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Variations in Vegetation Structure, Species Dominance and Plant Communities in South of the Eastern Desert-Egypt

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Abstract

For two successive years, the floristic diversity and vegetation composition in the southern part of the Eastern Desert of Egypt were investigated through four transects (3 crossing the Eastern Desert and one along the Red Sea). The data collected from 142 stands covering the study area included the species composition, functional groups, chorology and occurrences (Q-values). A total of 94 plant species belonging to 33 different families were recorded, with A*steracea*, *Zygophyllaceae*, *Fabaceae*, *Poaceae*, *Chenopodiaceae* and *Brassicaceae* as the largest families. Shrubs represented the largest functional group (39.4%), while perennial herbs represented the smallest ones (12.8%). Species occurrence (Q-value) revealed that *Zilla spinosa*, *Acacia tortilis* subsp. *raddiana*, *Morettia philaeana, Caroxylon imbricatum, Zygophyllum coccineum* and *Citrullus colocynthis* had wide ecological range of distribution (dominant species, Q-values ≥ 0.2). Saharo-Arabian chorotype was highly represented (72.6 %) in the flora of this area, eventually as mono, bi or pluriregional. Classification of the data set yielded 7 vegetation groups included: (A) *Zilla spinosa-Morettia philaeana*, (B1) *Zilla spinosa-Citrullus colocynthis-Morettia philaeana,* (B2) *Zilla spinosa,* (C1) *Zygophyllum album-Tamarix nilotica,* (C2) *Zygophyllum coccineum-Tamarix nilotica,* (D1) *Zilla spinosa-Zygophyllum coccineum* and (D2) *Zilla spinosa-Acacia tortilis* subsp. *raddiana-Tamarix aphylla-Balanites aegyptiaca.* Certain vegetation groups were assigned to one or more transects. Detrended Correspondence Analysis (DCA) revealed that electrical conductivity, sodium, potassium, calcium, magnesium, chlorides, moisture content, sulphates, pH, organic matter and gravel were the soil variables that affect the species distribution in this study.

Keywords: arid environment, chorology, flora, plant functional groups, soil-vegetation relationships.

Introduction

The Eastern Desert of Egypt occupies about 223,000 km^2, i.e. 21% of the total area of Egypt. It is characterized by two main ecological units, the Red Sea costal land and the inland desert with its wadis. In Egypt, like in the other arid lands, the desert vegetation is characterized by openness and is composed of a permanent framework of perennials, the interspaces of which may be occupied by ephemerals and their duration depends on the irregular rainfall and soil thickness (Zahran and Willis, 2009). The vegetation composition and plants distribution covering the Egyptian Eastern Desert and Red Sea coast such as in the northern inland part (Abd El-Ghani, 1998; Fossati *et al*., 1998), in Wadi Allaqi (Sheded *et al*., 2012), in Wadi Degla (Hegazy *et al*., 2012), in Wadi Gimal (Galal and Fahmy, 2011; Gomaa, 2012), in Wadi Natash (Suzan *et al*., 2013) and in central Eastern Desert (Abd El-Ghani *et al*., 2013a; Salama and El-Naggar, 1991; Salama and Fayed, 1990; Salama *et al*., 2012, 2013) have been studied.

Ecologically, this desert is characterized by two main units, the Red Sea costal land and the inland desert. The Red Sea coastal land extends from Suez to Mersa Halaib at the Sudano-Egyptian border, while the inland part lies between the range of the Red Sea coastal land in the east and the Nile Valley in the west (Hassib, 1951). It is a rocky plateau dissected by a number of wadis; each has a main channel with numerous tributaries.

The floristic compositions, life forms and chorological affinities of deserts paid the attention to many others. Along an altitudinal gradient in East Ladakh (NW Himalayas) of India, Klimes (2003) indicated the preponderance of hemicryptophytes followed by therophytes. Also, the main life-form classes in Brazilian (Cerrado sites) were the hemicryptophytes and the phanerophytes (Batalha and Martins, 2002). Therophytes also dominated many arid and semi-arid study areas as in northeastern Brazil (Da Costa *et al*., 2007), in Mount Hymettus of central Greece (Gouvas and Theodoropoulos, 2007), in Khulais region of western Saudi Arabia (Al-Sherif *et al*., 2013) and in Alborz Mountains of Iran (Mahdavi *et al*., 2013).

One approach to addressing the complexity of desert vegetation is functional analysis. Plant species can be classified into functional groups based on a variety of characteristics. Functional groups have been defined as sets of species showing either similar responses to the environment or similar effect on major ecosystem processes (Gitay and Noble, 1997). Each functional group potentially will partition the environmental gradient differently (Austin, 1990; Dale, 1998; Lyon and Sagers, 2003; Smith and Huston, 1989).

The availability of water is one of the major factors reglating the species distribution in arid zones that are usually characterized by irregular, scanty and unpredictable rainfall, and long periods of drought (Noy-Meir, 1973; Yair and Danin, 1980). Soil-vegetation relationships were the subject of several investigations in the arid regions of the Middle East, e.g., Hillel and Tadmor (1962), Kassas and Girgis (1965), Olsvig-Whittaker *et al.* (1983), Stahr *et al.* (1985). Recently, multivariate analysis techniques were extensively used to elucidate these relationships, e.g., Moustafa and Zaghloul (1996), Abd El-Ghani (2000) Abd El-Ghani and Amer (2003), Abd El-Ghani *et al.* (2013 a, b), Salama *et al.* (2012, 2013).

This study aimed to (1) determine the spatial distribution patterns of the recorded species in terms of plant functional groups, (2) assess the soil factors which controlle the vegetation and to identify the regional plant communities, and (3) analyze the floristic variations between the northern and southern parts of the Eastern Desert.

Materials and methods

Study area

The study area covered nearly the southern quarter of the Eastern Desert (about 54,500 km^2) between 26°45' and 24°1' N latitudes and 32°45' and 35°00' E longitudes (Fig. 1) It covered the area between Qena Governorate until Aswan Governorate on the Nile Valley and from Safaga until Berenice on the Red Sea coast. According to Zahran and Willis (2009), this area covered three desert types: (1) The limestone desert (Assiut-Qena Desert), (2) The sandstone desert (Idfu-Kom Ombo Desert), and (3) The Red Sea coastal plain. Detailed studies on the geology, geomorphology, topography and lithology have been documented by Said (1962), Abu Al-Izz (1971), and Zahran and Willis (2009).

The Egyptian desert is among the most arid parts of the world characterized by extreme aridity and high temperature. Available climatic records over the period 2003-2012 in four meteorological stations (Qena, Safaga, Aswan and Marsa Alam) demonstrated that the average monthly temperature ranged between 14.9°C in January (minimum) and 33.6°C (maximum) in July. Rainfall occurs only in winter and is due to random cloudbursts, a general feature in arid desert: rain may occur once every several years. Annual average rainfall records (over 30 years) showed notable decrease along north-south direction: 5.3 mm/year in Qene in the north along the Nile Valley to 3.4 mm/year in Quseir in the south along the Red Sea coast (Abd El-Ghani, 1998). Averages of relative humidity reached to the maximum of 51.5% and 52.7% (in December), while its minimum reached 25.6% and 32.4% (in June) for Mersa Alam and Safaga (Abd El-Ghani, 1998, Abd El-Ghani *et al.,* 2013a).

Data collection and vegetation analysis

Between 2011 and 2012, vegetation sampling was performed in the study area using 4 transects representing the 3 desert types (Fig. 1). One hundred and forty-two geo-referenced (using GPS model Garmin eTrex HC) randomly selected stands (20 × 30 m) were selected along the four transects to represent apparent variations in the physiognomy of vegetation and in the physiographic features. The sandstone desert included (T1) which comprised of Aswan-Berenice road (300 km; 24°05' - 24°00' N and 32°55' - 35°24' E); Wadi Kharit (250 km, 24°26' - 24°12' N and 33°11' - 34°40' E); W. Natash (100 km, 24°21' - 24°40' N and 33°24' - 34°30' E), and W. Gimal (65 km, 24°34' - 24°40' N and 34°35' - 35°05' E); (T2) Idfu-Marsa Alam road (100 km, 25°55' N, 32°55' - 34°55' E). In the limestone desert, (T3) included Qena-safaga road (155 km, 26°12' - 26°46' N and 32°44' - 33°56' E), and along the Red Sea coastal plain (T4) that extends for about 240 km between 24°39' - 26°36' N and 32°05'- 34°00' E.

In this study, plants were categorized into four functional

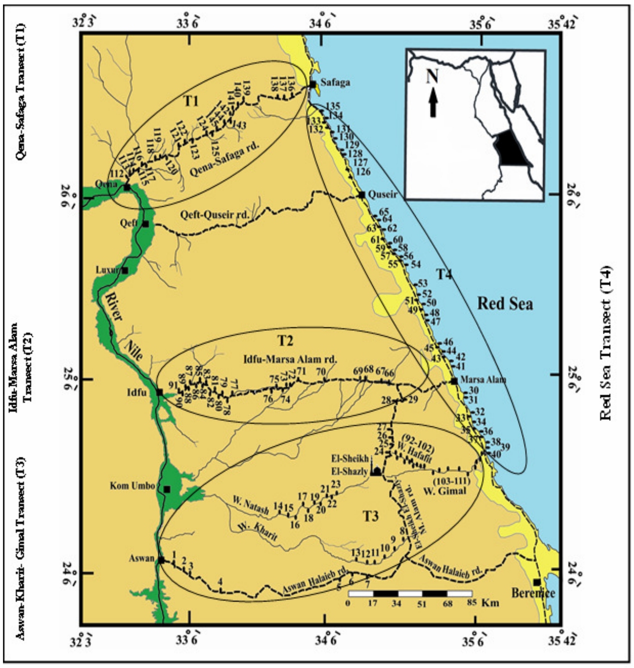

Fig. 1. Location map of the study area, showing the distribution of the studied stands along the 4 transects

groups: trees, shrubs, perennial herbs and annual herbs. Correspondingly, in each transect plant species were segregated into four a priori defined functional groups: tree layer species, shrub layer species, and herb species. The presence/absence for each species was recorded in the studied stands, and a count-floristic list was obtained. The number of species within each functional group category was expressed as a percentage of total number of species in each transect. Analysis of phytogeographical ranges was carried out according to White and Léonard (1991). Taxonomic nomenclature and functional groups categorizing was according to Täckholm (1974), Boulos (1995, 1999, 2000, 2002, 2005) and El Hadidi and Fayed (1978, 1995). Voucher specimens of each species were collected, and identified at the Herbaria of Assiut University (ASTU) and Cairo University (CAI), where they were deposited.

The degree of occurrence of each species was determined using the Q-value (Danin *et al*., 1985) as follows: Q= number of entries of a species X total number of species/13,348 (total number of entries). The Q-values and occurrences were categorized as follows: D=dominant, Q-value $\geq$ 0.2; VC=very common, Q-value 0.1– 0.199; C= common, Q-value 0.05-0.099; O=occasional or rare species, Q-value 0.01–0.049 and S= sporadic or very rare, Q-value $\leq$ 0.01.

A floristic presence-absence data matrix of 142 stands and 94 species was subjected to classification by cluster analysis of the program Community Analysis Package (CAP) version 1.2 (Henderson and Seaby, 1999) using squared Euclidean distance dissimilarity matrix with minimum variance (also called Ward's method) as agglomeration criterion (Orlóci, 1978). The resulted vegetation groups (plant communities) were named after the dominant species that have the highest presences percentages in the stands of this group.

Detrended Correspondence Analysis (DCA) ordination based on species presence-absence data for each species was performed to examine patterns in species composition among species of different vegetation groups. The relationship between the vegetation and soil variables were assessed by calculating the simple linear correlation coefficient (r) between the DCA axes (reflect the vegetation gradient) and the soil variables.

One Way Analysis of Variance was applied to examine the statistical differences between the functional groups.

Soil sampling and analysis

Soil samples (0-50 cm depth) were collected at 3 random points from each stand as a profile (composite samples). These samples were then air-dried, thoroughly mixed, and pass through a 2 mm sieve to get rid of gravel and boulders. The weight of gravel in each stand was determined and expressed as a percentage of the total weight of the soil sample. The soil texture was determined using the sieve method; the amount of each fraction (sand, silt and clay) was expressed as percentage of the original weight used (Ryan *et al*., 1996). Soil moisture content was estimated by drying at 105°C; then the percentage of soil moisture was calculated based on dry weight of the soil (Kapur and Govil, 2000). The soil portion less than 2 mm in size was kept for chemical analysis according to Jackson (1967) and Allen and Stainer (1974). Soil water extracts (1:5) were prepared for determination of electrical conductivity (EC) using conductivity meter, and pH using a glass electrode pH-meter. Organic matter (OM) was determined using the Walkely and Black rapid titration (Black, 1979). Sodium and potassium were determined by flamephotometer. Calcium and magnesium were estimated by titration against EDTA (ethylenediamine dihydrogen tetraacetic acid) using ammonium purpurate and eriochrome black T as indicators (Jackson, 1967). Chlorides were determined by direct titration against $AgNO_3$ using potassium chromate as an indicator, and bicarbonates by direct titration against HCl using methyl orange as indicator. Sulphates were determined by a turbidemetric technique with barium chloride and acidic sodium chloride solution using spectrophotometer (Model 1200) according to Bardsley and Lancaster (1965).

Results

Floristic composition

In total, 94 species (62 perennials and 32 annuals) constituted the floristic composition, representing 76 genera and 33 families (Tab. 1). About more than 50% of these species belonged to 6 families arranged in the following sequence, *Asteraceae* > *Zygophyllaceae* > *Fabaceae* > *Poaceae* > *Chenopodiaceae* > *Brassicaceae*. The largest family was *Asteraceae* (7 genera and 10 species), while 18 families were monospecific. The total number of recorded species was 46, 35, 52 and 46 for T1, T2, T3 and T4, respectively.

In terms of functional groups (Fig. 2), it can be noted that trees and perennial herbs were the least (2-7 species) represented among the 4 studied transect, while annual herbs and shrubs were the most (14-24 species). The distribution of functional groups within the studied transects showed significant difference (F-value=3.11, P=0.032) for the Red Sea transect (T4) among the others (F-value= 0.92, P=0.44, F-value=0.51, P=0.68, and F-value=0.65, P=0.58 for T1, T2 and T3, respectively). Few grasses (*Poaceae*) were recorded within transects (5, 2, 1, 5 species in T1, T2, T3 and T4, respectively), whereas shrubs dominated (17, 14, 20 and 23 species in T1, T2, T3 and T4, respectively).

Tab. 1 showed the distribution of the different functional groups within the study area. The recorded 13 tress were, amongst others, *Acacia tortilis* subsp. *raddiana, Tamarix aphylla, Balanites aegyptiaca, Ziziphus spina-christi, Avicennia marina, Hyphaene thebaica,* and *Moringa peregrina.*

Shrubs were the largest (37 species) represented functional group. The widely distributed species included *Zygophyllum coccineum, Zilla spinosa, Caroxylon imbricatum, Aerva javanica* and *Leptadenia pyrotechnica* that occurred in all transects. Whereas *Caroxylon villosum, Artemisia judaica, Atriplex leucoclada, Chrozophora oblongifolia, Fagonia mollis* and *F. bruguieri* were represented only in the northern transect (T1), *Zygophyllum album, Nitraria retusa, Limonium axillare, Arthrocnemum macrostachyum, Cornulaca monacantha, Taverniera aegyptiaca* and *Capparis spinosa* were confined to the Red Sea transect (T4), and another 3 shrubs showed consistency to the southern sector (Aswan-Kharit-Gimal transect; T3).

Four perennial herbs (*Aeluropus littoralis, Juncus rigidus, Leptochloa fusca* and *Cyperus rotundus*) showed consistency to the Red Sea transect (T4). For the northern transect (T1), *Imperata cylindrica, Stipagrostis plumosa, Dichanthum annulatum* and *Typha domingensis* exhibited certain degree of consistency to this transect (Tab. 1).

Three annual herbs (*Astragalus vogelii, Polycarpaea repens* and *Tetraena simplex*) had wide range of distribution (occurred in all transects). The Aswan-Kharit-Gimal transect (T3) was characterized by *Astragalus eremophilus, Hippocrepis constricta, Lupinus digitatus, Launaea amal-aminae, L. capitata, Polycarpaea robbairea* and *Glinus lotoides* which were not recorded elsewhere (Tab. 1).

Species abundance

The recorded species were categorized according to their Q-values (Tab. 1) as follwos: (i) Dominant species, of which *Zilla spinosa* had presence value of 61%, and *Acacia tortilis* subsp. *raddiana* with P=36%. *Caroxylon imbricatum* and *Zygophyllum coccineum* (shrubs), *Morettia philaeana* (annual herb) and *Citrullus colocynthis* (perennial herb) had lower presence values; (ii) Very common species, 10 species (e.g., *Tamarix aphylla, Fagonia thebaica, Aerva javanica, Pulicaria undulata, Schouwia purpurea*); (iii) Common species, 20 species included some salt-tolerant species such as *Nitraria retusa* and *Zygophyllum album*, and *Phragmites australis*; (iv) Occasional species, constituted the main bulk of the flora (33 species, 35.1% of total species), with their Q-values ranged between 0.01 and 0.049; (v) Sporadic species, comprised of 25 species with Q-values=0.007 which included 4 trees, 7 shrubs, 6 perennial herbs and 8 annual herbs.

Chorological affinities

The chorological spectrum of the recorded species was illustrated in Fig. 2. The cosmopolitan, palaeotropical and pantropical species constituted 12 species (12.8% of the total flora - Tab. 1). Monoregional Saharo-Arabian chorotype was well-represented (35 species) in the study area, while species of Sudano-Zambezian (*Crotalaria aegyptiaca*), Sudanian (*Acacia nilotica*), Mediterranean (*Lotus hebranicus* and *Lupinus digitatus*) and Irano-Turanian (*Cotula cinerea*) were very modestly represented.

A total of 30 species were bi-regional chorotypes representing 31.9% of the recorded species, distributed as follows: (1) 18 species belonging to Saharo-Arabian+Sudano-Zambezian (e.g., *Trichodesma africanum, Balanites aegyptiaca, Leptadenia pyrotechnica, Calotropis procera, Cleome amblyocarpa, Salvadora persica, Limonium axillare* and *Hyphaene thebaica*). (2) 7 species belonging to the Saharo-Arabian+Irano-Turanian (e.g., *Tamarix aphylla, Launaea nudicaulis, Cleome droserifolia* and *Fagonia bruguieri*, (3) 2 species belonging to Sudano-Zambezian+Guineo-Congo (*Moringa peregrina* and *Oxystelma esculentum*), (4) 1 species belonging to Mediterranean+Irano-Turanian (*Aeluropus littoralis*). (5) 2 species belonginig to Mediterranean+Saharo-Arabian (*Panicum turgidum* and *Chrozophora oblongifolia*). In general, 18 species were belonged to Saharo-Arabian+Sudano-Zambezian, while the Saharo-Arabian+Irano-Turanian species were represented by 7 species (Tab. 1).

About 12.8% of the recorded species (12 species) were pluri-regional with wide geographical range of distribution (e.g., *Citrullus colocynthis, Zygophyllum album, Arthrocnemum macrostachyum, Juncus rigidus* and *Capparis spinosa*).

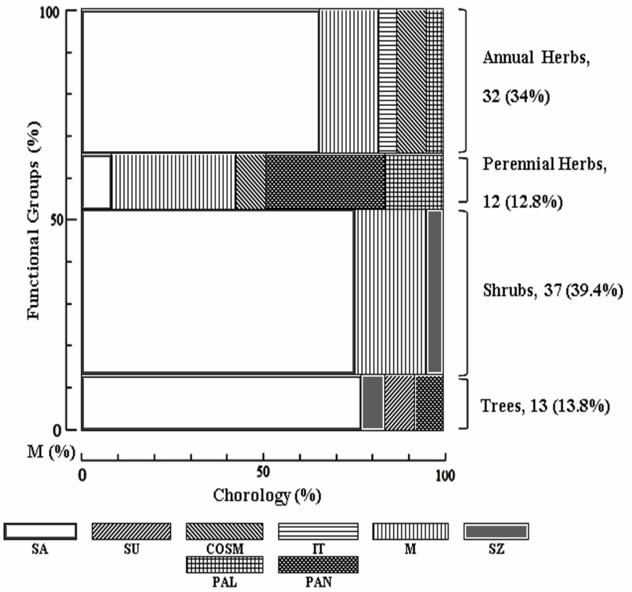

Fig. 2. Chorotype spectrum and functional groups diagram of the study area. M= species magnitude and average group abundance

Classification of the vegetation

Application of classification using cluster analysis to the floristic presence-absence data matrix of the study area yielded 7 vegetation groups (Tab. 2, Fig. 3). Each of the identified vegetation group will be named after the dominant species (i.e., highest presence percentages). Notably, none of the recorded species occurred in all the identified groups. Apart from coarse sand, clay and bicarbonates, the other thirteen (out of total of 16) measured soil variables showed significant differences ($p < 0.05, 0.01$) between the vegetation groups (Tab. 3).

Group (A): *Zilla spinosa-Morettia philaeana* group

The 18 stands of this group (41 species) were mostly located along Idfu-Marsa Alam transect (T2), with soil soil rich in its organic matter (OM)content and and highest pH, but had the lowest contents of fine sand, water content, Mg^{+2} and Cl^{-}. Co-dominant species included *Caroxylon imbricatum, Fagonia thebaica, Schouwia purpurea* and *Tetraena simplex.* Consistent species to this group were *Echium horridum, Glinus lotoides, Oxystelma esculentum, Caroxylon villosum, Stipagrostis plumosa* and *Tribulus megistopterus.*

Group (B1): *Zilla spinosa-Citrullus colocynthis-Morettia philaeana* group

The 18 stands of this group (26 species) were located along Wadi Natash, W. Kharit and El-Shekh El-Shazly-Marsa Alam road (T3). Soil contents of gravels, fine sand, OM and pH were higher than the total means. The lowest contents were recorded in Na^{+2} and HCO_3^{-}. Beside the dominants, *Acacia tortilis* subsp. and *Senna italica* were the co-dominants. Some species were confined to this group such as *Chenopodium album* and *Filago desertorum.*

Group (B2): *Zilla spinosa* group

This group (7 stands, 30 species) was characterized by the dominance of *Zilla spinosa* (P=100%), distributed along (Aswan-Kharit-Gimal transect, T3). Most of the examined soil variables (gravels, clay, EC, OM, Na^{+}, K^{+}, Ca^{+2}, HCO_3^{-} and SO_4^{-2}) attained their lowest levels in the stands of this group. However, fine sand content was the highest amongst the others. Among the important co-dominant species, *Astragalus vogelii, Cotula cinerea* and *Launaea nudicaulis* were included. Consistent species to this group were *Launaea capitata* and *L. cassiniana.*

Group (C1): *Zygophyllum album-Tamarix nilotica* group

Most stands of this group (41 stands, 32 species) were located along the Red Sea coast transect (T4) between Marsa Alam and Qusier, and occurred on saline soil with soluble anions and cations contents higher than the groups (A, B1, B2, D1 and D2). The dominant species of this group, together with the co-dominants *Nitraria retusa* and *Limonium axillare* exhibited the saline nature of this group. Certain species showed consistency to this group such as *Aeluropus littoralis, Arthrocnemum macrostachyum, Avicennia marina.*

Group (C2): *Zygophyllum coccineum-Tamarix nilotica* group

This group (8 stands) was the least diversified (19 species) among others. The stands of this group were mainly located in T4 (Qusier-Safaga transect) along the Red Sea coast occurred on saline soil with the highest silt, clay, electric conductivity, water content and all the examined ions. However, it recorded the lowest pH and coarse sand content. The co-dominant species included *Phragmites australis, Nitraria retusa, Limonium axillare* and *Zygophyllum album.* Four weed species (*Chenopodium murale*, *Cyperus rotundus, Leptochloa fusca* and *Sonchus oleraceus*) were recorded among the 6 confined species to this group.

Group (D1): *Zilla spinosa-Zygophyllum coccineum* group

This group of stands (31) was the most diversified (53 species) among other groups, and collected from three different transects (T1, T2 and T4) found on soil in rich in gravels and poor in silt content. The other soil factors had intermediate position amongst the other groups. The co-dominant species included *Caroxylon imbricatum, Lotus hebranicus* and *Ochradenus baccatus.* Twelve species showed consistency to this group such as *Acacia nilotica, Moringa peregrina, Ziziphus spina-christi* (trees), *Atriplex leucoclada, Fagonia bruguieri* (shrubs), and *Dichanthum annulatum, Imperata cylindrica* (herbs).

Group (D2): *Zilla spinosa-Acacia tortilis* subsp.-*Tamarix aphylla-Balanites aegyptiaca* group

This group (19 stands, 20 species) was characterized by the combination of the dominant species, mostly located in Wadi Gimal and its tributaries (T3) on a soil rich in fine sand, silt, pH and K^{+} and poor in Mg^{+2} and water contents. The co-dominants of this group had low presence values such as *Zygophyllum coccineum, Pulicaria undulata* and *Calotropis procera.* Two species were confined to this group, *Capparis decidua* and *Salvadora persica.*

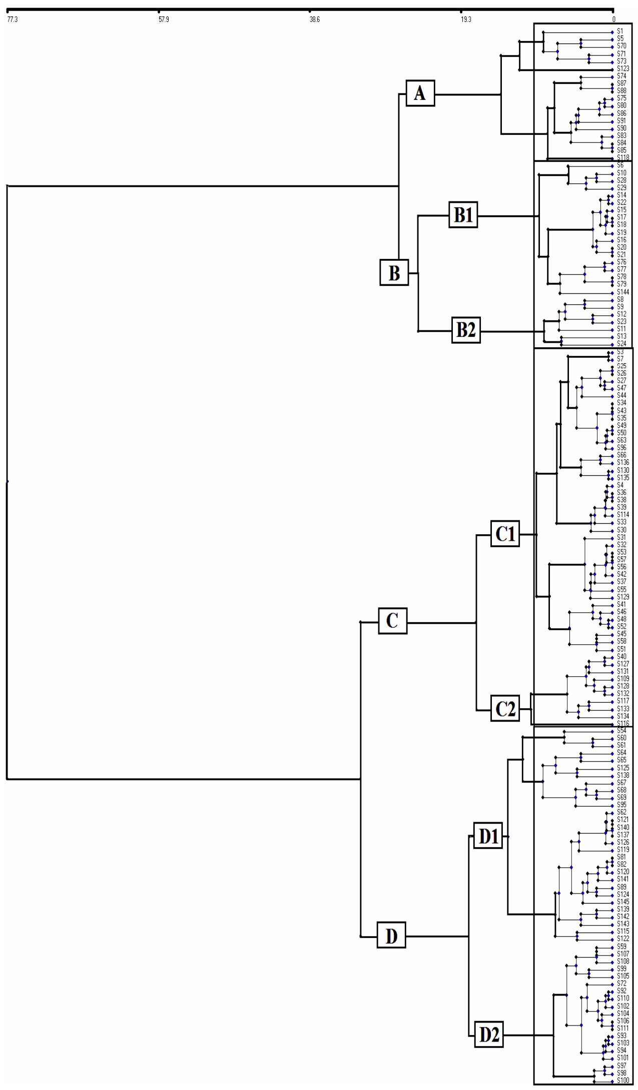

Fig. 3. Dendrogram showing cluster analysis of the studied 142 stands, with the 7 vegetation groups (A-D2) separated.

Ordination of the vegetation

Analysis of 142 stands along axes 1 and 2 (eigenvalues 0.707 and 0. 497, respectively) by DCA confirms the classification results, where the 7 vegetation groups were also segregated (Fig. 4). Linear response models were dropped because gradients along the first two axes were longer than 4 SD units (Jongman *et al.*, 1987). The length of gradient represented by axis 1 was > 9 SD, indicating a complete turnover in species composition along this gradient. Therefore, DCA was the appropriate ordination method or indirect gradient analysis to be used. The four DCA axes explained 5.3%, 3.7%, 2.8% and 2.6% of the total variation in the species data, respectively. This low percentage of variance explained by the axes was attributed to the many zero values in the vegetation data set. It can be observed that the eigenvalue for the first DCA axis was high, indicating that it captured the greater proportion of the variation in species composition among stands. It is clear that group C1 occupied the positive end of the first DCA axis, while groups B1 and B2 occupied the negative end. This arrangement may explain a gradient of increasing soil salinity and moisture content (Tab. 4), where stands of group C1 were located along the Red Sea coast transect, while B1 and B2 in the inland desert of Wadi Gimal-Aswan-Wadi Kharit transect. The first DCA axis was positively correlated with electrical conductivity (r=0.297), sodium (r=0.342), potassium (r=0.307), calcium (r=0.296), magnesium (r=0.318), chlorides (r= 0.217), moisture contents (r=0.418) and sulfates (r=0.612), and negatively with pH (r=–0.167) and gravels (r=-0.249). The second axis was positively correlated with sulfates (r=0.172) and organic matter (r=0.218).

Comparison between northern and southern parts of Eastern Desert

Tab. 5 displayed the floristic composition between two geographically distant (253 km) parts (northern and southern) of the Eastern Desert. Whereas the southern part represented by the 4 transects included in this study, the northern part (c. 28,800 km^2; 30° 05' - 28° 21' N and 31° 20'- 33° 50' E) included three transects; Cairo-Suez (T1N; 112 species), Korimat-Zaafarana (T2N; 111 species) and Sheikh Fadl-Ras Gharib (T3N; 54 species) mainly in the limestone part of this desert (Abdel-Aleem, 2013). Altogether, 60 species were in common, 103 species confined to the northern part, and 34 to the southern part.

Four trees: *Acacia tortilis* subsp. *raddiana, Tamarix aphylla, T. nilotica* and *Calotropis procera* exhibited a wide range of distribution as they recorded in the northern and southern parts. While 9 tree species confined to the southern part, and do not penetrate northwards (e.g., *Avicennia marina, Hyphaene thebaica, Balanites aegyptiaca, Moringa peregrina*), the northern part devoid of any characteristic tree species. Twenty-eight shrubby species were recorded in both areas and included amongst others: *Zilla spinosa, Zygophyllum coccineum, Caroxylon imbricatum, Suaeda monoica, Zygophyllum album* and *Pulicaria incisa.* Whereas 33 species were confined to the northern part, 9 species characterized the southern part. Perennial herbs were represented by 19 species (Tab. 5), of which 6 were in common (e.g., *Phragmites australis, Citrullus colocynthis, Stipagrostis plumosa*), 7 species showed consistency to northern part (e.g., *Lavandula stricta, Lasiurus scindicus, Aeluropus lagopoides*), and 6 species to the southern part (e.g., *Juncus rigidus, Aeluropus littoralis*) which inhabited wet and saline habitats. The annual herbs (96 species) constituted the major component of the floristic diversity and structure; 22 were in common, 64 species confined to the northern part and 10 species confined to the southern. The northern part included *Conyza bonariensis, Emex spinosa, Phalaris paradoxa, Lolium perenne, Cichorium endivia, Amaranthus viridis, Spergularia marina* and *Avena fatua* which are among the common weeds of the Egyptian arable lands.

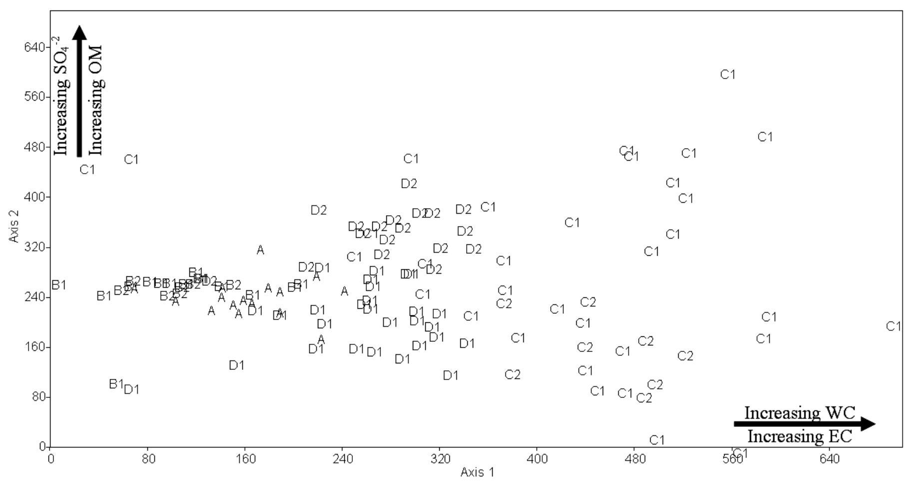

Fig. 4. First two axes of the DCA ordination of 142 stands with the 7 vegetation groups (A-D2) separated by cluster analysis superimposed.

Discussion

The classification and ordination analyses proposed that the vegetation of the study area can be divided into 7 major vegetation groups (plant communities). The members of each pair of groups are, in some cases, linked together by having one of the dominant species in common. It can be noted that certain vegetation groups characterized one or more of the studied transects; group (A) in Idfu-Mersa Alam transect (T2), groups (B1), (B2) and (D2) in Aswan-Kharit-Gimal transct (T3), groups (C1) and (C2) in Qusier-Safaga transect along Red Sea coast (T4), and group (D1) was widely distributed in the study area including T1, T2 and T4. It can be noted that the salt-tolerant plant *Tamarix nilotica* characterized vegetation group (C1) and (C2) form hillocks of huge sizes, and vigorously growing southwards (Springuel *et al*., 1991) representing the natural climax community type of the desert wadis with deep deposits and an underground water reserve (Kassas and Zahran, 1962). *Tamarix* has been identified as a major cause of salt accumulation on the soil surface (Springuel and Ali, 1990), and concentrating a high amount of sodium chloride in specialized glands within its leaves (Bosabalidis, 1992). In addition, there is a relationship between the amount of *Tamarix* litter and the electric conductivity of soil (Briggs *et al*., 1993). Meanwhile, the lower number of recorded species in vegetation group (C1) inhabiting the coastal plains of the Red Sea may be related to its high soil salinity. Such salinity stress on floristic diversity in the study area and related areas was reported by Moustafa and Klopatek (1995) and Shaltout *et al*. (1997). Most of the identified vegetation groups have very much in common with that recorded in some wadis of the Eastern Desert (Salama *et al*., 2012, 2013), Western Desert (Abd El-Ghani, 2000; Bornkamm and Kehl, 1990), in south Sinai region (Moustafa and Zaghloul, 1996) and in northwestern Negev, Israel (Tielbörger, 1997).

In extreme deserts, as in the study area, the plant growth is triggered mainly by rain, and thus is as scarce and unpredictable as the precipitation itself. Vegetation develops in 'contracted mode' (Monod, 1954) only in habitats receiving runoff water including wadis, depressions and channels- contracted desert (Shmida, 1985). This highly dynamic vegetation is neither permanent nor seasonal, but is accidental (Bornkamm, 2001; Bullard, 1997; Kassas, 1966). The vegetation structure in the study area is relatively simple, in which the species have to withstand the harsh environmental conditions. This it can be reflected by the presence of several highly adapted, drought-resistant species. The floristic diversity of the study area included 94 species of the vascular plants (67 perennials and 27 annuals) indicating the predominance of perennials. *Asteraceae*, *Fabaceae*, *Poaceae*, *Zygophyllaceae* and *Chenopodiaceae* were the species-rich families which formed the major component of the flora. The first three families represent the most common in the Mediterranean North African flora (Quézel, 1978; White, 1993). These findings were in line with those of Salama *et al*. (2012, 2013) in the Eastern Desert, and Abd El-Ghani and Fahmy (1998) in south Sinai, and Salama *et al*. (2005) along the western Mediterranean coast.

Chorological analysis revealed that the Saharo-Arabian element (37.2% monoregional, 28.7% biregional, 11.7% as pluriregional floras) forms the major component of the floristic structure along the four transects. That is because the study area lies within the Saharo-Arabian region of the Holarctic Kingdom (White, 1993). The results were in agreement with those of El-Demerdash *et al*. (1990), Fossati *et al*. (1998) and Salama *et al*. (2012) who concluded that plants of Saharo-Arabian region constituting the shrub layer as good indicators for desert environmental conditions, while species of Mediterranean origin (either mono, bi or pluriregional) flourish in more mesic conditions.

Comparing the results of floristic diversity in the study area (south of the Eastern Desert) with that in the northern part (Abdel-Aleem, 2013) indicated that 60 species were in common, 103 confined to the northern part, while 34 species were consistent to the southern part. So, the floristic diversity in the northern part is three times higher than that of the southern part of the Eastern Desert, which may be attributed to the mild climatic conditions prevailing in the north. Also, increasing the aridity southwards plays a paramount role in reducing floral diversity. On the other hand, 60% of the northern vegetation (not present in south) was represented as annual herbs. Decreased numbers of annuals in the southern part of the Eastern Desert can be attributed to the environmental aridity and thermal continentality which increases from north to south (Abd El-Ghani, 1998).

Vast areas in the Egyptian deserts (Western, Eastern, and Sinai) were subjected to land reclamation due to increased population growth (Biswas, 1993). In the study area, agricultural processes were practiced in the deltaic parts of several wadis such as Wadi Kherit, W. Natash and W. El-Shikh. As the land reclamation processes entail an almost complete change of the environmental factors, several common weeds of the agro-ecosystem were recorded (e.g., *Cynodon dactylon, Malva paviflora, Dicanthiun annulatum, Cyperus rotundus, Sonchus oleraceus* and *Chenopodium murale*). Thus, weeds find the new conditions favorable for their growth. Close to the boundaries of the desert in this study, xerophytic species naturally grow among the weeds of the cultivation. This indicated that these species are native to the natural desert vegetation and can remain after the reclamation process. Therefore, the reclaimed lands found at the desert outskirts can be considered as transitional areas of the succession process between the old cultivated lands and that of the desert (Abd El-Ghani *et al*., 2013b; Shaheen, 2002).

As for species abundance, *Zilla spinosa, Acacia tortilis* subsp. *raddiana* , *Morettia philaeana, Zygophyllum coccineum, Caroxylon imbricatum* and *Citrullus colocynthis* (especially in Wadi Natash) had the highest Q-Values (P= 0.61, 0.36, 0.3, 0.23, 0.22, and 0.21%, respectively). This result was in line with that obtained by Abd El-Ghani *et al*. (2013a) and Salama *et al*. (2012)

in northern and central parts of the Eastern Desert, and Springuel *et al*. (2006) in the south-eastern part of this desert. *Acacia tortilis* subsp. *raddiana, Morettia philaeana* and *Citrullus colocynthis* were completely absent in Red Sea transect, while the presence of the salt-tolerant species such as *Tamarix nilotica, Limonium axillare, Arthrocnemum macrostachyum, Juncus rigidus* and *Nitraria retusa* with high presence values in the Red Sea transect indicated its salinized habitat. The record of *Avicennia marina* dominating the mangal vegetation along the Red Sea coast (T4) is notable, and was documentd by Zahran and Willis (2009).

Tab. 1. Species composition of the 4 transects classified according to the different functional groups, together with their presence values (P%), chorology, Q-values and occurrences. T1= Qena-Safaga transect; T2= Idfu-Marsa Alam transect; T3= Aswan-Kharit-Gimal transect and T4= Red Sea transect. Choro= Chorology (SA= Saharo-Arabian, SZ= Sudano-Zambezian, M= Mediterranean, IT= Irano-Turanian, ES= Euro-Siberian, SU= Sudanian, GC= Gueno-Cungo, COSM= Cosmopolitan, PAN= Pantropical, PAL= Palaeotropical). Occ= Occurrence (D=Dominant, VC=Very common, C=Common, O=Occasional, S=Sporadic)

Species	p% for each transect				Choro	Q-value	Occ
	T1	T2	T3	T4			
1	2	3	4	5	6	7	8
Species present in all transects							
Shrubs							
Zilla spinosa (L.) Prantl.	81.8	96.4	73.9	15.2	SA	0.61	D
Zygophyllum coccineum L.	59.1	3.6	8.7	30.4	SA	0.23	D
Caroxylon imbricatum (Forssk.) Akhani & E. H. Roalson	45.5	67.9	2.2	2.2	SA	0.22	D
Lotus hebranicus Hochst. ex Brand	13.6	14.3	17.4	13	M	0.15	VC
Aerva javanica (Burm. F.) Juss ex Schult.	18.2	25	8.7	4.3	SA	0.12	VC
Leptadenia pyrotechnica (Forssk.) Decne.	18.2	7.1	6.5	2.2	SA+SZ	0.07	C
Annual Herbs							
Astragalus vogelii (Webb.) Bornm.	9.1	21.4	13	6.5	SA	0.12	VC
Tetraena simplex (L.) Beier & Thulin	9.1	28.6	8.7	2.2	SA+SZ	0.11	VC
Polycarpaea repens (Forssk.) Asch. & Schweinf.	4.5	3.6	4.3	6.5	SA	0.05	C
Species present in three transects							
Trees							
Acacia tortilis (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan	0	46.4	65.2	17.4	SA	0.36	D
Tamarix aphylla (L.) H. Karst.	0	10.7	26.1	17.4	SA+IT	0.16	VC
T. nilotica (Ehreub.) Bunge	18.2	0	4.3	30.4	SA+IT	0.14	VC
Calotropis procera (Aiton) W. T. Aiton	4.5	7.1	6.5	0	SA+SZ	0.04	O
Shrubs							
Fagonia thebaica Boiss.	18.2	46.4	0	2.2	SA	0.13	VC
Pulicaria undulata (L.) C. A. Mey	0	39.3	10.9	2.2	SA	0.12	VC
Panicum turgidum Forssk.	0	3.6	15.2	8.7	M+SA	0.08	C
Ochradenus baccatus Delile	18.2	0	2.2	6.5	SA	0.06	C
Pergularia tomentosa L.	13.6	10.7	2.2	0	SA	0.05	C
Suaeda monoica Forssk. ex J. F. Gmel.	0	7.1	2.2	6.5	SA+SZ	0.04	O
Cleome droserifolia (Forssk.) Delile	4.5	0	4.3	6.5	SA+IT	0.04	O
Perennial Herbs							
Citrullus colocynthis (L.) Schrad.	22.7	35.7	32.6	0	M+SA+IT	0.21	D
Phragmites australis (Cav.) Trin. ex Steud.	18.2	3.6	0	13	PAN	0.08	C
Monsonia heliotropioides (Cav.) Boiss.	0	3.6	10.9	2.2	SA	0.05	C
Annual Herbs							
Morettia philaeana (Delile) DC.	31.8	60.7	39.1	0	SA	0.3	D
Schouwia purpurea (Forssk.) Schweinf.	9.1	35.7	8.7	0	SA	0.11	VC
Trichodesma africanum (L.) R. Br.	22.7	25	4.3	0	SA+SZ	0.1	VC
Cotula cinerea Delile	9.1	3.6	19.6	0	IT	0.09	C
Forsskaolea tenacissima L.	18.2	3.6	6.5	0	SA+SZ	0.06	C
Eremobium aegyptiacum (Spreng.) Asch. & Schweinf. ex Boiss.	4.5	10.7	2.2	0	SA	0.04	O
Species present in two transects							
Trees							
Phoenix dactylifera L.	22.7	0	0	2.2	SA+SZ	0.04	O

1	2	3	4	5	6	7	8
Shrubs							
Farsetia stylosa R. Br.	0	10.7	17.4	0	SA+SZ	0.08	C
Pulicaria incisa (Lam.) DC.	27.3	0	4.3	0	SA	0.06	C
Senna italica Mill	0	3.6	17.4	0	SA+SZ	0.06	C
Convolvulus hystrix Vahl	0	0	2.2	8.7	SA	0.04	O
Fagonia indica Burm. F.	0	0	6.5	2.2	SA	0.03	O
Heliotropium bacciferum Forssk.	0	7.1	0	2.2	SA	0.02	O
Perennial Herbs							
Cynodon dactylon (L.) Pers.	13.6	0	0	4.3	COSM	0.04	O
Annual Herbs							
Launaea nudicaulis (L.) Hook. F.	0	0	13	8.7	SA+IT	0.07	C
Asphodelus tenuifolius Cav.	0	7.1	15.2	0	M+SA+IT	0.06	C
Tribulus pentandrus Forssk.	0	14.3	10.9	0	SA+SZ	0.06	C
Malva parviflora L.	0	0	2.2	10.9	M+ES+IT	0.04	O
Cleome amblyocarpa Barratte &Murb.	0	3.6	10.9	0	SA+SZ	0.04	O
Arnebia hispidissima (Lehm.) DC.	4.5	0	0	4.3	SA	0.02	O
Euphorbia granulata Forssk.	0	3.6	4.3	0	M+SA+IT	0.02	O
Reseda pruinosa Delile	0	0	2.2	2.2	SA	0.01	O
Cistanche phelypaea (L.) Cout.	4.5	3.6	0	0	M+SA+IT	0.01	O
Tribulus megistopterus Kralik	4.5	0	2.2	0	SA+SZ	0.01	O
Species present in one transect							
Trees							
Balanites aegyptiaca (L.) Delile	0	0	28.3	0	SA+SZ	0.09	C
Ziziphus spina-christi (L.) Desf.	18.2	0	0	0	SA	0.03	O
Avicennia marina (Forssk.) Vierh.	0	0	0	8.7	SA	0.03	O
Ricinus communis L.	9.1	0	0	0	PAN	0.01	O
Acacia nilotica (L.) Delile	4.5	0	0	0	SU	0.007	S
Capparis decidua (Forssk.) Edgew.	0	0	2.2	0	SA+SZ	0.007	S
Hyphaene thebaica (L.) Mart.	0	0	0	2.2	SA+SZ	0.007	S
Moringa peregrina (Forssk.) Fiori	4.5	0	0	0	SZ+GC	0.007	S
Shrubs							
Zygophyllum album L.	0	0	0	26.1	M+SA+IT	0.08	C
Nitraria retusa (Forssk.) Asch.	0	0	0	26.1	SA	0.08	C
Limonium axillare (Forssk.) Kuntze	0	0	0	21.7	SA+SZ	0.06	C
Crotalaria aegyptiaca Benth.	0	0	0	10.9	SZ	0.04	O
Arthrocnemum macrostachyum (Moric.) K. Koch	0	0	0	13	M+SA+IT	0.04	O
Salvadora persica L.	0	0	8.7	0	SA+SZ	0.03	O
Cornulaca monacantha Delile	0	0	0	6.5	SA	0.02	O
Artemisia judaica L.	9.1	0	0	0	SA	0.01	O
Senna holosericea (Freseu) Greuter	0	0	4.3	0	SA	0.01	O
Fagonia mollis Delile	9.1	0	0	0	SA	0.01	O
Iphiona mucronata (Forssk.) Asch. & Schweinf.	0	7.1	0	0	SA	0.01	O
Atriplex leucoclada Boiss.	4.5	0	0	0	SA+IT	0.007	S
Fagonia bruguieri DC.	4.5	0	0	0	SA+IT	0.007	S
Capparis spinosa L.	0	0	0	2.2	M+SA+SZ	0.007	S
Chrozophora oblongifolia (Delile) Spreng.	4.5	0	0	0	M+SA	0.007	S
Oxystelma esculentum (L.F.) R. Br.	0	0	2.2	0	SZ+GC	0.007	S
Caroxylon villosum (Schult.) Akhani & E. H. Roalson	4.5	0	0	0	M+SA+IT	0.007	S
Taverniera aegyptiaca Boiss.	0	0	0	2.2	SA	0.007	S

1	2	3	4	5	6	7	8
Perennial Herbs							
Aeluropus littoralis (Gouan) Parl.	0	0	0	6.5	M+IT	0.02	O
Imperata cylindrica (L.) Raeusch	9.1	0	0	0	PAN	0.01	O
Juncus rigidus Desf.	0	0	0	2.2	M+SA+IT	0.007	S
Leptochloa fusca (L.) Kunth	0	0	0	2.2	PAL	0.007	S
Stipagrostis plumosa (L.) Munro ex T. Anderson	4.5	0	0	0	M+SA+IT	0.007	S
Dichanthum annulatum (Forssk.) Stapf	4.5	0	0	0	PAL	0.007	S
Cyperus rotundus L.	0	0	0	2.2	PAN	0.007	S
Typha domingensis (Pers.) Poir. ex Steud.	4.5	0	0	0	PAN	0.007	S
Annual Herbs							
Astragalus eremophilus Boiss.	0	0	30.4	0	SA	0.1	C
Hippocrepis constricta Knuze	0	0	6.5	0	M+SA+IT	0.02	O
Lupinus digitatus Forssk.	0	0	6.5	0	M	0.02	O
Polycarpaea robbairea (Kuntze) Greuter & Burdet	0	0	6.5	0	SA	0.02	O
Launaea amal-aminae N. Kilian	0	0	4.3	0	SA	0.01	O
Echium horridum Batt.	4.5	0	0	0	SA	0.007	S
Chenopodium album L.	4.5	0	0	0	COSM	0.007	S
Ch. murale L.	0	0	0	2.2	COSM	0.007	S
Launaea capitata (Spreng.) Dandy	0	0	2.2	0	SA	0.007	S
Filago desertorum Pomel	4.5	0	0	0	SA+IT	0.007	S
Glinus lotoides L.	0	0	2.2	0	PAL	0.007	S
Oligomeris linifolia (Vahl.) ex Hornew J. F. Macbr.	0	0	0	2.2	SA+SZ	0.007	S
Sonchus oleraceus L.	0	0	0	2.2	COSM	0.007	S

Tab. 2. Species composition of the obtained 7 vegetation groups, together with their presence values (p%). Figures in bold are the dominant species that have the highest p%.

Vegetation groups	**A**	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**
Total number of stands	**18**	**18**	**7**	**41**	**8**	**31**	**19**
Total number of species	**41**	**26**	**30**	**32**	**19**	**53**	**20**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Species present in 6 groups							
Zilla spinosa	**100**	**94.4**	**100**		12.5	**90.3**	**78.9**
Acacia tortilis subsp. *raddiana*	38.9	77.8	71.4	19.5		16.1	63.2
Species present in 5 groups							
Tamarix aphylla	16.7			14.6	12.5	3.2	63.2
Zygophyllum coccineum	5.6			7.3	**100**	**51.6**	21.1
Aerva javanica	27.8		14.3	12.2		16.1	5.3
Pulicaria undulata	27.8	22.2		4.9		9.7	15.8
Lotus hebranicus	27.8	5.6	57.1	7.3		25.8	
Species present in 4 groups							
Citrullus colocynthis	44.4	**83.3**	57.1			9.7	
Morettia philaeana	**94.4**	**83.3**	85.7			12.9	
Pergularia tomentosa	5.6	5.6	14.3			12.9	
Tetraena simplex	50	11.1	14.3			9.7	
Tribulus pentandrus	27.8	11.1	14.3				5.3
Caroxylon imbricatum	83.3	22.2		2.4		35.5	
Astragalus vogelii	38.9		85.7			9.7	5.3
Forsskaolea tenacissima	11.1		28.6			9.7	5.3
Phragmites australis	11.1			7.3	37.5	9.7	
Tamarix nilotica	5.6			**22**	**100**	6.5	

1	2	3	4	5	6	7	8
Malva parviflora	5.6			2.4		9.7	5.3
Leptadenia pyrotechnica		5.6		4.9		12.9	15.8
Panicum turgidum			14.3	12.2		12.9	10.5
Species present in 3 groups							
Asphodelus tenuifolius	5.6	22.2	57.1				
Astragalus eremophilus	11.1	33.3	85.7				
Cotula cinerea	16.7	16.7	85.7				
Monsonia heliotropioides	11.1		57.1			3.2	
Pulicaria incise	11.1		28.6			12.9	
Schouwia purpurea	61.1		42.9			6.5	
Trichodesma africanum	44.4		14.3			16.1	
Eremobium aegyptiacum	16.7		14.3				5.3
Farsetia stylosa	16.7		85.7				10.5
Arnebia hispidissima	5.6			2.4		3.2	
Fagonia indica	5.6			4.9		3.2	
Cynodon dactylon	5.6				25	6.5	
Fagonia thebaica	72.2				12.5	12.9	
Polycarpaea robbairea		5.6	14.3	2.4			
Convolvulus hystrix		5.6		2.4		9.7	
Calotropis procera		11.1				3.2	15.8
Launaea nudicaulis			85.7	2.4		9.7	
Polycarpaea repens			28.6	2.4		12.9	
Nitraria retusa				17.1	50		5.3
Ochradenus baccatus					12.5	19.4	5.3
Species present in 2 groups							
Euphorbia granulata	11.1	5.6					
Suaeda monoica	16.7			7.3			
Cistanche phelypaea	5.6					3.2	
Ricinus communis	5.6					3.2	
Cleome amblyocarpa		11.1	57.1				
Hippocrepis constricta		5.6	28.6				
Lupinus digitatus		5.6	28.6				
Senna italica		44.4	14.3				
Artemisia judaica		5.6				3.2	
Fagonia mollis		5.6				3.2	
Limonium axillare				19.5	25		
Zygophyllum album				**24.4**	25		
Crotalaria aegyptiaca				7.3		6.5	
Heliotropium bacciferum				2.4		6.5	
Reseda pruinosa				2.4		3.2	
Balanites aegyptiaca				2.4			63.2
Cleome droserifolia					25	12.9	
Phoenix dactylifera					12.5	16.1	
Species present in one group							
Echium horridum	5.6						
Glinus lotoides	5.6						
Oxystelma esculentum	5.6						
Caroxylon villosum	5.6						
Stipagrostis plumosa	5.6						
Tribulus megistopterus	11.1						
Chenopodium album		5.6					
Filago desertorum		5.6					

1	2	3	4	5	6	7	8
Launaea capitata			14.3				
L. amal-aminae			28.6				
Aeluropus littoralis				7.3			
Arthrocnemum macrostachyum				14.6			
Avicennia marina				9.8			
Capparis spinosa				2.4			
Cornulaca monacantha				7.3			
Senna holosericea				4.9			
Chenopodium murale					12.5		
Cyperus rotundus					12.5		
Hyphaene thebaica					12.5		
Juncus rigidus					12.5		
Leptochloa fusca					12.5		
Sonchus oleraceus					12.5		
Acacia nilotica						3.2	
Atriplex leucoclada						3.2	
Chrozophora oblongifolia						3.2	
Dichanthum annulatum						3.2	
Fagonia bruguieri						3.2	
Imperata cylindrica						6.5	
Iphiona mucronata						6.5	
Moringa peregrina						3.2	
Oligomeris linifolia						3.2	
Taverniera aegyptiaca						3.2	
Typha domingensis						3.2	
Ziziphus spina-christi						12.9	
Capparis decidua							5.3
Salvadora persica							21.1

Tab. 3. Mean values, standard deviations (±SD) and ANOVA values of the soil variables in the vegetation groups (A-D2) of the study area. EC=Electrical conductivity ($mS.cm^{-1}$), soil fractions (%), CS=Coarse sand, FS=Fine sand, OM=Organic matter, Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^- and HCO_3^- ($mg.g^{-1}$ d.wt. soil), SO_4^{-2} (µg.g-1 d.wt. soil), OM (%), *= $p<0.05$, **= $p<0.01$.

Soil Factors	Total Means	Vegetation groups							F value
		A	B1	B2	C1	C2	D1	D2	
Gravel	11.27±10.62	13.03±10.42	12.03±8.62	6.91±3.58	9.56±10.07	7.44±14.14	16.22±11.67	7.76±9.86	2.223*
CS	20.97±16.48	15.37±10.64	21.67±11.86	20.49±9.31	25.44±21.94	8.53±7.56	24.06±14.88	16.36±14.60	2.145
FS	9.31±6.19	5.59±2.92	11.40±7.89	12.83±4.92	9.70±6.45	7.58±6.33	8.39±5.41	10.99±6.26	2.421**
Silt	35.52±16.51	39.59±13.71	34.16±13.09	44.85±9.03	33.44±17.59	48.35±14.83	26.38±12.96	43.52±19.20	4.36**
Clay	22.91±18.13	26.43±13.68	20.74±19.99	14.93±6.06	21.86±19.35	28.10±14.60	24.95±23.67	21.37±9.70	0.592
WC	2.61±4.40	1.20±1.14	1.51±1.24	1.27±0.80	5.16±6.07	5.33±8.71	1.58±2.14	0.53±1.08	5.186**
OM	1.09±0.10	1.13±0.10	1.12±0.04	1.01±0.10	1.08±0.12	1.12±0.03	1.11±0.09	1.03±0.09	3.639**
pH	7.80±0.48	8.02±0.34	7.97±0.68	7.67±0.81	7.78±0.45	7.20±0.48	7.77±0.38	7.86±0.16	3.599**
EC	1.22±3.35	0.32±0.11	0.22±0.05	0.21±0.05	1.62±2.27	8.78±10.77	0.60±1.00	0.39±0.51	11.296**
Na^+	0.83±2.33	0.11±0.07	0.05±0.02	0.05±0.02	1.29±1.73	5.86±7.35	0.31±0.66	0.25±0.48	10.916**
K^+	0.08±0.13	0.04±0.01	0.03±0.01	0.02±0.00	0.11±0.10	0.21±0.27	0.05±0.03	0.11±0.24	3.606**
Ca^{+2}	0.63±1.51	0.31±0.32	0.16±0.04	0.15±0.05	0.83±0.94	3.80±4.98	0.38±0.67	0.17±0.14	9.575**
Mg^{+2}	0.26±0.55	0.08±0.03	0.10±0.04	0.14±0.05	0.43±0.71	1.04±1.38	0.16±0.17	0.05±0.03	5.53**
Cl^-	1.41±6.04	0.09±0.07	0.10±0.03	0.10±0.03	1.51±4.12	15.08±20.02	0.33±0.81	0.15±0.18	10.51**
HCO_3^-	0.18±0.06	0.18±0.05	0.16±0.05	0.16±0.08	0.18±0.06	0.20±0.12	0.17±0.05	0.18±0.04	0.64
SO_4^{-2}	5.47±7.36	1.36±1.24	1.44±1.66	0.67±0.96	10.27±8.27	15.11±10.12	4.29±6.64	2.46±2.68	12.009**

Tab. 4. Simple linear correlation coefficient (r) between the soil variables and DCA axes. *= p<0.05, **: p<0.01. For soil factors abbreviations and units, see Tab. 4.

Soil variables	DCA axis 1	DCA axis 2
pH	-0.167*	-0.15
EC	0.297**	0.116
Na^+	0.342**	0.146
K^+	0.307**	0.026
Ca^{+2}	0.296**	0.119
Mg^{+2}	0.318**	-0.015
Cl^-	0.217**	0.098
HCO_3^-	0.119	0.072
SO_4^{-2}	0.612**	0.172*
MC	0.418**	-0.058
OM	-0.024	0.218**
Gravels	-0.249**	0.022
CS	0.034	-0.111
FS	-0.013	0.081
Silt	0.073	0.009
Clay	0.053	0.052

Tab. 5. Floristic diversity between the northern and southern parts of the Eastern Desert. ([1] =Data from Abdel Aleem, 2013); T1N= Cairo-Suez transect; T2N= Korimat-Zaafarana transect, T3N= Sheikh Fadl-Ras Gharib transect; T1S= Qena-Safaga transect; T2S= Idfu-Marsa Alam transect; T3S= Aswan-Kharit-Gimal transect and T4S= Red Sea transect.

Species	North			South			
	T1N	T2N	T3N	T1S	T2S	T3S	T4S
1	2	3	4	5	6	7	8
Species present in Both Areas							
Acacia tortilis (Forssk.) Hayne subsp. *raddiana* Savi (Brenan)	35	18.2	16.7	0	46.4	65.2	17.4
Tamarix aphylla (L.) H Karst.	0	0	16.7	0	10.7	26.1	17.4
Tamarix nilotica (Ehrenb.) Bunge	40	59.1	30	18.2	0	4.3	30.4
Calotropis procera (Aiton) W. T. Aiton	30	0	0	4.5	7.1	6.5	0
Zilla spinosa (L.) Prantl.	95	81.8	83.3	81.8	96.4	73.9	15.2
Zygophyllum coccineum L.	85	63.6	83.3	59.1	3.6	8.7	30.4
Caroxylon imbricatum (Forssk.) Akhani & E. H. Roalson	0	22.7	40	45.5	67.9	2.2	2.2
Aerva javanica (Burm. F.) Juss. ex Schult.	10	0	10	18.2	25	8.7	4.3
Lotus hebranicus Hochst. ex Brand	0	0	6.7	13.6	14.3	17.4	13
Leptadenia pyrotechnica (Forssk.) Decne.	0	0	10	18.2	7.1	6.5	2.2
Pulicaria undulata (L.) C. A. Mey	50	77.3	40	0	39.3	10.9	2.2
Panicum turgidum Forssk.	55	22.7	0	0	3.6	15.2	8.7
Suaeda monoica Forssk. ex J. F. Gmel.	0	13.6	0	0	7.1	2.2	6.5
Ochradenus baccatus Delile	55	59.1	56.7	18.2	0	2.2	6.5
Cleome droserifolia (Forssk.) Delile	0	0	3.3	4.5	0	4.3	6.5
Fagonia indica Burm. F.	20	22.7	10	0	0	6.5	2.2
Heliotropium bacciferum Forssk.	30	4.5	6.7	0	7.1	0	2.2
Zygophyllum album L.	0	9.1	0	0	0	0	26.1
Nitraria retusa (Forssk.) Asch.	0	4.5	0	0	0	0	26.1
Capparis spinosa L.	0	4.5	0	0	0	0	2.2
Taverniera aegyptiaca Boiss.	0	9.1	0	0	0	0	2.2
Crotalaria aegyptiaca Benth.	20	0	0	0	0	0	10.9
Cornulaca monacantha Delile	5	0	0	0	0	0	6.5
Pergularia tomentosa L.	25	40.9	6.7	13.6	10.7	2.2	0
Senna italica Mill.	15	0	0	0	3.6	17.4	0
Pulicaria incisa (Lam.) DC.	10	18.2	0	27.3	0	4.3	0
Iphiona mucronata (Forssk.) Asch. & Schweinf.	20	31.8	0	0	7.1	0	0
Artemisia judaica L.	5	9.1	10	9.1	0	0	0

1	2	3	4	5	6	7	8
Fagonia mollis Delile	25	50	13.3	9.1	0	0	0
Fagonia bruguieri DC.	30	36.4	43.3	4.5	0	0	0
Atriplex leucoclada Boiss.	0	0	6.7	4.5	0	0	0
Chrozophora oblongifolia (Delile) Spreng.	10	0	0	4.5	0	0	0
Phragmites australis (Cav.) Trin. ex Steud.	10	13.6	3.3	18.2	3.6	0	13
Cynodon dactylon (L.) Pers.	10	0	0	13.6	0	0	4.3
Leptochloa fusca (L.) Kunth	0	9.1	0	0	0	0	2.2
Citrullus colocynthis (L.) Schrad.	5	27.3	16.7	22.7	35.7	32.6	0
Stipagrostis plumosa (L.) Munro ex T. Anderson	0	4.5	3.3	4.5	0	0	0
Imperata cylindrica (L.) Raeusch	0	13.6	0	9.1	0	0	0
Tetraena simplex (L.) Beier & Thulin	60	18.2	30	9.1	28.6	8.7	2.2
Astragalus vogelii (Webb.) Bornm.	0	9.1	10	9.1	21.4	13	6.5
Launaea nudicaulis (L.) Hook. F.	25	59.1	6.7	0	0	13	8.7
Reseda pruinosa Delile	5	4.5	10	0	0	2.2	2.2
Malva parviflora L.	15	0	0	0	0	2.2	10.9
Sonchus oleraceus L.	15	45.5	0	0	0	0	2.2
Chenopodium murale L.	10	0	0	0	0	0	2.2
Cotula cinerea Delile	10	31.8	13.3	9.1	3.6	19.6	0
Forsskaolea tenacissima L.	10	4.5	10	18.2	3.6	6.5	0
Trichodesma africanum (L.) R. Br.	25	40.9	20	22.7	25	4.3	0
Eremobium aegyptiacum (Spreng.) Asch. & Schweinf. ex Boiss.	0	4.5	0	4.5	10.7	2.2	0
Cleome amblyocarpa Barratte & Murb.	25	22.7	6.7	0	3.6	10.9	0
Euphorbia granulata Forssk.	0	9.1	0	0	3.6	4.3	0
Asphodelus tenuifolius Cav.	20	0	0	0	7.1	15.2	0
Tribulus megistopterus Kralik	0	4.5	0	4.5	0	2.2	0
Glinus lotoides L.	0	40.9	6.7	0	0	2.2	0
Polycarpaea robbairea (Kuntze) Greuter & Burdet	0	0	6.7	0	0	6.5	0
Hippocrepis constricta Knuze	0	4.5	0	0	0	6.5	0
Launaea capitata (Spreng.) Dandy	0	36.4	0	0	0	2.2	0
Cistanche phelypaea (L.) Cout.	15	31.8	6.7	4.5	3.6	0	0
Filago desertorum Pomel	0	9.1	0	4.5	0	0	0
Chenopodium album L.	5	0	0	4.5	0	0	0
Species present in Northern Area							
Atriplex halimus L.	15	40.9	36.7	0	0	0	0
Anabasis setifera Moq.	40	31.8	33.3	0	0	0	0
Farsetia aegyptia Turra	60	50	13.3	0	0	0	0
Haloxylon salicornicum (Moq.) Bung ex Boiss.	65	59.1	56.7	0	0	0	0
Launaea spinosa (Forssk.) Sch. Bip. ex Kuntze	10	18.2	3.3	0	0	0	0
Retama raetam (Forssk.) Webb & Berthel.	45	27.3	13.3	0	0	0	0
Hyoscyamus muticus L.	50	22.7	3.3	0	0	0	0
Senecio glaucus L.	25	36.4	3.3	0	0	0	0
Astragalus trigonus DC.	0	9.1	3.3	0	0	0	0
Calligonum polygonoides L.	0	9.1	26.7	0	0	0	0
Deverra tortuosa (Desf.) DC.	35	0	3.3	0	0	0	0
Hyoscyamus boveanus (Dunal) Asch. & Schweinf.	0	0	3.3	0	0	0	0
Achillea fragrantissima (Forssk.) Sch. Bip.	5	13.6	0	0	0	0	0
Anabasis articulata (Forssk.) Moq.	40	9.1	0	0	0	0	0
Cynanchum acutum L.	15	9.1	0	0	0	0	0
Diplotaxis acris (Forssk.) Boiss.	10	4.5	0	0	0	0	0
Ephedra alata Decne.	10	9.1	0	0	0	0	0
Fagonia arabica L.	10	4.5	0	0	0	0	0
Gymnocarpos decandrus Forssk.	5	9.1	0	0	0	0	0
Haplophyllum tuberculatum (Forssk.) A. Juss.	10	9.1	0	0	0	0	0
Lycium shawii Roem. et Schult	10	18.2	0	0	0	0	0

1	2	3	4	5	6	7	8
Nauplius graveolens (Forssk.) Wiklund	10	31.8	0	0	0	0	0
Rumex vesicarius L.	30	22.7	0	0	0	0	0
Reichardia tingitana (L.) Roth	25	18.2	0	0	0	0	0
Agathophora alopecuroides (Delile) Fenzl ex Bunge	0	13.6	0	0	0	0	0
Astragalus sieberi DC.	0	9.1	0	0	0	0	0
Cullen plicata (Delile) C. H Stirt.	0	4.5	0	0	0	0	0
Helianthemum kahiricum Delile	0	4.5	0	0	0	0	0
Reaumuria hirtella Jaub. et Spach	0	31.8	0	0	0	0	0
Ephedra aphylla Forssk.	10	0	0	0	0	0	0
Artemisia monosperma Delile	20	0	0	0	0	0	0
Convolvulus lanatus Vahl	5	0	0	0	0	0	0
Helianthemum lipii (L.) Dum-Cours.	5	0	0	0	0	0	0
Kickxia aegyptiaca (Dum.) Nabelek	45	0	0	0	0	0	0
Phagnalon barbeyanum Asch. & Schweinf.	5	0	0	0	0	0	0
Pluchea dioscoridis (L.) DC.	15	0	0	0	0	0	0
Zygophyllum decumbens Delile	10	0	0	0	0	0	0
Lavandula coronopifolia Delile	5	4.5	0	0	0	0	0
Erodium glaucophyllum (L.) L'Hér. Poirin	20	4.5	0	0	0	0	0
Erodium oxyrrhynchum M. Bieb. Lam.	10	18.2	0	0	0	0	0
Lasiurus scindicus Henrad	5	18.2	0	0	0	0	0
Launaea mucronata (Forssk.) Muschl.	40	31.8	0	0	0	0	0
Aeluropus lagopoides (L.) Trin. ex Thwaites	0	4.5	0	0	0	0	0
Pennisetum divisum (Forssk. ex J. F. Gmel.) Henrard	10	0	0	0	0	0	0
Anastatica hierochuntica L.	10	40.9	16.7	0	0	0	0
Bassia muricata (L.) Asch.	30	18.2	3.3	0	0	0	0
Trigonella stellata Forssk.	35	54.5	3.3	0	0	0	0
Centaurea aegyptiaca L.	5	13.6	10	0	0	0	0
Euphorbia retusa Forssk.	35	22.7	13.3	0	0	0	0
Bassia indica (Wight) A.J. Scott	15	0	13.3	0	0	0	0
Lotus glinoides Delile	15	0	3.3	0	0	0	0
Lotononis platycarpa (Viv.) Pic. Serm.	0	0	3.3	0	0	0	0
Suaeda altissima (L.) Pall.	0	0	3.3	0	0	0	0
Althaea ludwigii L.	5	27.3	0	0	0	0	0
Anchusa hispida Forssk.	20	18.2	0	0	0	0	0
Diplotaxis harra (Forssk.) Boiss.	45	36.4	0	0	0	0	0
Centaurea calcitrapa L.	40	31.8	0	0	0	0	0
Astragalus bombycinus Boiss.	10	4.5	0	0	0	0	0
Conyza bonariensis (L.) Cronquist	5	4.5	0	0	0	0	0
Echinops spinosissimus Turra	70	22.7	0	0	0	0	0
Emex spinosa (L.) Campd.	5	4.5	0	0	0	0	0
Erodium malacoides (L.) L'Hér.	5	9.1	0	0	0	0	0
Matthiola longipetala (Delile) DC.	35	4.5	0	0	0	0	0
Paronychia arabica (L.) DC.	10	18.2	0	0	0	0	0
Plantago ovata Forssk.	5	27.3	0	0	0	0	0
Pteranthus dichotomus Forssk.	10	18.2	0	0	0	0	0
Convolvulus pilosellifolius Desr.	0	4.5	0	0	0	0	0
Astragalus hamosus L.	0	4.5	0	0	0	0	0
Astragalus schimperi Boiss.	0	4.5	0	0	0	0	0
Atractylis mernephtae Asch	0	9.1	0	0	0	0	0
Avena sterilis L.	0	4.5	0	0	0	0	0
Caylusea hexagyna (Forssk.) M.L. Green	0	4.5	0	0	0	0	0
Crypsis aculeata (DC.) Boiss	0	4.5	0	0	0	0	0
Herniaria hemistemon J. Gay	0	4.5	0	0	0	0	0
Ifloga spicata (Forssk.) Sch.-Bip.	0	22.7	0	0	0	0	0
Lappula spinocarpos (Forssk.) Asch. ex Kuntze	0	13.6	0	0	0	0	0

1	2	3	4	5	6	7	8
Morettia philaeana (Delile) DC.	0	0	0	31.8	60.7	39.1	0
Schouwia purpurea (Forssk.) Schweinf.	0	0	0	9.1	35.7	8.7	0
Tribulus pentandrus Forssk.	0	0	0	0	14.3	10.9	0
Astragalus eremophilus Boiss.	0	0	0	0	0	30.4	0
Lupinus digitatus Forssk.	0	0	0	0	0	6.5	0
Launaea amal-aminae N. Kilian	0	0	0	0	0	4.3	0
Echium horridum Batt.	0	0	0	4.5	0	0	0

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