, ─ = not included.

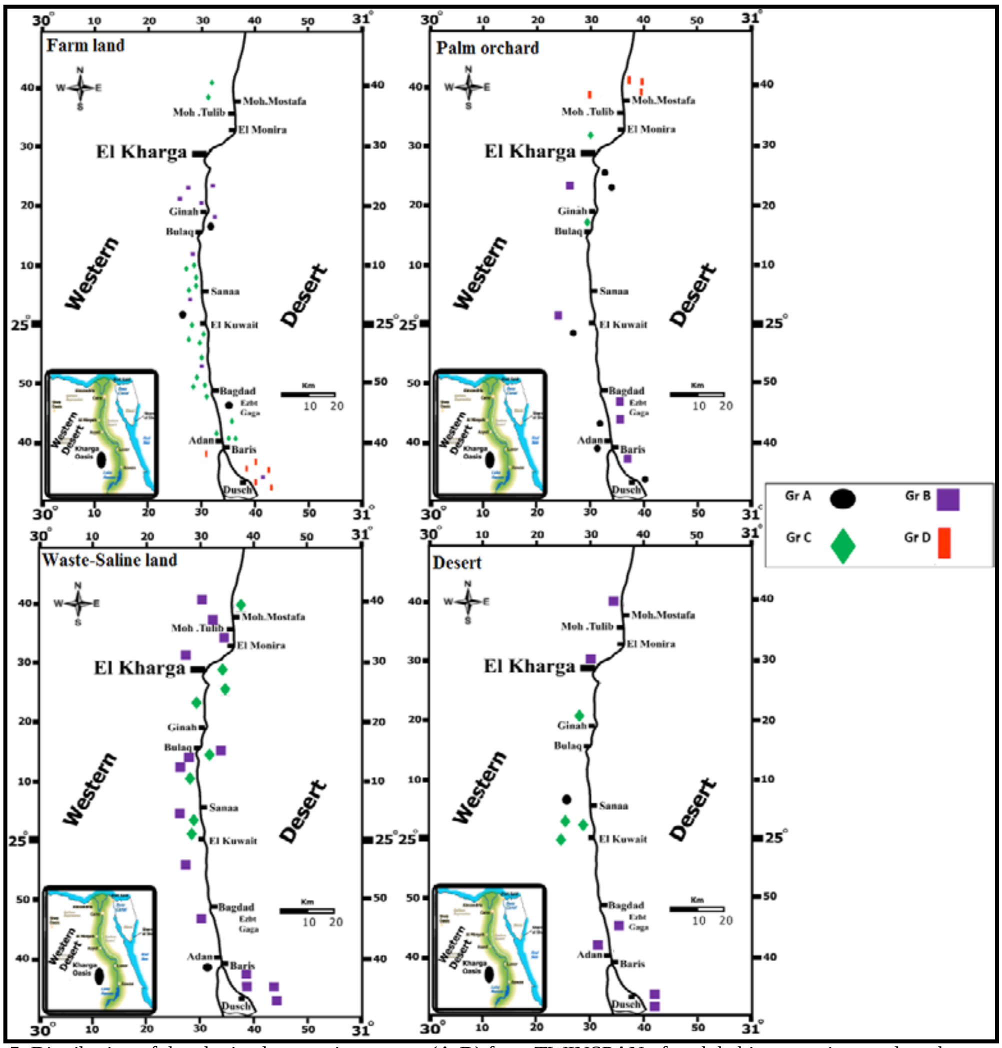


Figure 5. Distribution of the obtained vegetation groups (A-D) from TWINSPAN of each habitat superimposed on the map of the study area.

4. Discussion

Spatial heterogeneity is considered an important factor for the maintenance of diversity in ecosystems (De Smedt *et al.*, 2018). According to Reynolds *et al.*, (1997), species distribution in heterogeneous habitats may be affected by combinations of physical and chemical soil properties, and their ecological gradients can be defined by their variations in species diversity. The results of CCA analysis in the present study explained the most important environmental gradients which control the vegetation composition and species distribution in each of the recognized four habitats, and the positions of species and stands. In the surrounding desert, soil texture of different size classes, K and HCO_3 contents affect the distribution of species in this habitat. This can be reflected by the presence of several highly adapted, drought-resistant trees (*Ziziphus spina-christi*, *Calotropis procera*, *Tamarix aphylla*), shrubs (*Fagonia arabica*, *Hyoscyamus muticus*, *Zygophyllum coccineum*), and perennial herbs (*Trichodesma africanum*). The role of soil texture as a key factor in determining the spatial distribution of soil moisture in desert ecosystems is pronounced (Jafari *et al.*, 2004; Li *et al.*, 2018). Soil texture controls the distribution of plant species by affecting the moisture availability, ventilation and distribution of plant roots. The soil content of potassium was more effective in this habitat than the others, where K/Mg ratio is an indicator of grasslands and shrublands separation, and higher ratios of K/Mg are an indicator for the suitability of shrub growth (Jensen *et al.*, 1998). In the salinized lands, the plant species are surviving under the stress of high soil salinity (EC), as well as other factors such as water contents, organic matter, PO_4 and SO_4. Under such conditions, these habitats were characterized by salt-tolerant species such as *Tamarix nilotica*, *Phragmites australis*, *Bassia indica*, *Sporobolus spicatus*, *Aeluropus lagopoides*, *Salsola imbricata* subsp. *imbricata*. The results of this study indicate that species distributed in the salinized lands were strongly correlated with salinity and water content (MacDougall *et al.*, 2006). The topography, landform, soil texture, and soil surface sediments of different sizes control the moisture available for plant growth. The role of soil moisture, as a key element in the distribution of the plant species was described by Malkinson and Kadmon (2007) in the Negev desert and Abdel Khalik *et al.* (2017) in Wadi Fatimah of Saudi Arabia. The results of this study also confirmed the role of organic matter content as a key element in the soil fertility of the habitats of farmlands and date-palm orchards. This can be attributed to the application of fertilizers as well as the deposition of dry leaves and litter especially in the latter habitats. The results showed the effective role of soil variables on the weed community structure and diversity. The present findings agree with those of Fried *et al.* (2008) and Andreasen and Skovgaard (2009) who stressed the importance of soil texture, salinity, and organic carbon for the composition and species richness of weed communities. Common weeds of the arable lands in these habitats included: *Cyondon dactylon*, *Sonchus oleraceus*, *Chenopodium murale*, *Malva parviflora*, *Conyza bonariensis*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, and *Echinochloa colona*.

A detailed description of the concentric zonation of the vegetation in the habitats of agro-ecosystems of the oases of the Western Desert was presented by El-Saied *et al.* (2015) and Abd El-Ghani *et al.* (2017). Usually, three concentric zones (from outside to inside) were noticed: (1) the outer desert boundaries (surrounding desert), (2) the middle zone occupied by the salinized lands which receive the drainage water from (3) the inner cultivated lands (usually farmlands in the centre surrounded by the date-palm orchards). Accordingly, this may explain the high correlation coefficients between the species composition of the habitats of salinized lands and surrounding desert on one hand, and the date-palm orchards on the other. Although forming depressions in the Western Desert, yet this concentric type of habitats was not common in the Fayoum (Al-Sherif *et al.*, 2017) and Wadi El-Natrun (Abd El-Ghani *et al.*, 2017).

The wide distribution ranges of some species, mostly weeds with high frequency values such as *Cynodon dactylon, Sonchus oleraceus, Chenopodium murale, Malva parviflora* and *Dichanthium annulatum*, may be attributed to their being ubiquitous species with a wide ecological amplitude. Twenty-one species were represented in the farmlands and palm orchards while the surrounding deserts had none of them. This may be attributed to the high similarity in the species composition and site conditions for both. Due to the habitat heterogeneity, physico-chemical properties of the soil, and availability of water in the study area, some species exhibited certain consistency to a definite habitat. The consistency of forty-six species occurring in one habitat may be explained on the basis of habitat preference phenomenon. Common weeds of the arable lands in Egypt were confined to the farmlands such as *Trifolium alexandrinum*, *Euphorbia helioscopia*, *Dinebra retroflexa*, *Trianthema portulacastrum* and *Asphodelus tenuifolius*. Similar investigations of the weed flora of different parts of Egypt gave the same results (e.g., Shaheen, 2002), and in other parts of the arid and semi-arid regions (e.g., Turland *et al.*, 2004 in Crete, Karar *et al.*, 2005 in Sudan, Qureshi *et al.*, 2014 in Pakistan). Certain salt-tolerant plant species showed consistency to the habitats of salinized lands such as *Sporobolus spicatus*, *Aeluropus lagopoides* and *Scirpus maritimus*. These species may form pure or mixed halophytic plant communities (Zahran and Willis, 2003).

The special microhabitats of the date-palm orchards allow certain species to grow and flourish (e.g., *Oxalis corniculata*, *Mentha longifolia*, *Ambrosia maritima*, *Conyza bonariensis* and *Digitaria sanguinalis*). The plant communities of date-palm orchards in Siwa Oasis have been studied by Abd El-Ghani (1994) who reported three associations: (1) *Cynodo-Melilotetum indici*, (2) *Convolvulo (arvensis)-Imperatetum cylindrici*, and (3) *Euphorbia-stellarietum medici*. This study's results confirmed that the floristic composition of the date-palm orchards in Kharga Oasis is congruent with those in the Siwa Oasis. On the contrary, the floristic components of the date-palm orchards of Al-Hassa Oasis in eastern Saudi Arabia (Shaltout and El-Halawany, 1992) revealed its halophytic as well as mesophytic nature. Human activities, pests, and diseases are the main causes behind the degradation of date-palm trees and the low production of dates in North African and Arab countries (El-Juhany, 2010). Some orchards are in danger of dying out either because of human activities and/or severe dry arid conditions as in the Feiran Oasis in south Sinai, Egypt (Abd El-Ghani *et al.*, 2017).

In the habitats of the surrounding deserts and salinized lands, the psammophytes (e.g. *Zygophyllum coccinum, Citrullus colocynthis* and *Senna italica*) and halophytes (e.g. *Sporobolus spicatus* and *Aeluropus lagopoides*) showed their highest frequency values. Due to the differences in their ecological factors, the vegetation composition of the latter two habitats was characterized by species that are adapted to either salinity stress or harsh desert environments. Xerophytic species were naturally grown among the weeds of the cultivation. This indicates that these species are components of the natural desert vegetation, and can thrive after the reclamation process. Therefore, the reclaimed lands bounding the desert outskirts can be considered as transitional zones of the succession process between the old cultivated lands and those of the desert (Shaheen, 2002; Abd El-Ghani *et al.*, 2017). Also, this indicates that the floristic structure of the study area is more affected by human disturbances such as over-cutting of woody perennials (for fuel and domestic uses, building roofs) and the exploitation of reclaimed arable lands by salinization due to the lack of a network of drainage system.

Weeds of the arable lands constitute the major component (68 %) of the flora according to the present study. This study also states that the weedy species replaced the natural plant communities in the study area, and this is a widespread phenomenon (Yang *et al.*, 2006). It has also been found that weed diversity in the arable fields is higher in complex and heterogeneous landscapes (Petit *et al.*, 2010). The floristic composition of the farmlands in the study area included, in addition to arable weeds, some desert species that grow in the surrounding natural habitats such as *Citrullus colocynthis*, *Tamarix nilotica, T. aphyla*, and *Zygophyllum coccineum*. This suggests that the human practices in land reclamation in the Kharga Oasis entails that weed species replace the natural xeric plant communities (Baessler and Klotz, 2006). Also, several authors reported similar conclusions (Shaltout and El-Halawany, 1992). The results of the present study are in accordance with those of Abd El Ghani *et al.*, (2017) regarding the increased species richness in the farmlands and date-palm orchards.

The variations in species richness and Shannon's diversity index among the different habitat types may be attributed to the difference in soil characteristics, substrate discontinuities, and the allelopathic effect of one or more invasive species depending on their relative dominance among other associated species (James, 2006). The high level of species diversity would be brought about by a local differentiation in soil properties around individual plants, since the heterogeneity of environments allows for the satisfaction of the requirements of many species within a community (Whittaker and Levin, 1977). This agrees with the results obtained from this study which shows a low species richness (number of species/stand) in the extreme habitats either of higher contents of salinity or desert areas (as in the salinized lands and the surrounding desert habitats), and a high species richness in the habitats of lowest salinity (as in the farmlands and date-palm orchards). This finding is in partial agreement with the results reported by Hegazy *et al.,* (2008) in the Nile Delta region, but is congruent with those of Abd El-Ghani (1994) in the Siwa Oasis.

5. Conclusions

This investigation provides recent information on the floristic composition, habitat variation, and vegetation structure in relation to the soil conditions of the Kharga Oasis of the Western Desert in Egypt. According to the land use and the agricultural practices in this area, four major habitats can be recognized; each was characterized by three-four vegetation groups. A specific relationship between plant species and the prevailing environmental variables was detected. Such relationships may be attributed to the site conditions, tolerance adaptability, and nutrient requirements. The key elements of the environmental factors for each habitat may be helpful in the reclamation processes and the improvement of an ecosystem. Some species exhibited a certain degree of consistency which helps definite the habitat. Due to the lack of well-drainage system, vast areas of the cultivated lands were transformed to salinized lands which resulted in land exploitation and habitat loss. Soil texture, organic matter, and bicarbonate were the major determinants of the species distribution among habitats. The farmlands and date-palm orchards had the highest species diversity with the largest share of annuals, while the salinized lands and the surrounding desert had the lowest species diversity with the dominance of perennials. The vegetation composition of the latter two habitats was characterized by species that adapted to either salinity stress or harsh desert environments. The floristic diversity of the date-palm orchards as a characteristic habitat in the Kharga Oasis is under danger and threat due to severe uncontrolled human activities and the prevailing harsh environmental desert conditions. The establishment of socio-economic conservation measures is urgent for the sake of the prevention of uncontrolled human disturbances and the land-use management of the fragile and degraded habitats.

References

Abd El-Ghani MM. 1994. Weed plant communities of orchards in Siwa Oasis–Egypt. *Feddes Repert*, **105 (5-6):** 387-398.

Abd El-Ghani MM, Barakat HN and Shamloul AM.1992. Vegetation pattern and habitat types around old wells in Kharga Oasis – Egypt. *J Faculty of Education Ain Shams University*, **17**: 161-171.

Abd El-Ghani MM, Huerta-Martínez FM, Hongyan L and Qureshi R. 2017. **Plant Responses to Hyperarid Desert Environments.** Switzerland: Springer International Publishing AG.

Abdel Khalik K, Al-Gohary I and Al-Sodany Y. 2017. Floristic composition and vegetation: Environmental relationships of Wadi Fatimah, Mecca, Saudi Arabia. *Arid Land Res Manag.*, **31**: 316-334.

Al-Sherif EA, Ismael MA, Karam MA and El-Fayoumi HH. 2017. Weed flora of Fayoum (Egypt), one of the oldest agricultural regions in the world. *Planta Daninha*, **36**, Doi: 10.1590/S0100-83582018360100034.

Andreasen C and Skovgaard IM. 2009. Crop and soil factors of importance for the distribution of plant species on arable fields in Denmark. *Agric Ecosyst Environ.,* **133(1):** 61-67.

Baessler C and Klotz S. 2006. Effects of changes in agricultural land use on landscape structure and arable weed vegetation over the last 50 years. *Agric Ecosyst Environ.,* **115**:43-50.

Boulos L. 1999-2005. **Flora of Egypt.** Vols. 1-4. Al Hadara Publishing, Cairo, Egypt**.**

Boulos L. 2009. **Flora of Egypt Checklist.** Revised Annotated Edition. Al Hadara Publishing, Cairo, Egypt.

Buckley LB and Roughgarden J. 2004. Biodiversity conservation - effects of changes in climate and land use. *Nature,* **430**: 145-148.

De Smedt P, Ottaviani G, Wardell-Johnson G, Sýkora KV and Mucina L. 2018. Habitat heterogeneity promotes intraspecific trait variability of shrub species in Australian granite inselbergs. *Folia Geobot.,* **53**:133-145.

El-Amier YA and Abd El-Gawad AM. 2017. Plant communities along the international coastal highway of Nile delta, Egypt. *J Sci Agric.,* **1**: 117-131.

El Hadidi MN. 2000. **Flora Aegyptiaca.** Vol. 1, part 2. Cairo: Palm Press.

El-Juhany LI. 2010. Degradation of Date palm trees and date production in Arab countries: causes and potential rehabilitation. *Aust J Basic Appl Sci.*, **4(8):** 3998-4010.

Ellenberg H, Weber HE, Düll R, Wirth V, Werner W and Paulissen D. 1992. **Zeigerwerte von Pflanzen in Mitteleuropa.** 2nd Ed., *Scripta Geobot.,* **18**: 1–248.

El-Saied A, El-Ghamry A, AKhafagi O, Powell O and Bedair R. 2015. Floristic diversity and vegetation analysis of Siwa Oasis: An ancient agro-ecosystem in Egypt's Western Desert. *Ann Agric Sci.,* **60(2)**: 361-372.

Fried G, Norton LR and Reboud X. 2008. Environmental and management factors determining weed species composition and diversity in France. *Agric Ecosyst Environ.,* **128(1):** 68-76.

Hegazy AK, Mussa SAI and Farrag HF. 2008. Invasive plant communities in the Nile Delta coast. *Global J Environ Res.,* **2 (1):** 53-61.

Henderson PA and Seaby RMH. 1999. **Community Analysis Package (CAP)** version 1.2. Pisces Conservation Ltd. IRC House, UK.

Hermina M. 1990. The surroundings of Kharga, Dakhla, and Farafara oases. *In***:** Said R. (Ed)**, The Geology of Egypt**, Rotterdam: A.A. Balkema, pp 259-292.

Jackson ML. 1967. **Soil Chemical Analysis**. New Delhi: Prentice-Hall.

Jafari M, Zare Chahoukib MA, Tavilib A, Azarnivandb H and Zahedi Amirib Gh. 2004. Effective environmental factors in the distribution of vegetation types in Poshtkouh rangelands of Yazd Province (Iran). *J Arid Environ.,* **56:** 627–641.

James JJ, Caird MA, Drenovsky RE and Sheley RL. 2006. Influence of resource pulses and perennial neighbors on the establishment of an invasive annual grass in the Mojave Desert. *J Arid Environ.,* **67:** 528-534.

Jensen ME, Peck LS and Wilson MV. 1998. A Sagebrush community type classification for mountainous northeastern Nevada rangelands. *Great Basin Nat.,* **48:** 422–433.

Jongman RHG, Ter Braak CJF and Van Tongeren OFR. 1987. **Data analysis in community and landscape Ecology.** Cambridge University Press.

Kapur P and Govil SR 2000. **Experimental Plant Ecology.** CBS, Publisher and Distributors, Darya ganj, New Delhi, India.

Karar RO, Mohamed BF and Marrs RH. 2005. Factors influencing the weed flora in the Gezira Scheme, Sudan. *Weed Res.,* **45:** 121–129.

Kent M. 2012. **Vegetation Description and Data Analysis**: **A Practical Approach**, 2nd ed. Oxford: Wiley-Blackwell.

Lansdown RV and Juffe Bignoli D. 2013. *"Juncus rigidus". IUCN Red List of Threatened Species*. Version 2013.2. International Union for Conservation of Nature.

Legendre P and Legendre L. 1998. **Numerical Ecology**: second English edition. Elsevier Science BV, Amsterdam

Li S, Su P, Zhang H, Zhou Z, Xie T, Shi R and Gou W. 2018. Distribution patterns of desert plant diversity and relationship to soil properties in the Heihe River Basin, China. *Ecosphere,* **9(7):** e02355. 10.1002/ecs2.2355

MacDougall AS, Boucher J, Turkington R and Bradfield GE. 2006. Patterns of plant invasion along an environmental stress gradient. *J Veg Sci.,* **17:** 47–56.

Malkinsonm D and Kadmon R. 2007. Vegetation dynamics along a disturbance gradient: Spatial and temporal perspectives. *J Arid Environ.,* **69:** 127–143.

Mashaly IA and Awad ER. 2003. Weed Flora of Orchards in the Nile Delta, Egypt: Floristic Features. *Asian J Plant Sci.,* **2(3):** 314-324.

Pansu M and Gautheyrou J. 2007. **Handbook of Soil Analysis: Mineralogical, Organic and Inorganic Methods.** Springer Science & Business Media.

Petit S, Boursault A, Le Guilloux M, Munier-Jolain N and Reboud X. 2010. Weeds in agricultural landscapes. A review. *Agron Sustain Dev.,* **31(2)**: 309-317.

Pielou EC. 1975. **Ecological Diversity.** New York: Wiley.

Qureshi R, Shaheen H, Ilyas M, Ahmed W and Munir M. 2014. Phytodiversity and plant life of Khanpur Dam, Khyber Pakhtunkhwa, Pakistan. *Pak J Bot.,* **46(3):** 841-849.

Reynolds HL, Hungate BA, Chapin FS and D'Antonio CM. 1997. Soil heterogeneity and plant competition in an annual grassland. *Ecol.*, **78:**2076–2090.

Salama FM, Abd El-Ghani MM 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 FM, Abd El-Ghani MM, El-Tayeh NA, Amro AM and Abdrabbu HS. 2016. Weed flora of common crops in desert reclaimed arable lands of southern Egypt. *Taeckholmia,* **36:** 62-85.

Salama FM, Abd El-Ghani MM, El-Tayeh NA, Amro AM and Abdrabbu HS. 2017. Correlations between soil variables and weed communities in major crops of the desert reclaimed lands in southern Egypt. *Rend Lincei Sci Fis Nat.,* **28:** 363–378.

Shaheen AM. 2002. Weed diversity of newly farmed lands on the southern border of Egypt (eastern and western shores of Lake Nasser). *Pak J Biol Sci.,* **5(7):** 602-608.

Shaltout KH and El-Halawany EF. 1992. Weed communities of date palm in eastern Arabia. *Qatar University Sci J.,* **12:** 105-111.

Shaltout KH and Al-Sodany YM. 2008. Vegetation analysis of Burullus Wetland: a RAMSAR site in Egypt. *Wetl Ecol Manage,* **16(5):** 421-439.

Sheded M, Hamed S and Badry M. 2014. Vegetation analysis of six riverian islands in hyper-arid environments at Qena Governorate (Upper Egypt). *Acta Bot Hung.,* **56(3-4):** 409-431.

Täckholm V. 1974. **Students' Flora of Egypt.** 2nd ed. Cairo University Press, Cairo, Egypt.

Ter Braak CJF and Šmilauer P. 2002. **CANOCO Reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5).** Ithaca: Microcomputer Power.

Ter Braak CJF. 2003. **CANOCO, version 4.** Wageninge: Wageningen University and Research Centre, the Netherlands.

Titus JH, Nowak RS and Smith SD. 2002. Soil resource heterogeneity in the Mojave Desert. *J Arid Environ.,* **52:**269–292.

Turki Z and Sheded M. 2002. Some observations on the weed flora of rice fields in the Nile Delta, Egypt. *Feddes Repert,* **113(5-6):** 394-403.

Turland N, Phitos D, Kamari G and Bareka P. 2004. Weeds of the traditional agriculture of Crete. *Willdenowia,* **34:** 381-406.

Upadhyay RM and Sharma NL. 2005. **Manual of Soil, Plant, Water and Fertilizer Analysis.** New Delhi: Kalyani.

Whittaker RH. 1972. Evolution and measurement of species diversity. *Taxon* 21: 213–251.

Whittaker RH and Levin SA. 1977. The role mosaic phenomena in natural communities**.** *Theor Popul Biol.,* **12:** 117-139**.**

Yang H, Lu Q, Wu B, Zhang J and Lin Y. 2006. Vegetation diversity and its application in sandy desert revegetation on Tibetan Plateau. *J Arid Environ.,* **65:** 619-631.

Zahran MA and Willis AJ. 2003. **Plant Life in the River Nile in Egypt.** Mars Publishing House: Riyadh Saudi Arabia.

Zar JH. 1999. **Biostatical Analysis**. Upper Saddle River: Prentice Hall.