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Vegetation Analysis and Species Distribution in the Lower Tributaries of Wadi Qena in the Eastern Desert of Egypt

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Abstract

Vegetation composition and soil attributes in the lower tributaries of Wadi Qena in the Eastern Desert of Egypt are studied from fifty-one stands in three wadis, namely Wadi El-Ghuza, Wadi Naq El-Teir, and Wadi El-Atrash. Altogether, fifty-two species from twenty families and thirty-nine genera, mainly of the Saharo-Arabian focus of distribution, were recorded. Chamaephytes and therophytes constituted 73 % of the main bulk of life form the spectrum of the recorded flora. After the removal of unicates, the presence/absence datasets of thirty-six species and fifty-one stands were classified by TWINSPAN yielding four vegetation groups: *Zygophyllum coccineum-Zilla spinosa-Calligonum polygonoides* (group A) mainly in Wadi Naq El-Teir, *Zygophyllum coccineum-Zilla spinosa* (group B) in Wadi El-Ghuza, *Morettia philaeana* (group C) from the southern part of Wadi El-Atrash, and *Zygophyllum coccineum-Morettia philaeana* (group D) from the northern part of Wadi El-Atrash. These groups were clearly separated along the first two axes of DCA. Soil-vegetation correlations performed by Redundancy Analysis (RDA) indicated that axis 1 was shaped by calcium and organic matter, while axis two was controlled by pH and phosphate contents. Variations of species richness and Shannon diversity index within the separated TWINSPAN groups were highly significant.

Keywords: Vegetation analysis, Arid ecosystems, Soil-environment relationships, Inland wadis, Distribution patterns, Egypt.

1. Introduction

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. It consists essentially of high back bone of high rugged mountains running parallel to and at a relatively short distance from the coast. These mountains are flanked to the north and west by intensively dissected sedimentary plateau (Said, 1962). Mountains of the eastern desert are of two types: igneous and limestone. The igneous mountains extend southward from about Lat. 28^o N to beyond the Sudano-Egyptian borders at Lat. 22^o N. To the north of the igneous mountains are the extensive and lofty limestone mountains of North Galala, South Galala, and Gebel Ataqa separated by a broad wadi. One of the main features of this desert is that it is intersected by numerous canyon-like depressions (wadis) running to the Red Sea or to the Nile Valley.

The wadis are unique intrazonal landscapes in arid and semi-arid regions of the world (Fossati *et al.*, 1998), as they represent one of the most prominent desert landforms, which exhibit physiographic irregularities that lead to parallel variations in species distribution (Kassas and Girgis, 1964). These wadis are drainage systems for collecting water from extensive catchments areas such as hills, cliffs, slopes, etc. Accordingly, the water supply of a wadi is many times the recorded rainfall with richer vegetation than other types of desert habitat. This advantage is, however, counterbalanced by two destructive agents: torrents and grazing. The water way of the torrents is usually devoid of plant cover, which is restricted to the wadi sides. The influence of torrents on plants is partly mechanical, destroying and uprooting the plants, and partly erosion removing the soil (Kassas and El-Abyad, 1962). In addition, certain species are subjected to serious grazing by animals, while woody plants are liable for cutting as a source of fuel. The development of wadi bed includes the gradual accumulation of transported material. The soil barren bed allows the growth of chaemophytes, while a shallow soil cover, moistened during the rainy season, allows the appearance of the ephemerals. When a deep soil is accumulated allowing the establishment of a wet-soil layer, perennials will find it favourable for their growth. At an advanced stage, deep alluvial deposits allow free water to be stored in the subsoil and a water table is established. At this stage shrubs and/or trees are characteristic of the habitat

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Since Schweinfurth (1901), the botanical exploration of the wadis of the Eastern Desert attracted many botanists and geographers. Ever since, wealth of monumental and documentary works concerned with the flora, vegetation and habitats of the Eastern Desert were published (Abd El-Ghani *et al.*, 2014). The floristics, chorological affinities, plant communities, functional groups, and their environmental relationships received much attention, and yielded several publications in the past few years (Salama *et al.*, 2013, 2014, 2015).

The phytosociological study on the deltaic part and the principal channel of Wadi Qena has been investigated by Salama and Fayed (1990). In the last decades, Wadi Qena was affected by human activities including; cultivation of the deltaic part, the intensive collection of plant species for its values (medicinal, fuel, fibers…etc.), establishment of new settlements and high ways, etc. Undoubtedly, these activities affect the natural flora and vegetation, and changed the distribution of plant species in Wadi Qena. This wadi represents a rather complex heterogeneous ecosystem necessitating arbitrary dismantling on investigation. Due to the variety of chances of water-feeding of its tributaries, it was found appropriate to investigate them in more or less homogeneous groups, apart from the main trunk of the wadi, which collects such waters into a vast delta pouring directly south to the Nile Valley, shortly north east of the city of Qena.

Therefore, the present study was designed to answer the following questions: (1) What is the present status of the floristic composition of the lower tributaries of Wadi Qena (Wadi El-Ghuza, Wadi Naq El-Teir, and Wadi El-Atrash)? (2) What are the plant communities inhabiting different habitats of these wadis? (3) What are the major environmental gradients associated with the species distribution and plant communities in these wadis? and (4) What are the factors affecting the diversity of plant communities inhabiting the study area? These objectives were addressed by applying multivariate analyses methods to the data of species composition and soil environment from fifty-one sample plots.

2. Material and Methods

2.1. Study Area

Wadi Qena (between latitudes 26° 10´ and 28° 00´N) is one of the most notable features of the Eastern Desert of Egypt. The north-south course of its principal channel is unique. It is the largest and greatest dry valley which runs in this desert for a distance of about 220 km. It runs from north to south (i.e., in an opposite direction to the Nile Valley) and debouches at the city of Qena 600 km south of Cairo (Figure 1). Its width varies from 5 to 25 km, and its widest part lies north of Gebel Abu Had. Although this wadi is generally dry all over the year, some seasonal rainfall is experienced in winter time which may occasionally (not regularly) become torrential in autumn and spring times. The torrential rains (in January, 1980 and November, 1996) that swept suddenly over a limited area in the Eastern Desert facing Qena Province (Upper Egypt) resulted in enriching the vegetation of some extremely dry wadis at this location. This leads to the prevalence of annuals and the flourishing of scarce perennial vegetation (El-Sharkawi *et al.*, 1982a, 1982b).

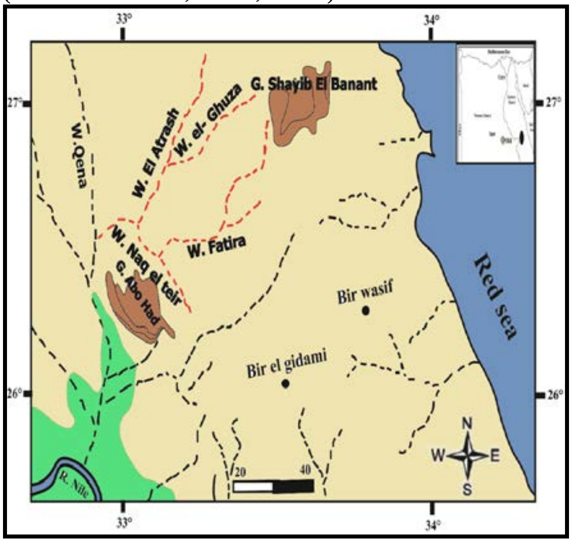

Figure 1. Location map of the 4 studied wadis

Unlike other wadis of the Eastern Desert of Egypt, the main trunk of Wadi Qena has a unique north-south orientation extending for a distance of about 220 km. Its tributaries cover an area between longitudes 32° 10´ and 33° 30´E (Figure 1). The main wadis which debouch their water in Wadi Qena are: Wadi El-Qreiya, Wadi Naq El-Teir, Wadi Fatira, Wadi Hammad and Wadi Zubeir from the east and Wadi Gurdi is the main of the western tributaries. Accordingly, the catchment area of this wadi is immense. Its tributaries, therefore, are not of equal opportunity in receiving waters of sporadic rain. Due to the variety of chances of water feeding of the tributaries of Wadi Qena originating in the mountain range of the Red Sea and pouring their flood waters into its principle channels, difference in floral characteristics and vegetation composition are somewhat expectable.

The scarp around Wadi Qena belongs to the upper Cretaceous-Lower Tertiary rocks. Available meteorological records from the South Valley University station at Qena showed that the average maximum summer temperature was 40.9 °C and the minimum temperature was 25.1 °C. The maximum temperature in the coldest winter month was 23.3 °C and the minimum temperature was 8 °C. Relative humidity ranges from 45.9 % in winter to 17.1 % in summer. Rainfall is negligible occurring only in May with 0.5 mm.

2.2. Vegetation Data Collection

This study was carried out over two successive years, 2014 and 2015. Fifty-one geo-referenced randomly chosen stands (20×20m) were studied in the main wadis where considerable vegetation cover was encountered. These wadis were Wadi El-Ghuza, Wadi Naq El-Teir and lower tributary of Wadi El-Atrash (Figure 1), located between latitudes of 26° 38' and 26° 57'N with mean elevation ranging from 254 m to 498 m above the sea level. The presence and absence of species were recorded from each stand, and a presence percentage (P %) for each species was calculated. The recorded species were classified according to their life forms (Raunkiaer, 1934). The number of species within each life form was expressed as a percentage of the total number of species in the study area. Taxonomic nomenclature was according to Täckholm (1974), Boulos (1995, 1999, 2000) and El-Hadidi and Fayed (1995). Analysis of phytogeographical ranges of each species follows Zohary (1966, 1972) and Feinbrun-Dothan, 1978).

2.3. Soil Sampling and Analysis

Three soil samples (0-50 cm) were collected from each of the stands, pooled into one composite sample and were left to air drying. Different fractions of sandy soil were separated by the dry sieving method (Ryan *et al.*, 1996). Calcium carbonate ($CaCO_3$) was determined according to the titration method after Jackson (1967). The organic matter contents of the soil samples were determined by loss on ignition methods (Sparks *et al.*, 1996). Water content was determined by weighing the fresh soil sample, drying it in an oven at 105˚C for twenty-four hours, then the dry weight was determined. Sodium and potassium ions were determined by flame photometry according to Williams and Twine (1960), while calcium and magnesium were determined volumetrically by the versene titration method described by Johnson and Ulrich (1959). Chlorides were volumetrically determined as AgCl according to Jackson (1967), sulfates by turbidimetry according to Bardsley and Lancaster (1965), phosphates were determined colourimetrically according to Vogler (1965), and carbonates were estimated by titration using the method described by Jackson (1967). Electric conductivity (EC) of the clear soil filtrate was determined using the conductivity meter according to Jackson (1967). Electric pH-meter was used to determine the soil reaction of the collected samples.

2.4. Multivariate Analyses

Classification and ordination techniques were used to analyze the vegetation. Species recorded in one stands (unicates) were removed from analysis to avoid distortion. So, a presence/absence data matrix of fifty-one stands × 36 species was used and subjected to classification by Two-Way Indicator Species Analysis (TWINSPAN) using the default settings of the computer program CAP (Community Analysis Package) (version 1.2) for Windows (Henderson and Seaby, 1999), and a dendrogram was elaborated. All ordination procedures were performed with CANOCO software (version 4.5) (Ter Braak, 1987, 1990). Detrended Correspondence Analysis (DCA) estimated the compositional gradient in the vegetation data to be ranged from 2.89 to 2.50 S.D units for most subset analysis. Therefore, Redundancy Analysis (RDA) was used as the appropriate direct analysis to measure the soil-vegetation relationships (Ter Braak and Prentice, 1988). Prior to RDA analysis, all data variables were assessed for normality (SPSS version 10.0 for Windows), and appropriate transformations were performed when necessary (Zar, 1984). Six soil variables (sand, clay, electrical conductivity (EC), potassium, sodium and sulphates) were eliminated from the RDA analysis due to the high collinearity (Kutner *et al.*, 2004), and the inflation factor did not exceed 7.5. Therefore, nine soil variables were used in the RDA analysis: gravel, silt, pH, organic matter (OM), water content (WC), calcium, magnesium, phosphates and chlorides. A Monte Carlo permutation test (499 permutations) was used to test for significance of the eigenvalues of the first canonical axis. The TWINSPAN vegetation groups were subjected to ANOVA (One-Way Analysis of variance) based on the soil variables to investigate whether there were significant variations among the groups.

2.5. Species Diversity

Two species diversity measures were employed. Species richness (SR) within each separated TWINSPAN vegetation group was calculated as the average number of species per stand. The Shannon-Wiener diversity index (H') was calculated according to the formula: $H' = -\Sigma_i^S P_i \log_2 P_i$ (Pielou, 1975), where S is the total number of species and P_i is the presence percentage of the i th species.

2.6. Life Forms and Soil Relationship

After classifying these species within their vegetation groups, the number of species within each life form was expressed as a percentage of the total number of species in the vegetation group. DCA estimated the length of gradient in the floristic data, and was 4.12 SD units. Then a data-set of the species life forms (presence or absence) with the soil variables for each stand was analysed by the Canonical Corresponding Analysis (Leps and Šmilauer, 2003) to estimate the correlations between each life form and the soil variables. After eliminating three soil variables (clay, electrical conductivity and potassium) due to their high collinearity, twelve soil variables were used in the CCA analysis: gravel, silt, FS, CS, pH, OM, WC, calcium, magnesium, sodium, phosphates and chlorides. Monte Carlo permutation test (499 permutations) was also used in this analysis. Percentages of four life forms within four TWINSPAN groups were subjected to ANOVA to find out the degree of significance among the groups (Sokal and Rohlfs, 1981).

3. Results

3.1. Floristic Composition

A total of fifty-two species from twenty families of the vascular plants and thirty-nine genera were recorded. Largest families with the highest numbers of species were Zygophyllaceae (nine species), Brassicaceae (six species), Fabaceae and Asteraceae (five species for each), Chenopodiaceae (four species) and Boraginaceae and Resedaceae (three species for each). These families constituted the main bulk of the total flora (thirty-five species or 67.3 %). Analysis of the life form spectrum showed chamaephytes, and therophytes were equally distributed and constituted the main bulk (36.5 % for each) of the recorded flora, while phanerophytes were very scarce (9.6 %). *Fagonia* was the largest genus (four species), whereas the remaining genera were represented by 1-2 species. The majority of the recorded species belong to the Mediterranean and Saharo-Arabian chorotypes.

3.2. Classification of Vegetation

Four vegetation groups were separated after the application of TWINSPAN analysis to the presence/absence data set of thirty-six species recorded in fifty-one stands (Figure 2, Table 1). These groups included five dominant species that have the highest presence percentages (P %) and were recorded in all groups; viz., *Zygophyllum coccineum, Zilla spinosa, Calligonum polygonoides, Aerva javanica* and *Acacia tortilis* subsp. *raddiana*. Five species showed consistency:

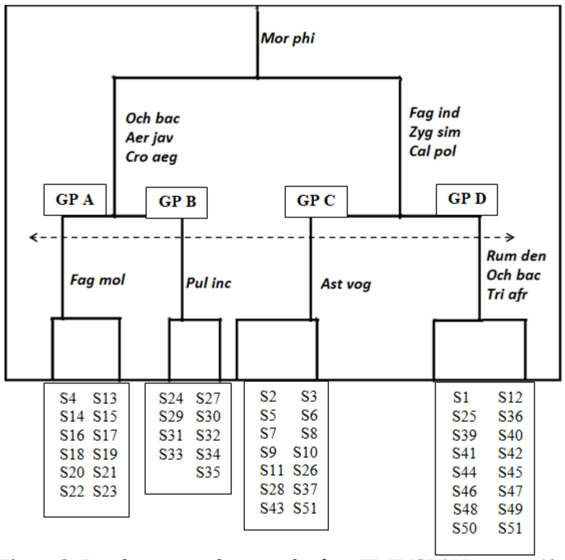

Figure 2. Dendrogram indicating the four TWINSPAN groups (A-D), together with their indicator species resulted from the classification of the 51 stands. For species abbreviations, see Appendix.

group (D) *Rumex dentatus, Tribulus pentandrus, T. longipetalus, Pergularia tomentosa* and *Plantago ciliata.* Notably, groups (C) and (D) share ten species (Table 1) with a lower presence percentages (P = 6.2-37.5 %), whereas *Zygophyllum simplex* and *Forsskaolea tenacissima* attained their highest records (93.7 % for the former and 62.5 % for the latter) in group D.

Similar observation can be noted to another eight species shared groups (B), (C) and (D), but with highest (P %) for *Faginia indica* and *Pulicaria incisa* in group (D). The soils inhabited the fifty-one studied stands were alkaline in nature with pH ranged between 8.57 in group (A) and 8.83 in group (D). Variations between groups showed that sand fractions were the only soil parameter that caused significant difference ($p = 0.018$).

Group (A) included eleven species from twelve stands collected from Wadi Naq El-Teir (Table 1), and was the least diversified among the other groups. Dominant species were *Zygophyllum coccineum, Zilla spinosa, Calligonum polygonoides*, and co-dominated by *Crotalaria aegyptiaca*. Soil of this group (Table 2) was characterized by the highest contents of sand, sodium and chloride ions, but attained the lowest values of several soil parameters (e.g., organic matter, water content, electrical conductivity, etc.). The fifteen species of group (B) that were sampled from nine stands from Wadi El-Ghuza were dominated by *Zygophyllum coccineum* and *Zilla spinosa*, and co-dominated by *Calligonum polygonoides* and *Aerva javanica.* The soil of this group showed the highest contents of water, electrical conductivity, gravel, calcium and magnesium ions (Table 2), and lower contents of sodium and phosphates. *Morettia philaeana* dominated (P = 100 %) the fourteen stands of group (C) which was sampled from the southern part of Wadi El-Atrash. *Zygophyllum coccineum, Zilla spinosa* and *Calligonum polygonoides* were the co-dominant species with P = 92.8 % for each (Table 1). The stands of this group had the highest values of soil organic matter, and lower contents of other variables. Group (D) was the most diversified among the others (thirty-six species). This group was dominated by *Zygophyllum coccineum* and *Morettia philaeana,* and co-dominated by *Fagonia indica* and *Zygophyllum simplex*. Important but not dominant species included *Forsskaolea tenacissima* and *Stipagrostis plumosa*. Sporadic species included *Seriphidium herba-alba, Crotalaria aegyptiaca, Eremobium aegyptium* and *Diplotaxis acris*. The stands of this group inhabited soil with highest contents of fine sediments (silt and clay), sulphates, pH, sand fractions, and the lowest contents of calcium and potassium ions (Table 2).

Table 1. Floristic composition in the TWINSPAN vegetation groups of studied wadis. Full names of and authorities of species abbreviations are presented in the Appendix.

Species Abbreviations	GP A	GP B	GP C	GP D
Number of stands	12	9	14	16
Number of species	11	15	27	35
Zyg coc	100	100	92.8	100
Zil spi	100	100	92.8	93.7
Cal pol	100	88.9	92.8	12.5
Aer jav	25	88.9	35.7	25
Aca sp	16.7	11.1	28.6	31.2
Fag mol	16.7		14.3	12.5
Mor phi	8.3		100	100
Fag ara	8.3		14.3	6.2
Och bac		44.4	64.3	25
Pul inc		22.2	28.6	75
Fag ind		11.1	35.7	93.7
Cit col		11.1	50	25
Sti plu		11.1	7.1	62.5
Lep pyr		11.1	7.1	18.7
Art jud		11.1	7.1	6.2
Hel dig		11.1	7.1	6.2
Cro aeg	91.7			6.2
Art her	41.7			6.2
Hel bac	8.3			12.5
Chr pli		11.1		25
Res pru		11.1	7.1	
Zyg sim			33.3	93.7
Ere aeg			33.3	6.2
For ten			14.3	62.5
Tri afr			14.3	37.5
Ast vog			7.1	25
Lot pla			7.1	18.7
Oli lin			7.1	12.5
Asp ten			7.1	6.2
Bas mur			7.1	6.2
Dip acr			7.1	6.2
Rum den				31.2
Tri pen				31.2
Per tom				18.7
Tri lon				18.7
Pla cil				12.5

Table. 2 Mean values, standard deviations (SD) and ANOVA values of the soil variables in the TWINSPAN vegetation groups (A-D) of the studied wadis.

Soil variables		TWINSPAN groups A	B	C	D	F-value	*P*
pH		8.57 ± 0.39	8.79 ± 0.51	8.70 ± 0.55	8.83 ± 0.44	0.752	0.526
Gravel		3.53 ± 4.24	5.31 ± 5.50	5.04 ± 5.39	4.97 ± 6.03	0.259	0.855
Sand		60.56 ± 17.32	38.81 ± 19.03	51.02 ± 22.97	35.66 ± 23.73	3.692*	0.018
Silt	(%)	34.06 ± 18.45	50.76 ± 22.73	36.73 ± 20.92	51.77 ± 22.44	2.432	0.077
Clay		1.85 ± 1.21	5.13 ± 3.56	7.21 ± 5.42	7.60 ± 9.82	2.18	0.103
WC		0.08 ± 0.02	0.19 ± 0.22	0.11 ± 0.06	0.14 ± 0.10	2.024	0.124
OM		0.86 ± 0.51	1.22 ± 0.36	1.57 ± 0.85	1.56 ± 0.90	2.727	0.055
EC	(mS/cm)	1527.97 ± 705.35	2341.07 ± 2970	1596.87 ± 1515	1723.28 ± 3520	0.219	0.883
Ca		0.31 ± 0.19	0.49 ± 0.69	0.33 ± 0.35	0.25 ± 0.44	0.579	0.632
Mg		0.04 ± 0.02	0.08 ± 0.07	0.05 ± 0.04	0.07 ± 0.10	0.712	0.55
Cl		0.34 ± 0.06	0.34 ± 0.23	0.30 ± 0.14	0.30 ± 0.13	0.28	0.84
SO_4		0.33 ± 0.26	0.33 ± 0.39	0.40 ± 0.31	0.41 ± 0.40	0.184	0.907
PO_4	(mg/g soil)	0.02 ± 0.00	0.02 ± 0.01	0.04 ± 0.02	0.03 ± 0.04	1.949	0.135
Na		0.42 ± 0.13	0.30 ± 0.28	0.34 ± 0.29	0.38 ± 0.60	0.175	0.913
K		0.32 ± 0.10	0.36 ± 0.29	0.34 ± 0.23	0.30 ± 0.22	0.154	0.926
SR		5.25 ± 0.75	5.66 ± 1.22	8.28 ± 3.5	11.87 ± 2.12	23.26**	0.001
H'		2.01 ± 0.01	2.11 ± 0.33	2.57 ± 0.65	3.01 ± 0.03	20.90**	0.001

OM=organic matter, WC=water content, EC=Electric conductivity, SR=Species richness and H'=Shannon-Wiener index.**= $p < 0.01$, *= $p < 0.05$.

3.3. Stand and Species Ordination

Figure 3 shows the ordination results of the DCA analysis of the floristic data set. The four TWINSPAN groups were separated along the first (eigenvalue = 0.416) and second (eigenvalue = 0.230) DCA axes. Higher eigenvalues of the first DCA axis indicated that it captured the greater proportion of the variation in the species composition among stands. The four DCA axes explained 14 %, 7.8 %, 5.1 % and 3.8 % of the total variation in the species data, respectively.

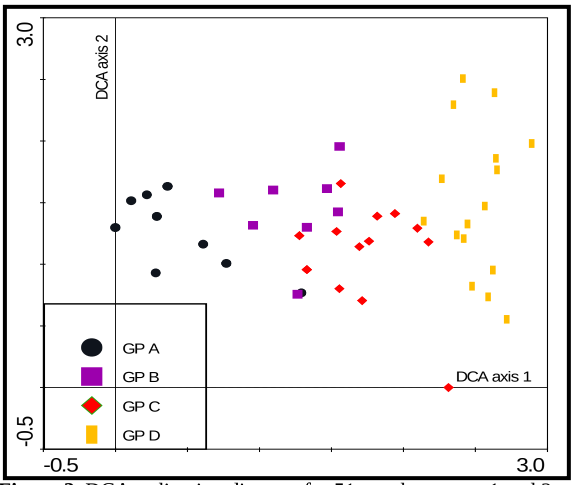

Figure 3. DCA ordination diagram for 51 stands on axes 1 and 2, with the four TWINSPAN groups superimposed.

The lengths of gradients were relatively short: 2.891 for the first axis, and 2.508 for the second. Stands of group (A) were separated toward the negative end of DCA axis 1, while stands of group (D) were separated out along the other end, and those of group (B) and (C) were transitional in their composition between the other groups. DCA axis 1 showed significant positive correlations with organic matter (r = 0.23), water content (r = 0.21) and clay (r = 0.20) and negative correlation with sand (r = -0.28). DCA axis 2 was positively correlated with magnesium (r = 0.26) and pH (r = 0.37) and negatively correlated with PO_4 (r = -0.27). Species ordination by using DCA (Figure 4) revealed the separation of *Calligonum polygonoides*, *Crotalaria aegyptiaca* and *Seriphidium herba-alba*, which characterized group (A), along the negative side of DCA axis 1 from all other species. In the centre of DCA axis 1, *Zygophyllum coccineum* and *Zilla spinosa* occupied an intermediate position along this axis.

3.4. Soil-Vegetation Relationships

Redundancy Analysis (RDA) was used to assess the relationship between the vegetation and soil variables. The TWINSPAN groups (A-D), and the examined soil variables were indicated in the RDA ordination biplot (Figure 5). The species–environment correlations were higher for the first two axes, explaining 60.4 % of the cumulative variance (Table 3).

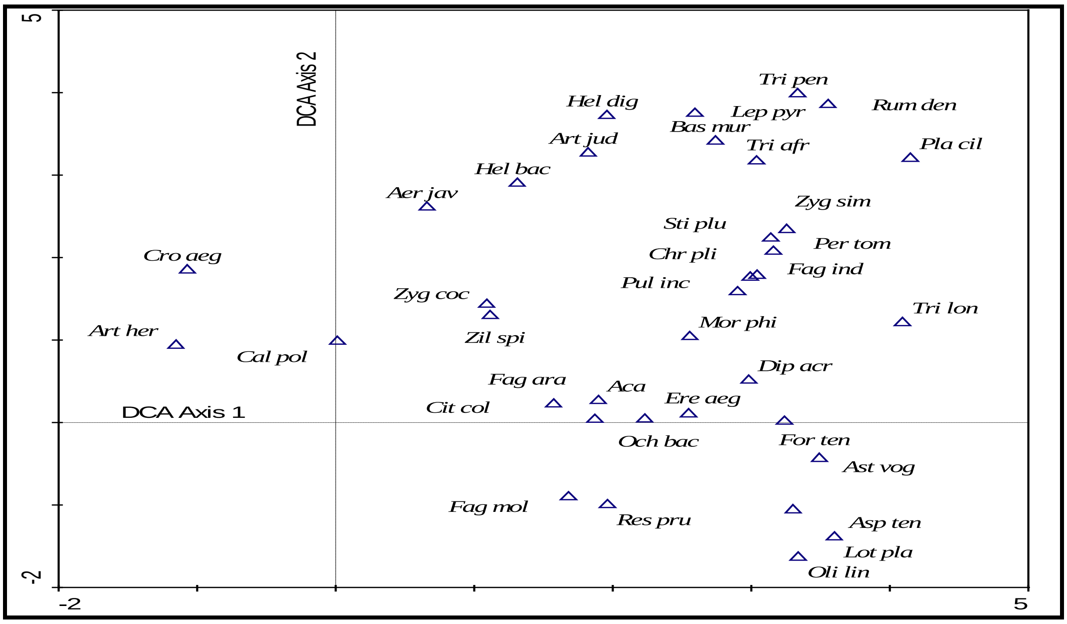

Figure 4. DCA ordination diagram of the 36 species scores on axes 1 and 2. For species abbreviations see Appendix.

The nine soil variables contributed independently to the overall ordination since none of the inflation variables reached higher scores than 15.0 From the interset correlations of the soil factors with the first two axes of RDA (Table 3), it can be inferred that the first axis was negatively correlated with organic matter (r = -0.316) and positively correlated with calcium (r = 0.21). The second axis was defined by pH (r = -0.25) and phosphate contents (r = 0.382). A test for significance with unrestricted Monte Carlo permutation test (499 permutations) indicated that the F-ratio for the eigenvalue of axis 1 and the trace statistic to be significant (p = 0.002). The ordination diagram produced by RDA showed similar pattern to the floristic DCA ordination, with most of the stands remaining in their respective TWINSPAN vegetation groups. It can be noted that stands of groups (A) and (B) occupied the right side of the ordination plane, and were correlated by calcium and chloride ions. On the other hand, the remaining vegetation groups (C and D) occupied the left side of the plane and were correlated by several soil factors such as organic matter, phosphates, sulphates and magnesium ions, pH and gravel.

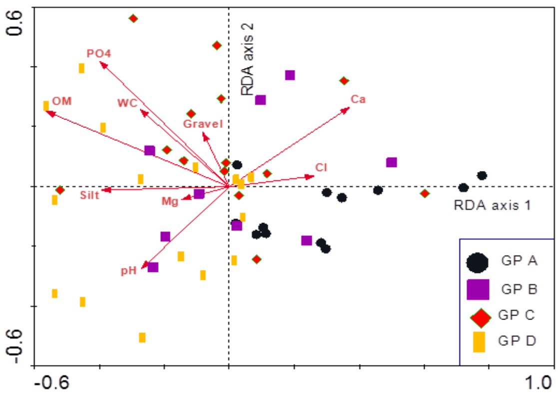

Figure 5. Ordination biplot yielded by Redundancy Analysis (RDA) of the 51 stands with their TWINSPAN groups and soil variables.

Table 3. Interset correlation of the soil variables together with eigenvalues and species–environment correlation along the first 2 RDA axes.

	RDA Axes	
Soil variables	1	2
Eigenvalues	0.09	0.049
Species-environment correlations	0.63	0.74
% Cumulative variance of species data	39.9	60.4
Organic Matter (OM)	-0.316	0.23
Water Content (WC)	-0.153	0.23
Ca	0.21	0.242
Mg	-0.08	-0.040
Gravel	-0.045	0.165
Silt	-0.220	-0.011
Cl	0.146	0.032
PO_4	-0.223	0.382
pH	-0.151	-0.25

3.5. Species Diversity

Both estimated species diversity indices (species richness and Shannon-Wiener index) showed significant variations among the separated TWINSPAN groups (Table 2). However, Pearson correlation coefficients (r) between the examined soil variables and diversity indices exhibited insignificant correlations (results not shown). In addition, group (A) had the lowest species richness (5.25±0.75 species stand^{-1}) and Shannon-Wiener index (2.01±0.01), while group (D) had the highest diversity records.

3.6. Life Forms and Soil Relationships

This relationship was clear between most of the annuals (therophytes) and the soil water content, organic matter, silt, pH, Mg and PO_4. Meanwhile, the soil-surface buds-bearing perennials (hemicryptophytes) were mainly dependent on silt, fine sand, and soil reactions (pH). Also, there was a correlation between the low-growing perennial shrubs (chamaephytes) and the salinity factors (Na and Cl), coarse sand, and fine sand. The woody trees and shrubs (phanerophytes) were concentrated in the upper half of CCA biplot (Figure 6) with organic matter and most estimated soil anions and cations.

The successive decrease of eigenvalues of the two CCA axes (0.206 and 0.158 for axes 1 and 2, respectively), illustrated in Table (4), suggested a well-structured data set. The species environment correlations were high for the first two axes, explaining 81.3 % of the cumulative variance.

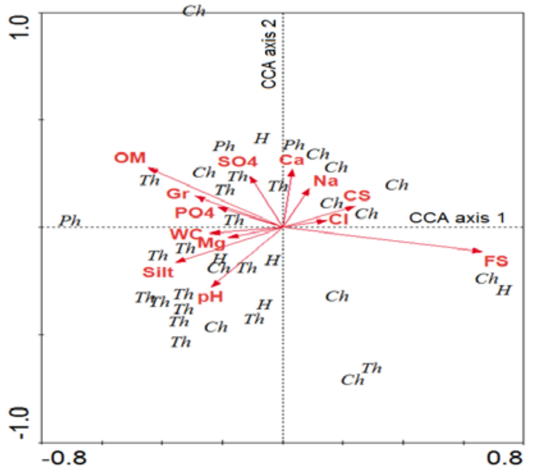

Figure 6. CCA biplot indicating the relationship between life form categories of the studied species and soil variables.

The interset correlations resulted from Canonical Correspondence Analysis (CCA) of the examined soil variables were displayed in Table (4). CCA axis one can be interpreted as fine sand-organic matter gradient; also axis two can be interpreted as organic matter-pH gradient, while the third axis may name PO_4-pH gradient. A test for significance with an unrestricted Monte Carlo permutation test (499 permutation) for the eigenvalue of axis one was found to be significant (p = 0.03).

Significant differences (ANOVA) between the percentages of each life form within the separated vegetation groups were demonstrated in Table 2. The variations of hemicryptophytes and therophytes among the four vegetation groups showed high significant differences among groups at p < 0.01, while phanerophytes showed significant difference among these groups at p < 0.05. However, there was no difference between their chamaephytes. These calculations indicated a significant rise of hemicryptophytes in group D (42.5 %), while the minimum percentage was in group B (8.89 %; Table 2). For phanerophytes; the highest percentage was in group C (30.95 %), and the minimum was in group A (5.56 %). On the other hand, the most represented life form (therophytes) recorded the highest percentage (25.78 %) at group D, but it was nearly not represented in group A (0.52 %).

4. Discussion

As in most of the hyperarid desert environments, the vegetation in the study area is restricted to wadis, runnels and depressions with deep fine sediments that receive an adequate water supply (Abd El-Ghani *et al.*, 2017). Minimal precipitation and frequent droughts characterized the vegetation in the arid regions; therefore the availability of water is one of the primary factors controlling the distribution of species (Yair and Danin, 1980; Salama *et al.*, 2016).

Table 4. Interset correlation of the life forms and soil variables, together with eigenvalues and species–environment correlations along the first 2 CCA axes.

	CCA Axes	
Soil variables	1	2
Eigenvalues	0.206	0.158
Species-environment correlations	0.748	0.813
% Cumulative variance of species data	17.8	31.4
OM	-0.33	0.226
WC	-0.18	-0.02
Ca	0.024	0.22
Mg	-0.14	-0.04
Gravel	-0.22	0.118
CS	0.18	0.08
FS	0.496	-0.09
Silt	-0.27	-0.13
Na	0.066	0.148
Cl	0.111	0.027
PO_4	-0.16	0.077
SO_4	-0.08	0.195
pH	-0.18	-0.23

Parker (1991) suggested that the distribution of the dominant species and variations in distributional patterns over a small geographic area in the desert ecosystem may be related to edaphic factors and local topography. The plant life in the study area is restricted to microenvironments (as in wadis, runnels and depressions), where runoff water collects and provides sufficient moisture for plant growth which is mainly formed of xerophytic shrubs and sub-shrubs to withstand the harsh environmental conditions. The vegetation is mosaic characterized by sparseness of plant cover, a limited number of plant species (mean species richness 8.2±3.5 on the average in studied stands), and paucity of trees (less than 5 % of the recorded species). Mono-dominant stands are not as common as those dominated by more than one species. Walter *et al.* (1975), considered the study area within the subtropical dry zone which has very hot summers and mild winters with a short rainy season. Therefore, the dominant perennial species provide the permanent character of the plant cover. Shortly after rainfall, the appearance of annuals provides a characteristic physiognomy to the vegetation (Alatar *et al.*, 2012).

Chorological analysis of the floristic data revealed that the Saharo-Arabian chorotype forms the major component of the floristic structure where it was represented by more than 50 % in the studied wadis. This can be attributed to the ability of the Saharo-Arabian species to withstand the harsh environmental desert conditions. Similar conclusions were indicated in the Egyptian desert (Salama *et al.*, 2012), in the Saudi Arabia highlands (Abdel Khalik *et al.*, 2013), and in the Libyan Sahara (Hegazy *et al.*, 2011). Preponderance of chamaephytes and therophytes over other life forms may be attributed to the hot dry climate and the continuous anthropogenic effects (Asri, 2003).These results are congruent with the vegetation spectra in other parts of the Middle East (Danin and Orchan, 1990).

The dominance of *Acacia tortilis* subsp. *raddiana* in wadi channels has been reported in many parts of the arid Middle East (Robinson, 2004; Woldewahid *et al.*, 2007) and is supported in this study. It is an important fodder tree for the livestock and as a source of fuel wood for the Bedouin people. A recent evaluation of the conservation status of this species has pointed to the massive mortality of mature trees, and a corresponding lack of recruitment by young trees (Rohner and Ward, 1999). Therefore, it is believed to be endangered in many parts of the Middle East (Wiegand *et al.*, 1999).

In the different vegetation patterns, plant life forms (Boulos, 1999, 2000, 2002, 2005) showed a characteristic distribution. True annuals (e.g., *Astragalus vogelii*, *Asphodelus tenuifolius*, *Cotula cinerea*) occurred directly after rainfall. Most other species proceed through therophytic, short-lived perennial (*Morettia philaeana*, *Pulicaria incisa*, *Zygophyllum simplex*) or even long-lived perennial life cycles (*Crotalaria aegyptiaca*, *Fagonia* spp., *Pulicaria incisa*, *Zilla spinosa*) depending on the soil moisture content (Springuel *et al.*, 2006). These species with life cycles determined not by an internal but by an external factor are called poikilorhythmic species (Bornkamm, 2001). They are the characteristic life form of accidental vegetation, and were described in parts of the Western Desert of Egypt (Abd El-Ghani, 2000). The xeropsammophytes such as *Fagonia arabica*, *Cornulaca monacantha*, *Zilla spinosa*, *Calligonum polygonoides*, *Pulicaria incisa*, *Citrullus colocynthis*, and *Heliotropium digynum* were found in dry non-saline sandy sites with higher fertility soils, where infiltration is higher and water accumulates in deeper layers. These species are distributed widely in Egypt (Zahran and Willis, 2009) and the neighbouring countries (Wojterski, 1985).

In most of the arid regions, correlation of soils and vegetation were investigated in various habitats through the application of multivariate analyses techniques. In the desert ecosystem García-Novo *et al.* (2004), Enright *et al.* (2005), Salama *et al.* (2016) and van Etten and Fox (2017) worked in this direction. These investigations include large areas, and therefore they reported striking gradients referring to soil conditions and vegetation. In this study, two approaches of multivariate analyses were used. The heterogeneity of microclimatic conditions and the local topography affected the variation of the distributional behaviour of the plant associations in the study area. In terms of vegetation and floristic composition, four vegetation groups (plant communities) were identified and represented the plant communities that characterized the studied wadis: *Zygophyllum coccineum-Zilla spinosa-Calligonum polygonoides* (group A) mainly in Wadi Fatira, *Zygophyllum coccineum-Zilla spinosa* (group B) in Wadi El-Ghuza, *Morettia philaeana* (group C) from the southern part of Wadi El-Atrash, and *Zygophyllum coccineum-Morettia philaeana* (group D) from the northern part of Wadi El-Atrash. Most of the identified vegetation groups have very much in common with that recorded in some wadis vegetation of the Egyptian desert and the neighbouring countries (Tielbörger, 1997; Sheded *et al.*, 2014). Analysis of the vegetation-soil relationships using Redundancy Analysis (RDA) indicated that the distribution of vegetation in the study area was mainly controlled by pH, organic matter, calcium, and phosphate contents. The role of organic carbon as a key element in soil fertility is well known. Sharaf El-Din and Shaltout (1985) pointed out the importance of soil organic matter in delimiting vegetation groups in the bed of Wadi Araba in the northern part of the Eastern Desert. The role of the percentages of surface sediments of different size classes in the spatial distribution of soil moisture was reported in similar investigations (Dasti and Agnew, 1994). The precipitation of silt and clay that are carried by rains and torrents to the studied wadis increased their percentages in the soil texture. The decomposition of plant residues increased the organic matter content in the soil, and the dissolved potassium and calcium that came with rainwaters decreased the sodium toxicity (Taiz and Zeiger, 2002), and lead to enrich the vegetation diversity (Traut, 2005).

Differences in responses of the life forms to their soil variables indicated that the soil water content, organic matter, silt, pH, Mg and PO_4 act as the main environmental requirements to therophytes of this study area. Meanwhile, most of perennials (hemicryptophytes, chamaephytes and phanerophytes) were mainly preferred organic matter, soluble ions especially salinity factors (Na and Cl), coarse sand and fine sand. From this investigation, it was clear that annuals dominated the silty plains of the study area while the others (perennials) prefer sandy soils.

These calculations indicated a significant rise of hemicryptophytes and therophytes in the northern silty-fertile half of Wadi El-Atrash (group D), while their lower representation was in the poor area of Wadi El-Guzah (group B). Phanerophytes went in a similar manner of the previously mentioned life forms, but they increased significantly in the southern half of Wadi El-Atrash (group C) which is rich in OM, SO_4, PO_4 and K. This increase in such life forms in the main trunk of Wadi El-Atrash may be because this Wadi is considered as a main runoff in the rainy seasons which debouch their water in Wadi Qena. On the other hand; the saline soil of group A (Wadi Naq El-Teir) was nearly deprived of the upstory (trees and shrubs) and the annuals. All these results were previously observed by Salma *et al.* (2014) in three transects in the southern quadrate of Eastern Desert between Aswan and Marsa Alam provinces.

5. Conclusions

The local topography and heterogeneity of the microclimatic conditions affected the distributional patterns of the plant associations in the study area. This study has revealed a much richer variety of floristic resources in Wadi El-Ghuza than the others. It has shown that the distribution of its vegetation is more strongly related to physical environmental factors associated with substrate conditions that affect the water supply (silt and organic matter), than to soil salinity factors. Nevertheless, the latter designed the poor vegetation of Wadi Naq El-Teir. This study area had mainly a simple xerophytic floristic composition, mostly of Sahao-Arabian chorotype focus of distribution, thus, they are relatively not affected by human disturbances. Annuals exhibited clear relationship between most of the soil water content, organic matter, silt, pH, Mg and PO_4. It was clear that annuals dominated the silty plains of the study area, while others (perennials) prefer the sandy soils.

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Appendix

Species	Spp Abb
Acacia tortilis subsp. *raddiana*	Aca
Aerva javanica (Burm. f.) Juss. ex Schult.	Aer jav
Artemisia judaica L.	Art jud
Asphodelus tenuifolius Cav.	Asp ten
Astragalus vogelii (Webb) Bornm.	Ast vog
Bassia indica (Wight) A. J. Scott	Bas ind
Bassia muricata (L.) Asch.	Bas mur
Calligonum polygonoides L.	Cal pol
Chrozophora oblongifolia (Delile) Spreng.	Chr obl
Chrozophora plicata (Vahl) Spreng.	Chr pli
Citrullus colocynthis (L.) Schrad.	Cit col
Cleome arabica L.	Cle ara
Cornulaca monacantha Delile	Cor mon
Cotula cinerea Delile	Cot cin
Crotalaria aegyptiaca Benth.	Cro aeg
Diplotaxis acris (Forssk.) Boiss.	Dip acr

Species	Spp Abb
Diplotaxis harra (Forssk.) Boiss.	Dip har
Eremobium aegyptiacum (Spreng.) Asch. & Schweinf. ex Boiss.	Ere aeg
Fagonia arabica L.	Fag ara
Fagonia bruguieri DC.	Fag bru
Fagonia indica Burm.f.	Fag ind
Fagonia mollis Delile	Fag mol
Fagonia thebaica Boiss.	Fag the
Filago desertorum Pomel	Fil des
Forsskaolea tenacissima L.	For ten
Heliotropium bacciferum Forssk.	Hel bac
Heliotropium digynum (Forssk.) C. Chr.	Hel dig
Leptadenia pyrotechnica (Forssk.) Decne.	Lep pyr
Lotononis platycarpa (Viv) Pic.Serm.	Lot pla
Mesembryanthemum nodiflorum L.	Mes nod
Morettia philaeana (Delile) DC.	Mor phi
Ochradenus baccatus Delile	Och bac

Species	Spp Abb
Oligomeris linifolia (Hornem.) J. F. Macbr.	Oli lin
Pergularia tomentosa L.	Per tom
Plantago ciliata Desf.	Pla cil
Polycarpaea repens (Forssk.) Asch. & Schweinf.	Pol rep
Pulicaria incisa (Lam.) DC.	Pul inc
Reseda pruinosa Delile	Res pru
Retama raetam (Forssk.) Webb & Berthel.	Ret rae
Rumex dentatus L.	Rum den
Salsola villosa Schult.	Sal vil

Species	Spp Abb
Seriphidium herba-alba (Asso) Soják	Art her
Sisymbrium irio L.	Sis iri
Stipagrostis plumosa (L.) Munro ex T. Anderson	Sti plu
Tamarix aphylla (L.) H. Karst.	Tam aph
Tamarix nilotica (Ehrenb.) Bunge	Tam nil
Trichodesma africanum (L.) R. Br.	Tri afr
Tribulus longipetalus Viv.	Tri lon
Tribulus pentandrus Forssk.	Tri pen
Zilla spinosa (L.) Prantl	Zil spi
Zygophyllum coccineum L.	Zyg coc