Study of Flora Composition and Distribution in Siwa Oasis

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ABSTRACT

The aim of this research is to study the composition and distribution of the Flora of Siwa Oasis depression. The study includes all different components to identify the role and interaction with the environment. The study has been conducted in Siwa depression in 4 cross-sections taking the four lakes of Siwa: Maraki, Siwa, Aghourmi and Zeitun as a reference from west to east. The random samples taken along one cross section form a data set. The 4 data sets cover the natural vegetation area from South to North. GPS points have been recorded for 142 sample quadrates and the characteristics of natural flora and relevant environmental factors observed were recorded and analyzed. The analysis of the data has been conducted through a multivariate procedures using: indices to identify the importance of each species, β diversity to evaluate the biodiversity; the two–way indicator species analysis (TWINSPAN) for the community classification; Chi square (χ^2) for the analysis of species association and canonical correspondence analysis (CCA) to identified the relation between the plant communities and the environmental factors.The area studied covers a total of 14 perennial species (9 shrubs, 4 herbs and 1 parasite) which have been taxonomically classified, as follows: *Alhagi maurorum, Arthrocnemum macrostachyum, Atriplex coriacea, Calligonum comosum, Cistanche phelypaea, Cornulaca monacantha, Phragmites australis, Imperata cylindrica, Juncus rigidus, Nitraria retusa, Stipagrostis scoparia, Tamarix nilotica, Zygophyllum album and Zygophyllum coccineum.* The study demonstrates that the natural vegetation in Siwa depression is represented by few species with a unique genetic resources and is distributed and organized in function and depending directly on the environmental factors. The flora distribution is characterized by: a community that populates the sand environment in the southern area of the depression, represented by 5 species the *Cornulaca monacantha, Stipagrostis scoparia, Zygophyllum album, Calligonum comosum* and the *Cistanche phelypaea* which is a parasite on the roots of the *C. monacantha*; a community that populates the wet and dry sabkha close to the lakes' edges represented by 4 species *Juncus rigidus, Arthrocnemum macrostachyum, Phragmites australis* and *Imperata cylindrica* which occurred only in the dry sabkha; and three species, the *Alhagi maurorum, Tamarix nilotica* and *Nitraria retusa*, that populate the northern part of the depression and are wide spread in the oasis in different environmental conditions. The more dominant, frequent and disdreputed species in the Oasis is *Alhagi maurorum*

Key words: Siwa Oasis, natural vegetation, flora, plant community, species diversity, species association, canonical correspondence analysis, taxonomic classification, species importance.

INTRODUCTION

It is well known that Egypt is the home of many species of flora which are completely adapted to the different environmental conditions. Some of them could be considered as natural ancestors of some important food crops, others constitute the main source of pastorals and medicinal plants.

It is well Know that about 10 percent of the world's flora species are in danger of extinction. And many ecosystems around the world are currently undergoing dramatic changes with a reduction in species diversity and changes in species composition, due to the influence of human activity. The protection and conservation of the indigenous plants whether flora or cultivated varieties of different species must have more consideration in the objectives of the responsible scientific institutions and applied authorities. Many of these plants could be utilized in the genetic improvement of many crop varieties by either hybridization or by using genetic engineering techniques. These methods could be utilized to benefit from the genes of the indigenous species which mostly have the high adaptive value to environmental stresses such as salinity, drought and pathogenic agents, etc....

One of the impressive characteristics of Egypt is the presence of several isolated sites (i.e. Oases) which represent enclaves for rare and endemic plants. Siwa Oasis is a good example of a naturally isolated area. As a natural depression in the western Desert of Egypt, Siwa could be considered as a specific location of plant genetic diversity for flora and other cultivated crops.

The Oasis represents a unique ecosystem. It has always managed to survive: its biodiversity has been naturally preserved due to its isolation. The changes occurring in Siwa, as a direct result of its recent introduction to modernity are inevitable. The agricultural development is one of the main aspects of the oasis modernity and the impact of agricultural extension and imported practices on the biodiversity of the natural flora in the Oasis region cannot be predicted today in which flora biodiversity of Siwa depression is continuously deteriorating starting from the last few decades.

The aim of the present study is to taxonomically classify, evaluate species diversity, identify plant communities, analyze the relation between plant and key environmental factors on the flora of Siwa depression and consider the effect of human activities on the natural distribution of the flora.

MATERIALS AND METHODS

This research was conducted in the Siwa Oasis during the period from March 2002 until April 2003.

Study Area

The Siwa Oasis, located in Egypt's western desert, is about 600km west of Alexandria and 300km South-West of Matrouh (Mediterranean coast) and about 65 km East of the Libyan borders. Siwa is located on the northern edge of the Great Sand Sea, one of the largest sand areas in the world. Siwa depression is one of a series of numerous depressions scattered in the western desert of Egypt (Figure 1). Siwa Oasis is about 75 km long and its width varies between 5 and 25 km. The area bounded by the zero contour line lies between latitudes 29° 06′ and 29° 24′ N and longitudes 25° 16′ and 26° 12′ E with a total area of about 1088 km^2.

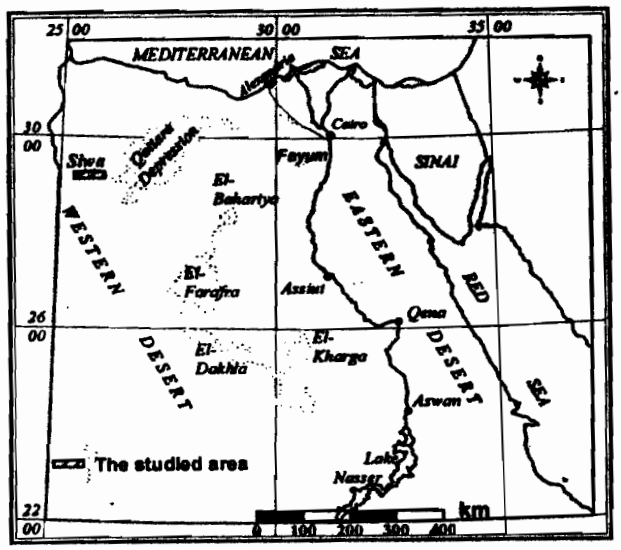


Figure 1. Location Map of Siwa Oasis

The study area covers the natural vegetation area that surrounds the inhabited area of the Siwa depression. The study area extends between latitude 25° 16' and 25° 52'.

The map, Figure 2, of Siwa Oasis shows the depression in relation to the 4 lakes of Siwa and their relative basins which act as the natural drainage into the lakes. These lakes from West to East are: Maraki, Siwa, Aghourmi and Zeitun.

The climate of Siwa is hot/dry in summer and warm/dry in winter. The rainfall is almost negligible with an average rainfall of approximately 10 mm/year. Data recorded by the Egyptian Climatic Authority, Siwa Meteorological station shows that some years record no rainfall at all.

The maximum temperatures do not vary much along the year, reaching their highest value in July (38 °C) and their lowest in January (19.6 °C). However, the minimum temperatures vary greatly between seasons: from 3.8 °C in January to 20 °C in July. So the climatic characteristics of Siwa Oasis, pluviometric regime and thermic regime, is considered arid during all year around.

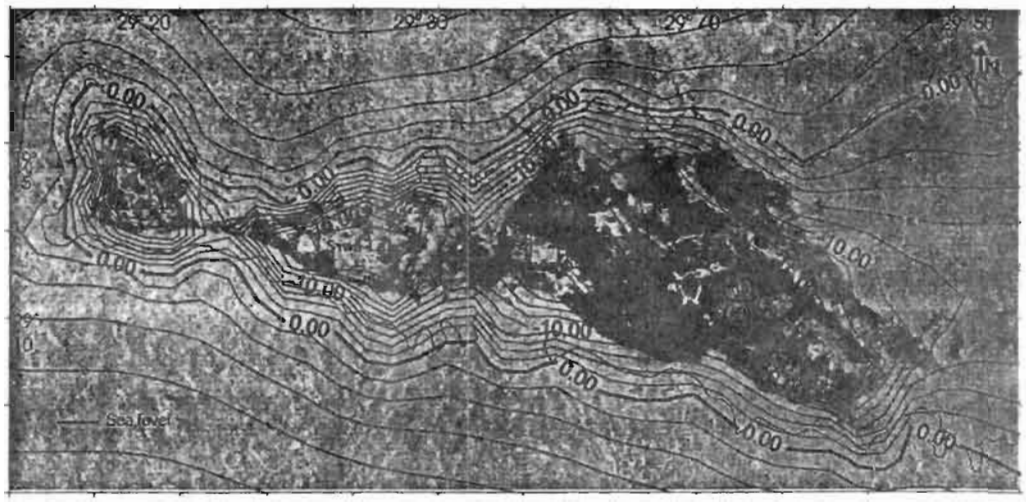


Figure 2. Siwa depression the 4 lakes and their relative basins

The main wind blow directions are NW, NE and SE having general ratios of 24.4%, 18.2% and 12.4% respectively.

The geomorphology structure of Siwa depression is longitudinally differentiated with the mountains on the northern side, the sand sea on the southern and the lakes intermediary. This longitudinally structure distinguishes different geo-pedological characteristics by sand dune and sand sheets soil in the southern; marshes sabkha dry and wet around the lakes; and, limestone and bedrock covered by sand in the northern side up to the edge of the depression, HYDEA-NARSS (2000). These geo-pedologic characteristics have distinguished three different vegetation distributions, these are:

- the sand environment localised in the southern area of the lakes from the edge of the Sabkha area up to the sand dune;
- the moist area, wet and dry Sabkha around the lake, in the depression the Sabkha cover a total surface of 355.9 km^2 Gad (2001); and,
- the dry area, sand covering bedrock on the northern side of the lakes edge of the Sabkha area up to the margin of the depression.

Data collection

The study area was divided into 4 sets. Each set consisted of a section orientated from South to North corresponding to a lake and its relative basin (figure 3).

142 plant community samples (quadrates) were collected. Each quadrate is 100 m^2 (10x10m), Gilbertson, et al (1985).

The sample quadrates were distributed as follows: 37 samples in the 1st set related to Maraki Lake; 27 samples in the 2nd set related to Siwa Lake; 35 samples in the 3rd set related to Aghourmi Lake; and 43 samples in the 4th set related to Zeitun Lake. All sites from which data was collected were located with a GPS (Global Positioning System).

Figure 3. Location of the 4 sets in the study area

The locations of the quadrates were selected to represent the natural vegetation in the different areas of the Oasis. The quadrates were located by random sample distribution. The plant community (biological data) of each quadrate sampled was surveyed and recorded. Measurements related to the environmental variables (physical data) were recorded.

1. Vegetation measurements

The survey was conducted in 4 different periods of the year. For each of the 142 quadrate samples, a number of quantitative and qualitative biological information related to the plant community were recorded.

For each quadrate, all species that occurred in the quadrate were recorded and the following data were collected following Hanson and Churchill (1965) as described below:

- *Density* (Abundance), the quantity of each species expressed as number of individuals, counting the individuals of each species that occurred in the quadrate; and,

- *Dominance*, % coverage of each species recorded in the quadrate, to determine the space occupied by each species that occurred in the quadrate measuring the smallest and largest plant of the same species o

The data related to *Phoenixs dactylifera* was recorded and excluded in the data analysis as its presence as natural vegetation is limited and scattered as localized niches most of the time at the boundary of the natural vegetation, designing the horizon. it is also difficult to separate the spontaneous occurrence of *P. dactylifera* from the ones linked with human activities in the past.

2. Measurement of the Environmental Variables

For each quadrate 4 main environmental variables related to the vegetation composition and characterize the plant habitat were observed and recorded. Those environmental variables are: Longitude, distribution South – North; water table, level and quality (pH and EC); soil, chemical and physical characteristics; and, altitude, topography.

Longitude: each sample was located with a GPS and a relative longitude (taking longitude 29° as a reference point) was calculated. For the conversion of the GPS point to metric distance, an approximate conversion (1' Longitude = 1.849 km) is used for Egypt.

Altitude: for each sample was located on a digital topographic map 1=25,000 (Egyptian maps) with a range of 0.5 meter.

Water Table: 37 piezometers, located around the oasis, monitored during a period of one year, (Masini, A. 2003) measuring the water table level (depth from the soil surface), pH (pH meter) and salinity (electric-conductivity meter) on monthly basis. For each measurement, a year mean was calculated. Each sample was located on a contour map and a relative value of water table was attributed:

- *Level*, following a range <60 cm, 61-120 cm and >120 cm;
- *pH*, correspondent value; and,
- *EC ppt*, correspondent value with 0.5 range.

Soil Factor: for each sample, a soil type was recorded and classified following the study of HYDEA/NARSS (2000), through locating the quadrate on the soil map 1:25000 of HYDEA/NARSS (2000). The soil type was grouped in 6 categories following the typologies, physical and chemical characteristics, as follows: Sand Dunes, Sand Sheets, Hammocks, Wet Sabkha, Dry Sabkha and Sand Cover on Bedrock.

Data analysis

1. Species classification and Importance value

All species present in the quadrate were classified, referring to the study of Aly and Hassan, (1980, 1993 and 1998); Hassan and El-Wakil, (2001) and following the Taxonomic nomenclature of Tackholm, (1974) updated by Boulos, L. (1999 and 2000). A description of characteristics of the species and performance in various environmental conditions was also documented.

For each species Relative Density, Frequency and Relative Dominance were used to calculate the importance of each species (DFD index) McIntosh (1967) as follows:

$$\text{Importance value (DFD)} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance}$$

The Relative Density (abundance) represented by the number of individual species that occurred in the quadrate, was calculated as follows:

$$\text{Relative density of species A} = \frac{\text{Total no. of individuals of species A}}{\text{Total number of individuals of all species}} \times 100$$

The relative Frequency of the individual species that occurred in the sampling quadrates, was calculated as percentage of the following formula:

$$\text{Relative Frequency} = \frac{\text{Frequency species x}}{\text{Sum of frequency values of all species}} \times 100$$

The Relative Dominance represented by the space occupied by the single species that occurred in each quadrate, was calculated as follows:

$$\text{Relative dominance} = \frac{\text{Dominance of species A}}{\text{Total dominance of all species}} \times 100$$

Where the Importance index can range from 0 to 300.

2. Species Diversity (β diversity)

The diversity of plant community was analyzed confronting the 4 sets. A computer program (Species Diversity and Richness III, 2003) was used to analyze vegetation composition in the area related to the four lakes, and the different habitat identified within the soil units. β diversity measures the increase in species diversity, using presence/absence data. The samples are arranged in the data grid South – North in their order of occurrence along the set. All samples have the same size (quadrate 10x10 meters).

Based on an assessment of the properties of the six indices proposed by Wilson and Schmida (1984) in representing the trends and ability to detect the change of the species diversity in the study area (4 sets), the 5th index of Routledge (β_E) – Reference to Species Diversity and Richness (2003)- was selected.

$$\beta_E = \exp(\beta_l) - 1$$

$$\beta_l = \log(T) - \left[\left(\frac{1}{T}\right)\sum e_i \log(e_i)\right] - \left[\left(\frac{1}{T}\right)\sum \alpha_i \log(\alpha_i)\right]$$

where e_i is the number of samples along the transect in which species i is present and α_i the species richness of sample i and T is $\sum e_i$.

3. TWINSPAN

TWINSPAN was used as a method for the division of recorded species in clusters. This method originally devised by Hill (1979) was used for the classification of plant community, dominance value (% of coverage) .

For the analysis of plant communities (division in clusters), a computer program,(CAP version 2, 2002) was used.

4. Association Chi square

The association between species was conducted with presence-absence observations and calculated using Chi-squared (χ^2). Using a contingent table. For the calculation a computer program has been used (Cap version 2, 2002).

5. Ordination: Canonical Correspondence Analysis

Canonical correspondence analysis (ECOM, Version 1.3, 2002) is the ordination method in which the ordination of the biological (main) matrix by correspondence analysis or reciprocal averaging is constrained using multiple regression on the variables included in the environmental matrix. For the CCA a matrix for the biological data and a matrix for environmental variables were prepared for each set and included:

Biological data: recorded abundance of the species in each quadrate not transformation of the data.

Environmental matrix including:

- soil, the data was regrouped in three according to the pedological characteristics, sand dune/sheet, sabkha (wet and dry) and sand covering bedrock, using a binary value;
- water table, the level was reduced in three class <60 cm=1, 61-120=2 and >120=3; the pH and EC values have been converted to log10;

- Altitude the value was divided by the maximum value absolute; and,
- Longitude the distance calculated as previously illustrated has been divided by the maximum value.

RESULT AND DISCUSSION

In the Siwa depression the flora distribution is directly characterised by the 4 lakes and the relative environmental condition created by them. For a comprehensive image of the composition of the natural vegetation and distribution in the depression the results are presented in four different sections: classification, description and relative DFD of each species; species diversity; plant community organisation; species association; and, species ordination with respect to the environmental variables.

Classification, description and relatives DFD value of the flora

1. Taxonomical classification

fourteen perennial species belonging to 9 different families were photographed by EL-Wakil and Masini during field survey of the study and recorded in the natural area outside the cultivated gardens in the Oasis. The following is a brief description for each species following their alphabetical family order following Tackholm, (1970) and Boulos, (1999 and 2000).

Fam. CHENOPODIACEAE

Three recorded species belong to this family: the *Atriplex coriacea, Arthrocnemum macrostachyum* and *Cornulaca monacantha.* These species live in different habitats varying from wet-moist (sabkha) to sand dune and bedrock.

Atriplex coriacea Forssk. (figure 5)

Perennial shrub monoecious, yellowish-white tomentose; leaves ovate-elliptic very thick, coriaceous, entire, the apexacute or obtuse, the midrib prominent on the lower surface, flowers in terminal leafless in panicles, flowers unisexual, fruiting bracteoles quadrangular (4mm), seeds 1-2 mm dark brown.

The *A. coriacea* is recorded in the eastern point observed North of Zeitun Lake. The area is characterized by a dry habitat with sand covering bedrock. The *A. coriacea* shrubs measure 60 cm high and 100 cm large. The unique presence of this species in one quadrate in the survey restricts its analysis.

Arthrocnemum macrostachyum Moric. Moris (figure 6)

The *A. macrostachyum* is a perennial shrub with fleshy and branched stems. The flowers are located on the annual branches and are classified as hermaphrodite. The shrub reaches 30-100 cm in height.

The *A. macrostachyum* occurs principally in salty marshes (wet sabkha) around the lakes. This species is recorded alone on the moist border of the lake and in association with *Juncus rigidus, Phragmites australis* and *Tamarix*

nilotica further from the border. These associated species inhabit areas characterized by a shallow water table with high salinity which represent a very hostile environment for plant growth.

Cornulaca monacantha Del. (figure 7)

The *C. monacantha* is a shrub which grows in the Sahara desert, forms compact, round bushes bearing small yellow thorns. The *C. monacantha* is a blue-green shrub, leaves short triangular re-curved narrowing from the base into a rigid spin, flowers polygamous surrounded by dense tufts of white wooly hairs.

In the Oasis, this shrub contributes to the formation of hammock that some times reaches 100 cm high. The branches of the plant are about 20-50 cm high above the sand surface, the round bushes are 150-250 cm large. The *C. monacantha* is distributed in the sand area of the depression with a deep water table in South of Zeitun, Aghourmi and Siwa lakes and S-West of Maraki lake. The *C. monacantha* is parasited by the *Cistanche phelypaea* and associated in the same habitat with the *Zygophyllum album*, *Stipagrostis scoparia* and *Calligonum comosum*. In the same habitat where the *C. monacantha* grows, the *Alhagi maurorum*, *Tamarix nilotica* and *Nitraria retusa* species which are widely diffused in the Oasis are also present.

Fam. GRAMINEAE

Three different perennial grasses are recorded species that belong to this family, the *Imperata cylindrica*, *Phragmites australis* and *Stipagrostis scoparia*.

Imperata cylindrica L. (figure 8)

Medium sized perennial grass with long leaves in a dense basilar rosette and spike-like soft panicle up to 20 cm, flowers surrounded by long hairs.

The *I. cylindrica* has been recorded in the four sets in the different soil conditions with a shallow water table; The *I. cylindrica* is prevalently associated with the *Alhagi maurorum* in the sand soil and in the *Karchif* (dry sabkha) soil with the *Juncus rigidus*.

Phragmites australis Cav. (figure 9)

Perennial grass; culms erect, 2–4 m tall, occasionally up to 6 m, with stout creeping rhizomes, often also with stolons; leaf-blades broad, flat, 15–60 cm long, 1–6 cm broad, glabrous, green or glaucous, the sheaths overlapping; panicle tawny or purplish, 15–40 cm long; lemmas glabrous, sharp-pointed, not bifid, with long hairs confined to rachilla joints; lowest floret staminate.

The *P. australis* is especially common in alkaline and brackish (slightly saline) environments and can also thrive in highly acidic wetlands. In Siwa, its growth is greater in fresh water in the border of the cultivated gardens around

the irrigation and drainage canals. In the wild area, it is often found in association with other wetland plants including species from the following Genera *Juncus rigidus, Imperata cylindrica* and *Arthrocnemum macrostachyum.*

Stipagrostis scoparia Trin. (figure 10 a, b)

Glabrous perennial desert grass, tall (120cm) and stiff, with filiform pungent leaves.

The *S. scoparia* is present in the sand sheet with deep water table and its distribution is limited to the South side of the depression. The growth of the *S. scoparia* contributes to the formation of hummocks. The *S. scoparia* is recorded as part of the community represented by the *Cornulaca monacantha* and *Zygophyllum album.*

Fam. JUNCACEAE

Juncus rigidus C.A. Mey (figure 11)

Marsh herbs, with symposia rhizome developing one leaf every year. The culm is unbranched and has no leaves. Flowers protogynous, wind pollinated, typically in a pale separate flowers, seeds with a large white appendage, the culm is continued above the inflorescence.

The *J. rigidus* has been recorded in salty marsh land, *Karchif*, sabkha dry and wet, around the lakes and occasionally around the gardens in the proximity of irrigation and drainage canals. Inside the garden, another species of *Juncaceae* has been observed: the *Juncus acutus* that is similar to the *Juncus rigidus* The *Juncus rigidus* is represented in a community with *Arthrocnemum macrostachyum* and *Phragmites australis.* The *Juncus rigidus* is associated with one or more of the following species as *Tamarix nilotica, Nitraria retusa, and Alhagi maurorum* in wet or dry sabkha. It is also associated with the *Imperata cylindrica* in the dry sabkha. In case of association with *Imperata cylindrica*, it is evident that the roots of the two plants are completely separate and don't intersect.

Fam. LEGUMINOSAE (FABACEAE)

Alhagi maurorum Medic. (figure 12 a, b)

The *A. maurorum* is a deep-rooted, rhizomatous, perennial shrub with somewhat woody stems that renew every year, with roots, rhizome that can extend six meters into the ground. The spiny, intricately-branched shrub reaches 20-100 cm in height. The plant has simple entire leaves that are alternately arranged. The leaf shape is oval to lance-shaped. The small, pea-like flowers are pinkish purple to maroon and are borne on short, spine-tipped branches that arise from the leaf axils. The species spreads by seeds and rhizomes, the non-dehiscent seedpods are constricted between 5 to 8 mottled greenish brown seeds. The seeds turn dark brown when ripe.

The *A. maurorum* in the Oasis represents the most adapted plant and the most resistant in different environmental conditions varying from sand dunes to wet sabkha. *A. maurorum* is associated with all species recorded. The plant is especially abundant in the border of reclaimed land and is also spread in the cultivated land. The seeds propagation is observed in the cultivation area. However, in the natural area, seeds propagation is limited due to the negligible precipitation of rainfall.

Fam. NITRARIACEAE
The only genus in the family is represented by the *Nitraria*.

Nitraria retusa Forssk. (figure 13)
Thorny shrub up to 3 meters, stems spinescent; the leaves are simple with the abovate shape, flashy, alternate or clustered; the flowers are bisexual and the fruit are red flashy drupe with pear shape.

The *N. retusa* is present in different habitats varying from sand dune to the border of the marshes as isolated plants or associated with other species without preferences. The *N. retusa* did not show a particularly preference in habitat, however, the sand dune seems to be the habitat where it grows better.

Fam. OROBANCHACEAE
Cistanche phelypaea L. (figure 14 a, b)
Yellowish squamose parasite perennial branchless growing 30-60 cm from the ground with single whitish stem 5 cm thick and overlapping brown or paler scales 2-3 cm long and pointing up wards, more or less clasping. Flowers spikes to half the length of the plant with broad bracts. Corolla trumpet-like 4-6 cm long, the petals bright yellow some times with strong purple tinge, with rolled-out margins. Capsule black, pea-like, the majority of the seeds apparently turn rotten in the capsule on the plant.

The *C. phelypaea* parasite the root of the Chenopodiaceae (Tackholm, 1974) and has been observed on the root of *Cornulaca monacantha*. The presence and distribution of the *C. phelypaea* in the Oasis is directly dependent on the host plant which dominates the plants community in the sand environment.

Fam. POLYGONACEAE
Calligonum comosum L'Hér. (figure 15 a, b)
Tall glabrous shrub with articulated, almost leafless, often clustered with internodes 3-4 cm long, fragile branches. The flowers white-pinkish are fasciculate in the axis of membranous ocreases. The fruit are 3-4 mm oblong densely clothed with reddish brawn.

The *C. comosum* is a typical sand dune plant that often covers the entire dune. In the Oasis, it is present in the southern part of the 4th set, scattered, forming big hummocks of about 150 cm high and 200-300 cm large. Some plants occupy the top of the dune. The *C. comosum* is recorded in the same habitat with the *Cornulaca monacantha* and *Zygophyllum album*

The presence of *C. comosum in the Oasis is confined to the South-East corner of the depression.* The young branches are grazed by animals in particular camels present in the eastern part of the Oasis.

Fam. TAMARICACEAE

The Genus *Tamarix* covers 54 species. In Siwa Oasis, only one species the *T. Nilotica* has been recorded.

Tamarix nilotica Ehrenb. (figure 16)

Multiform species varying from a shrub to a tree of 5 meter high, foliage green grayish and some time covered with salt crystals. The flowers bisexual white or pink are in racemes that vary much in size and of shape.

The *T. nilotica* is diffused in all the oasis in extreme conditions varying from the top of the dunes to the salt marshes of wet sabkha. The plant shape varies from trees in the sand areas to small shrubs in the wet sabkha. The *T. nilotica* is not part of a specific community as its diffusion is not restricted to particularly environmental conditions. The small trees of *T. nilotica* are associated with the *Cornulaca monacantha* and *Zygophyllum album* in the sand environment; with the *Juncus rigidus* and *Arthrocnemum macrostachyum* in the wet sabkha; and, with the *Alhagi maurorum* and *Nitraria retusa* in the North part of the depression which is characterized by sand covering bedrock.

Fam. ZIGOPHYLLIACEAE

17 genera with 270 species. In Siwa oasis, 2 species of the *genera Zygophyllum*, the *Z. album* and *Z. coccineum* were recorded.

Zygophyllum album L. (figure 17)

Mealy canescent low shrub 25-60 cm high with erect stems and in some areas the shrub form a small hummock. Usually desert plants with cylindrical-ovoid fleshy leaves. Flowers white, pinkish or yellow. Stamens 8-10 with 1-2 scale-like appendages at the base of each filament. Capsule 5-valved, angled or winged. Shrubby plants with compound leaves. Leaflets terete. Peduncle as long as or longer than flower and capsule, leaves green glabrous. Capsule + or – cylindrical, wingless. Capsule about 10 mm long and 5 mm broad.

Z. album, is widespread in the southern side of the Oasis on the sand sheet. The small shrubs are present in all the four sets in association with the

Cornulaca monacantha and *Stipagrostis scoparia*. In the 4th set, the *Z. album* is also associated with *Calligonum comosum*. In addition, the *Z. album* is also associated with the *Alhagi maurorum* which is a widespread species in the Oasis in particular on the border of the gardens of the newly reclaimed lands in the southern part of the depression, sand sheet, where many small *Z. album* seedlings have been observed.

Zygophyllum coccineum L. (figure 18)

Shrub of perennial herbs up to 75 cm. Leaflets 2, bright green, glabrous, cylindrical, at least 10 mm. long. Capsule 8-10 mm. long, apex obtuse.

The *Z. Coccineum* is widespread in Egypt. In the Oasis, it has been recorded in some quadrates in the 2nd and the 4th sets in the northern part of the depression which is characterised by sand covering bedrock with a deep water table. Due to the few records of *Z. coccineum* occurrence, it is not possible to associate this shrub with any other particular species in the Oasis.

2. Species Importance (DFD)

The importance value (DFD) as calculated in table 1 and represented in the graphic (figure 4) for each species, expressed by the sum of the relative density, relative frequency and relative dominance, reflects the quantitative weight of any singular species independently from the qualitative evaluation of flora biodiversity in the Oasis.

According to the calculation of the relative importance (DFD), the mean relative (DFD) values for each species recorded in the four sets are as follows:

- the *Alhagi maurorum* represents the most significant species in the oasis predominating largely the four sets with the highest mean DFD value of 82.32 populating the different environmental conditions;
- a group of species with an average importance value ranging between 30-50 DFD is represented by the *Imperata cylindrica* 49.56 and the *Juncus rigidus* 44.91 predominating the sabkha environment and the *Cornulaca monacantha* 34.97 and *Zygophyllum album* 27.15 predominating the sand environment;
- the DFD value of *Tamarix nilotica* is 12.98 and that of *Nitraria retusa* is 10.09, recorded in the different environmental conditions, both species are predominant in the first and fourth set;
- the DFD value of *Phragmites australis* is 17.13. This value is directly linked with the biological characteristics of the species: low dominance and high density. The occurrence of the species is observed mostly in the sabkha environment;
- the DFD value of *Arthrocnemum macrostachyum* is 7.72 and that of *Stipagrostis scoparia* is 7.70. This reflects the scattered distribution (low density) of these two species in the depression. While the distribution of

the former is limited to the wet sabkha environment (lake shore), the latter is limited to sand sheet environment;

- one of the species with very low importance values is the *Cistanche phelypaea* 2.33 DFD. This is due to that fact that as a parasite plant, its occurrence depends on that of the host plant and because of the biological characteristics of the plant; and,
- and other species with low importance value are the *Calligonum comosum* 1.50, *Zygophyllum coccineum* 1.37 and *Atriplex coriacea* 0.28 reflecting their rare occurrence in the quadrate samples.

In general, it is evident from the DFD calculations that the importance value of the species which populate the sabkha is higher than that of the species which populate the sand and bedrock habitats.

Figure 4 Importance value (DFD) for each species, as a mean of the four sets

Fig. 5 *Atriplex coriacea*

Fig. 6 *Cornulaca monacantha*

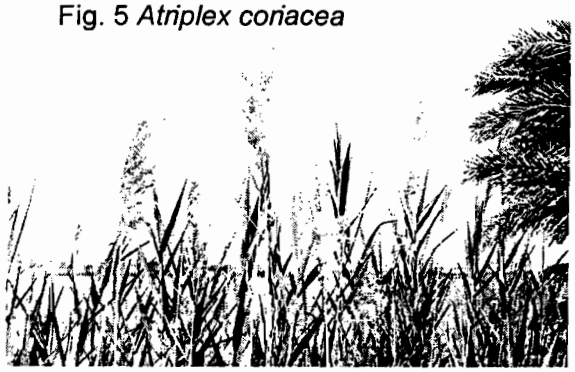


Fig. 8 *Phragmites australis*

Fig. 7 *Arthrocnemum macrostachyum*

Fig. 9 *Imperata cylindrica*

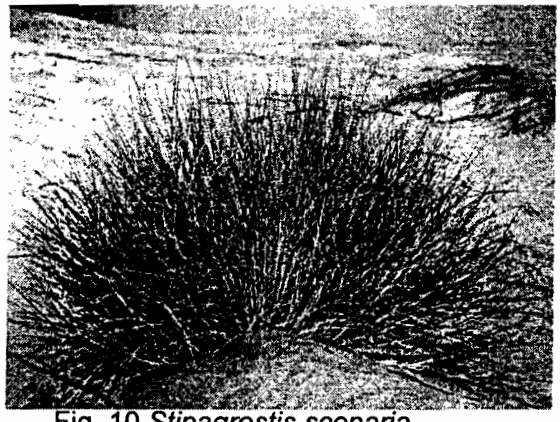


Fig. 10 *Stipagrostis scoparia*

Fig. 11 *Juncus rigidus*

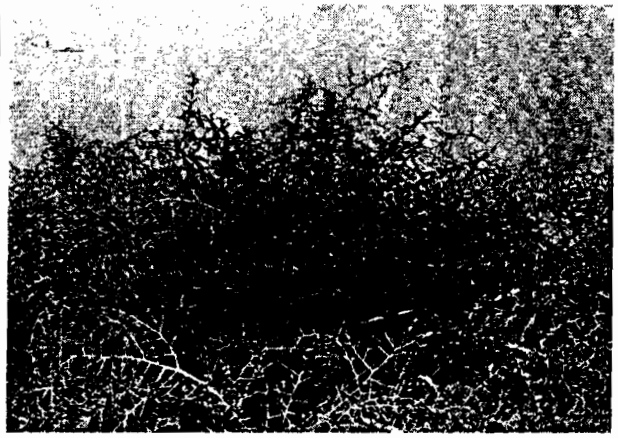


Fig. 12a *Alhagi maurorum*

Fig. 13 *Nitraria retusa*

Fig. 12b *Alhagi maurorum*

Fig. 14a *Cistanche phelypaea*

Fig. 14b *Cistanche phelypaea;* Branched trunk parasitized on a thin root of the host (*Comulaca monacantha*).

Fig. 15a *Calligonum comosum*

Fig. 15b *C. comosum*

Fig. 16 *Tamarix nilotica*

Fig. 17a *Zygophyllum album*

Fig. 18 *Zygophyllum coccineum*

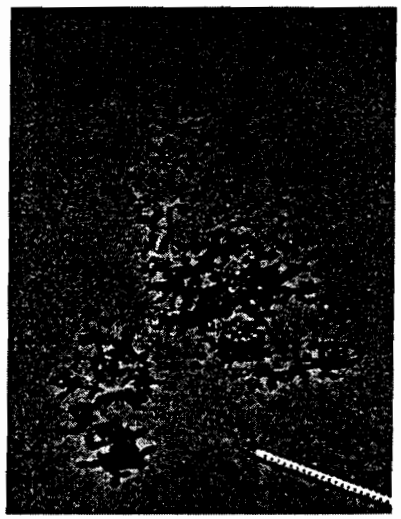


Fig. 17b *Zygophyllum album*

Table 1. Species importance (DFD) as a sum of relative density, frequency and dominance in relation to the four sets studied in the oasis

Species	S1				S2				S3				S4				Mean
	Dens.	Fre.	Dom.	DFD	Dens.	Fre.	Dom.	DFD	Dens.	Fre.	Dom.	DFD	Dens.	Fre.	Dom.	DFD	DFD
Alhagi maurorum	18.20	24.53	23.58	66.31	36.96	20.00	32.65	89.61	28.67	26.80	29.82	85.29	34.74	20.00	33.33	88.07	82.32
Arthrocnemum macrostachyum	0.23	1.89	3.35	5.47	0.03	1.43	0.25	1.72	0.65	4.12	4.73	9.51	0.72	6.96	8.50	14.17	7.72
Atriplex coriacea													0.05	0.87	0.19	1.12	0.28
Calligonum comosum													0.05	4.35	1.59	5.99	1.50
Cistanche phelypaea					0.27	5.71	0.00	5.98	0.23	3.09	0.00	3.33					2.33
Cornulaca monacantha	1.12	18.87	16.09	36.08	4.08	22.86	30.72	57.66	1.59	14.43	21.60	37.63	0.22	4.35	3.91	8.48	34.96
Phragmites australis	7.87	3.77	2.00	13.64	10.35	1.43	1.36	13.13	10.99	9.28	1.54	21.81	9.07	9.57	1.31	19.95	17.13
Imperata cylindrica	36.71	5.66	15.27	57.64	23.00	4.29	4.83	32.12	37.22	5.15	9.08	51.45	27.44	11.30	18.29	57.03	49.56
Juncus rigidus	33.79	5.66	20.73	60.18	17.24	1.43	5.78	24.45	12.64	6.19	16.46	35.28	23.65	12.17	23.89	59.72	44.91
Nitraria retusa	0.11	9.43	5.47	15.01	0.08	4.29	3.64	8.01	0.10	4.12	3.98	8.21	0.10	5.22	3.82	9.14	10.09
Stipegrostis scoparia	0.01	0.94	0.21	1.16	0.69	8.57	11.43	20.69	0.18	4.12	2.67	6.97	0.02	1.74	0.19	1.96	7.70
Tamarix nilotica	0.20	13.21	8.78	22.19	0.18	7.14	2.49	9.81	0.26	6.19	1.19	7.64	0.29	10.43	1.57	12.30	12.98
Zygophyllum album	1.75	16.04	4.52	22.31	6.88	21.43	6.06	34.37	7.46	16.49	8.92	32.88	2.92	11.30	4.83	19.06	27.15
Zygophyllum coccineum					0.24	1.43	0.79	2.46					0.71	1.74	0.58	3.02	1.37

Note: Density (Dens.); Frequency (Fre.); Dominance (Dom.) and the sum of Density, Frequency and Dominance (DFD)

Species diversity (*β Diversity)*

A total number of 14 species were recorded. Among these species, 10 were identified in the 1st set, 12 in the 2nd set, 11 in the 3rd set and 13 in the 4th set. In general, the simplest measure of diversity is to count the number of species. This is termed as species richness (McIntosh 1967).

The application of the β diversity to measure the species diversity gives us an overall diversity in the whole area (Species Diversity and Richness, 2003) and shows the difference in species diversity between the four sets. Set 4 evidences a higher overall diversity. On the other hand, set 1 presents the lowest value. The fluctuation of the values is directly dependent on the presence or absence of one or two species.

The index of Routledg βe is 2.448, 2.874, 2.881 and 3.374 in the 1st, 2nd, 3rd and 4th set respectively and represented in the graphic of figure 19.

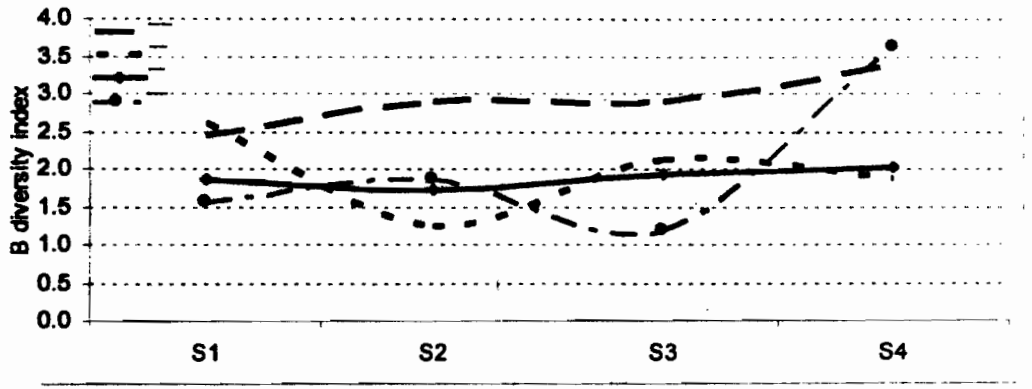


Figure 19. Graphical representation of Routledge β diversity in the different sets and habitats

As demonstrated in the above chart, the species diversity in the extreme west of the Oasis, Maraki Lake, (set 1) is lower than that in other sites of the study area. In Siwa Lake (set 2) despite limited vegetation in terms of quantity, it has higher species diversity than that of set 1. The highest diversity index was spotted in the Zeitun area (set 4) where 13 different species were recorded.

The β diversity evidences the species diversity of the community composition with respect to the different habitats (Species Diversity and Richness, 2003). The β diversity relative to the three identified habitat conditions (bedrock, sand and sabkha) shows the trend in diversity from West set 1 to East set 4 (figure 19).

From the graph, it is demonstrated that the species diversity in the sand habitat, (to the South of the lakes) is the most homogeneous trend and that there is a slight trend of diversity increase from West to East.

As for the species present in the wet sabkha (marshes around the lakes), the indices calculated for samples from Maraki Lake (set 1) are higher than those calculated for other sets (2,3 & 4). However, the set of Siwa Lake (set 2) shows the poorest diversity. This is due to the fact that all the sabkha around the Siwa Lake has been reclaimed during the last few decades, while the rest of the sabkha area around the lake is flooded by water from the lake during the winter period.

The species diversity in the bedrock habitat dominating the northern part of the depression shows high values in the 2nd and 4th sets. This is due to the presence of rare species (*Zygophyllum coccineum* in the 2nd set and *Atriplex coriacea* in the 4th set).

In general, while the flora biodiversity of the oasis consists of 14 perennial species which might seem to be relatively poor, those species could be considered as a plant genetic resource with unique genotypes adapted to the specific environmental conditions of the Oasis.

Classification of plant community

The analysis of plant community was based on the TWINSPAN which is a clustering method originally devised by Hill (1979). 14 species were recorded in the depression and from a general view of the generated dendrograms, it is evident that the plant community organisation is directly related to the landform, It is important to note that although the majority of the species are classified and organised in different community clusters, some species e.g. *Alhagi maurorum* show no preferences in most of the sets.

The 10 species recorded in the 1st set were classified in four vegetation clusters (figure 20a):

- community associated with the dry sabkha, composed of *Alhagi maurorum*, *Juncus rigidus*, *Imperata cylindrica* and *Phragmites australis*;
- community associated with the sand dune, sand sheet and sand cover on bedrock, composed of *Cornulaca monacantha*, *Nitraria retusa*, *Stipagrostis scoparia* and *Zygophyllum album*;
- the *Tamarix nilotica* is represented as one community as it is scattered in the different environmental conditions with low relative density value; and,
- community associated with the wet sabkha (wet marshes), this community is represented by the *Arthrocnemum macrostachyum*.

The *Alhagi maurorum* classified in the first community was recorded in most of the quadrates and in all different environmental conditions except for the wet sabkha (salt marshes).

The 12 species recorded in the 2nd set were classified in six vegetation clusters (figure 20b):

- community associated in the sand sheet, this community is represented by the *Cornulaca monacantha*, *Cistanche phelypaea*, *Stipagrostis scoparia* and *Zygophyllum album*;
- the *Tamarix nilotica* is behaving as shown in the set 1;
- *Alhagi maurorum* is presented as a separate community due to its interaction with different plant communities sharing different habitats;
- the plant community in the northern side of the lake at the border with the area of wet and dry sabkha and sand cover by bedrocks is represented by the *Imperata cylindrica* and *Nitraria retusa* in the higher areas and *Zygophyllum coccineum* and *Arthrocnemum macrostachyum* in some small depressions with shallow water-table; and,
- community associated with the wet and dry sabkha, represented by the *Juncus rigidus* and *Phragmites australis.*

The 11 species recorded in the 3rd set were classified in four vegetation clusters (figure 20c):

- the community associated with the sand sheet, represented by the *Cornulaca monacantha*, *Cistanche phelypaea*, *Stipagrostis scoparia* and *Zygophyllum album*;
- *the Nitraria retusa* represented as one community. It was recorded South of the lake in the areas covered by sand dune and areas of sabkha near the border of the lake and in the North close to the end of the depression bedrock covered by sand;
- the *Alhagi maurorum* and *Imperata cylindrica* correspond to a plant community associated prevalently with the border of the sand sheet before reaching the sabkha with shallow water table South of the lake and in the sabkha at the border of the lake in the North; and,
- the *Juncus rigidus*, *Phragmites australis*, *Arthrocnemum macrostachyum* and *Tamarix nilotica* correspond to a plant community located in the wet and dry sabkha with a shallow water table.

The 13 species recorded in the 4th set were classified in six vegetation clusters (figure 20d):

- community associated with the sand sheet, this community is represented by the *Cornulaca monacantha*, *Stipagrostis scoparia*, *Zygophyllum album* and *Calligonum comosum*;

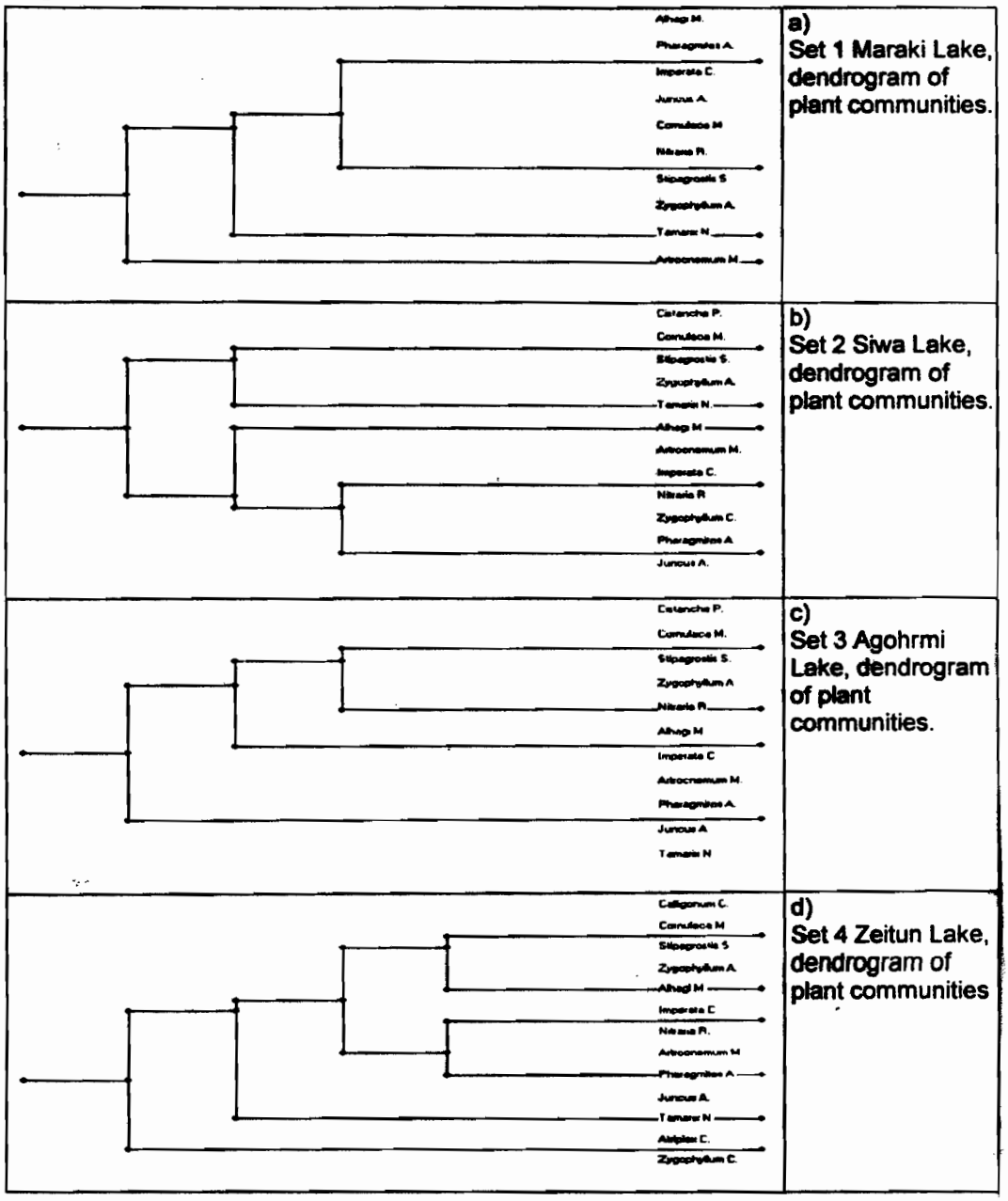
- *Alhagi maurorum* is represented separately as it shares different habitats with other communities;
- community associated with the sand with a shallow water table and sabkha, this community is represented by the *Imperata cylindrica* and *Nitraria retusa* which could be considered an atypical association. However, seeing that the *Nitraria retusa* is recorded in extreme conditions from the top of the dune to the wet sabkha with a shallow water table, this is expected;
- *Tamarix nilotica* is presented as one community as it is present with all other communities and has no association and habitat preferences; and,
- community associated in the bedrock area at the North – East extreme of the study area, this community is represented by *Atriplex coriacea* and *Zygophyllum coccineum.*

From the analysis of plant communities in the 4 sets, it is evident that the Siwa depression is characterised by:

- two well identified communities, the *Cornulaca monacantha*, *Cistanche phelypaea*, *Stipagrostis scoparia*, *Zygophyllum album* and *Calligonum comosum* that are in the South of the Oasis in the sand sheet characterize with deep water table, lower salinity and pH; and the, *Juncus rigidus.*, *Phragmites australis* and *Arthrocnemum macrostachyum* that have shown a clear preference for the wet areas localized in the border of the lakes and in depressions with swallow water table, high salinity and high pH of water table and soil;
- one intermediary, the *Imperata cylindrica* that covers an intermediary position, even if its presence was recorded frequently associated with *Juncus rigidus* and *Alhagi maurorum*, the habitat is characterized by a swallow water table; and,
- there are three species which have no association and habitat preference. The first is *Alhagi maurorum* which is recorded in most quadrates observed and occurring in various landforms varying from sand dune (not often) to wet sabkha; the second is the *Tamarix nilotica* which is highly adaptable to extreme environmental conditions and shows high performance in salt marshes together with the *Arthrocnemum macrostachyum*; and, the *third, the Nitraria retusa* which is part of different communities and therefore has no clear habitat definition.

Concerning the *Atriplex coriacea* and *Zygophyllum coccineum,* these two species have no sufficient records that allow their classification, even if field observation shows association in bedrocks.

Figure 20. Dendrograms



Association

The aim of measuring the degree of association between the different species in each set is to quantify the significance of community organisation. For each species, the Chi-square (χ^2) values which indicate a significant degree of positive or negative association were calculated.

The results obtained show the level of association between species in all the sets. From the χ^2 (table 2), it is evident that *Alhagi maurorum* is found to be associated with all other species except with the *Arthrocnemum macrostachyum*, this is due to the habitat characteristics in which the latter is restricted (wet sabkha). *Alhagi maurorum* also shows a limited association with *Phragmites australis* which mostly occurs in wet land.

Also, from the Chi square results (table 2), it is evident that the majority of the species are in negative association. Regardless whether the negative value of the Chi square is significant or not, it still reflects that the species of flora recorded adapt to particular ecological niches under the stressful environmental conditions of the Oasis (high salinity, high draught, etc..).

On the other hand, table 2 shows two groups of species with a significant positive association values: group 1 composed of the *Juncus rigidus*, *Arthrocnemum macrostachyum* and *Phragmites australis* with reciprocal positive association reflecting the occurrence of these species in the sabkha area (wet moist soil) around the lakes; and, group 2 composed of the *Cornulaca monacantha*, *Zygophyllum album*, *Stipagrostis scoparia* and *Calligonum comosum* with reciprocal positive association and occurrence in sand areas. Through the Chi square analysis it, became evident that there is a significant negative association between species belonging to group 1 and those belonging to group 2. For example the association value between the *Juncus rigidus* and the *Cornulaca monacantha* is -19.11. This means that the probability of these two species to be dependent is less than 1 % and indeed the data recorded show no occurrence of these two species in any single quadrate surveyed.

It is important to note that the Chi square value calculated for the parasite plant *Cistanche phelypaea* and the host plant *Cornulaca monacantha* is 9.09 indicating a highly significant association.

The Chi square value calculated for the *Nitraria retusa* shows that the species has a high possibility to be independent of any other species.

Species as *Atriplex coriacea* and *Zygophyllum coccineum* are limited to two sites which makes it difficult to define their association with other species.

Table 2. Species association

Species	Alhagi maurorum	Artr. Macrost.	Atriplex corlacea	Calligonum comosum	Cistanche phelypaea	Cornulaca monacant.	Phragmites australis	Imperata cylindrica	Juncus rigidus	Nitraria retusa	Stipagrostis scoparia	Tamarix hilotica	Zygophyl. album	Zygophyl. coccineum
Alhagi maurorum														
Artrocnemum macrostachyum	-11.10													
Atriplex corlacea	-0.07	-1.66												
Calligonum comosum	-0.12	0.00	-6.40											
Cistanche phelypaea	-0.51	-0.09	-4.37	-0.28										
Cornulaca monacantha	-1.12	-8.86	-0.05	0.26	9.09									
Phragmites australis	-4.42	18.88	-0.79	-0.18	-0.50	-16.38								
Imperata cylindrica	1.30	0.20	-0.63	-0.27	-0.67	-15.46	5.06							
Juncus rigidus	-3.82	36.20	-0.63	-0.27	-0.67	-19.11	36.96	5.66						
Nitraria retusa	0.00	0.00	-0.85	-0.15	-0.44	-0.43	-0.71	-2.78	-0.26					
Stipagrostis scoparia	-0.15	-0.68	-2.02	2.71	0.04	10.66	-1.74	-2.14	-2.14	-1.61				
Tamarix nilotica	-0.68	12.76	0.32	-0.65	-0.06	-0.03	0.05	-1.70	10.70	1.95	-1.44			
Zygophyllum album	0.00	-10.41	-0.02	0.13	1.47	24.73	-18.34	-14.87	-14.87	-1.05	8.70	-2.10		
Zygophyllum coccineum	-0.21	0.12	11.17	-1.58	-0.90	-0.63	0.00	-0.01	-0.01	0.00	-0.21	0.12	-0.82	

Note: If χ^2 is greater than 3.384 the probability of the species to be independent is less than 5%, if the observed value for X^2 is more than 6.64 the probability is less than 1%. Therefore the same negative value of the χ^2 expresses a strong negative association.

Canonical correspondence analysis

The analysis of community structures and the distribution of individual species in relation to environmental variables in each of the four sets is represented in the ordination plots figure 21. In general, this ordination confirms the strong position of two communities: the first community represents the species which inhabit the wet-dry sabkha with a shallow water table (*Arthrocnemum macrostachyum*, *Juncus rigidus*, *Phragmites australis* and *Imperata cylindrica*); and, the second represents the species which inhabit the sand area with deep water table and low salinity and pH (*Cornulaca monacantha*, *Zygophyllum album*, *Stipagrostis scoparia*, *Calligonum comosum* and *Cistanche phelypaea*). It is also evident that a large space is occupied by some species as the, *Alhagi maurorum*, *Tamarix nilotica* and *Nitraria retusa*.

The ordination plot of Set1 (Maraki Lake) shows the position of two opposite groups with respect to the environmental factors as follows:

- on the right side of the ordination plot, distributed on the environmental axis 2, is the group composed of the *Arthrocnemum macrostachyum*, *Juncus rigidus* and *Imperata cylindrica* characterised by the sabkha environment with shallow water table and low topographic level; and,
- on the left side of the ordination plot, there is the group composed of *Stipagrostis scoparia*, *Zygophyllum album Cistanche phelypaea*, *Cornulaca monacantha*, *Nitraria retusa*, *Alhagi maurorum*, *Phragmites australis* and *Tamarix nilotica*. These last two are, slightly separated, occupying a larger space. The whole group occupies the space identified by the environmental vectors as dune and sheet sand, topographically higher with respect to the other group and with a deep water table.

The ordination plot of Set 2 (Siwa Lake) shows a linear distribution on the 0 value of the Species/samples axis 2 and Environment axis 2 with the exception of the *Juncus* and *Phragmites australis* that are at the end of the Axis. In this plot four different groups are evidenced which are:

- communities that are isolated on the left side of the ordination plot as the community of Juncus A and *Phragmites australis* with a huge distance from all the others. This clearly shows the space occupied by them with a preferable wet-dry sabkha environment with swallow water table and low topography;
- the community occupying the right (down) space of the plot, composed of *Stipagrostis scoparia*, *Zygophyllum album*, *Cistanche phelypaea*, *Cornulaca monacantha*, inhabit the sand sheet soil in the southern part of the 2nd set;
- the central position of the *Alhagi maurorum* shows the typical characteristics of this species that occupies most of the space and different habitats; and,

- on the right side of the plot is the group composed of *Imperata cylindrica*, *Nitraria retusa*, *Zygophyllum coccineum* and *Arthrocnemum macrostachyum*. The atypical position of *Arthrocnemum macrostachyum* is due to the micro condition of some areas in the northern part of the Siwa Lake mainly related to the depth of the water table, shallow water table. The area corresponding to the northern side of the set, bedrock covered by sand with high water table. In this area, the majority of the natural areas have been converted into agricultural land and the natural vegetation only grows between the reclaimed land areas;

The ordination plot of Set 3 (Aghourmi Lake) shows the space occupied by the different communities and the gradient of vegetation distribution, the ordination shows three groups:

- the community occupying the right (down) of the plot which is composed of *Stipagrostis scoparia*, *Zygophyllum album Cistanche phelypaea*, *Cornulaca monacantha*, which inhabits the sand sheet environment in the southern side of the Set with high topography and deep water table;
- the decentred to the right down space of the plot is the plant communities represented by *Alhagi maurorum*, *Tamarix nilotica* and *Nitraria retusa*, it is evident that the three species occupy the largest space of the ordination plot and shows the vegetation composition of the northern side of the set, characterised by bedrock covered by sand with a deep water table. the *Alhagi maurorum* inhabits the sabkha environment confirming its diffusion in the area;
- the left side of the plot is occupied by the *Arthrocnemum macrostachyum* and *Juncus rigidus* directly related to the sabkha area; and,
- in the upper area of the ordination plot, *Imperata cylindrica* and *Phragmites australis* are located on the border of the Sabkha area with the sand sheet.

The ordination plot of Set 4 (Zeitun Lake) shows the dynamism of the space occupied by the community and gradient of the vegetation distribution around the lake of Zeitun. This plot representation can be summarized as follows:

- in the right (top) side of the ordination plot, the *Cornulaca monacantha* and *Stipagrostis scoparia* are located in the southern area of the depression from West to East. The plot shows the change in vegetation composition around the East part of Zeitun Lake. It is evident that *Zygophyllum album* and the *Calligonum comosum* cover a larger space;
- *Alhagi maurorum* and *Imperata cylindrica* centrally posted showing a larger position with respect to the environmental factors;

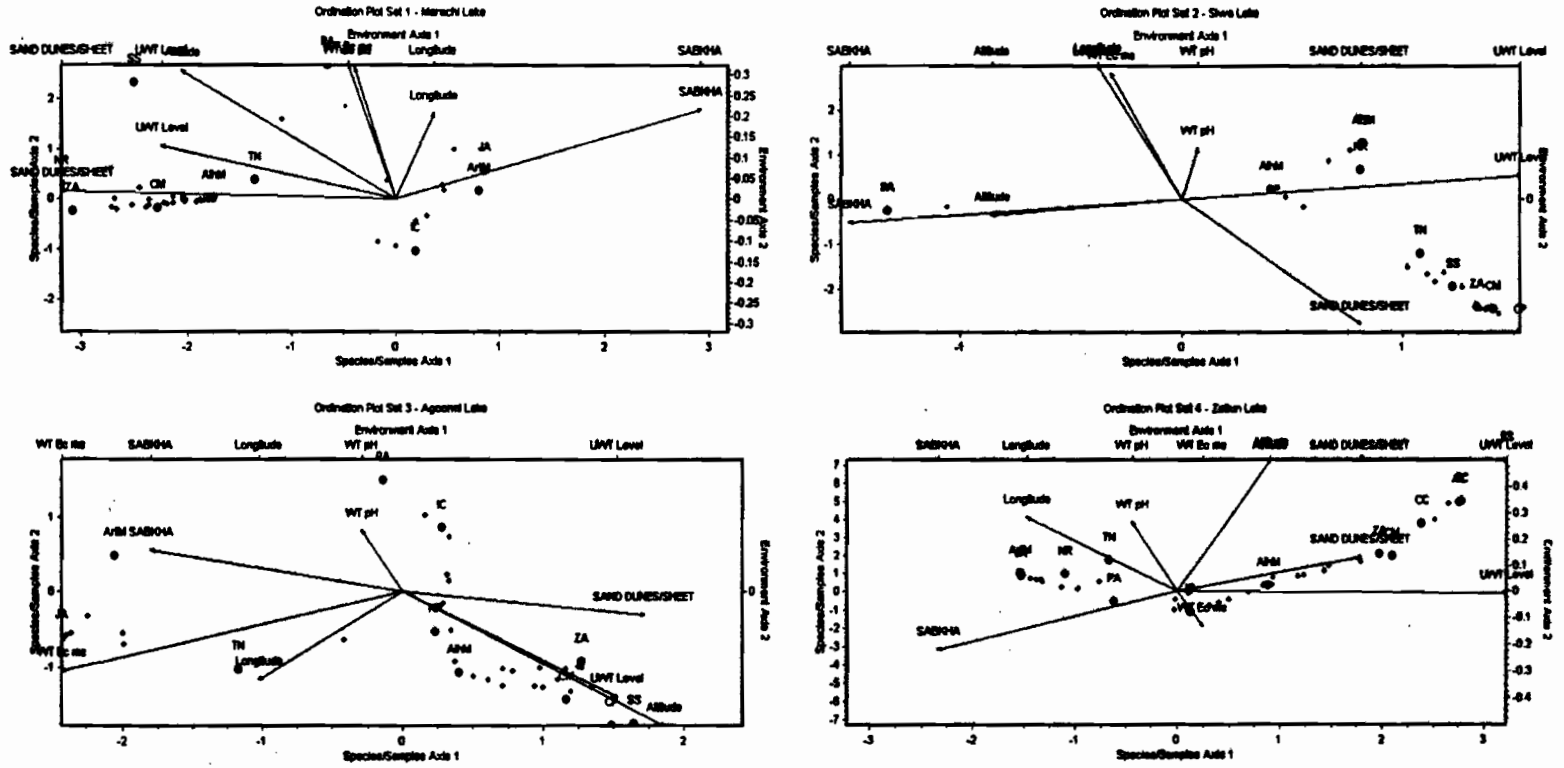


Figure 21. Ordination plots of the 4 sets – Abbreviation: *Alhagi maurorum* (AlhM), *Arthrocnemum macrostachyum* (AntM), *Atriplex coriacea* (AC), *Calligonum comosum* (CC), *Cistanche phelypaea* (CP), *Cornulaca monacantha* (CM), *Phragmites australis* (PA), *Imperata cylindrica* (IC), *Juncus rigidus* (JA), *Nitraria retusa* (NR), *Stipagrostis scoparia* (SS), *Tamarix nilotica* (TN), *Zygophyllum album* (ZA), *Zygophyllum coccineum* (ZC)

- the left side of the plot is occupied by *Arthrocnemum macrostachyum*, *Juncus rigidus* and *Phragmites australis* which inhabit the sabkha area;
- the community composed of *Atriplex coriacea* and the *Zygophyllum coccineum* is present only in the northern part of the Set which is characterised by sand cover bedrock with deep water table; and,
- *Tamarix nilotica* and *Nitraria retusa* cover undefined positions as few samples are recorded, but in different environmental contexts.

From the interpretation of the four ordination plots, it is evident that the Natural Vegetation of Siwa Oasis is characterized by three different conditions of vegetation distribution:

- South, characterised by the sand, sand sheet and hummocks with a poor soil, a high topography level with respect to the depression, a deep water table and low salinity and pH in soil and water table with respect to the sabkha;
- the vegetation in the northern side of the depression with a bedrock pedological characteristics distinguished in two area:
  - East by the *Alhagi maurorum Nitraria retusa* and *Tamarix nilotica* and,
  - West with the *Imperata cylindrica*, *Alhagi maurorum*, *Tamarix nilotica* and *Nitraria retusa*; and,
- the wet-dry sabkha environment, around the lakes, characterised by shallow water table with high salinity. The vegetation is composed of *Arthrocnemum macrostachyum*, *Juncus rigidus* and *Phragmites australis* where *Tamarix nilotica*, *Imperata cylindrica*, *Alhagi maurorum*, and *Nitraria retusa* are also present.

CONCLUSION AND RECOMMENDATION

The distribution of the natural vegetation in the study area is directly associated with the geo-pedological characteristics and water table quality (depth, salinity and pH). In the study area, given the arid climatic conditions, and the fact that the annual rainfall precipitation average is 9 mm, it is evident that the only source of water for the Siwa flora is the water table.

The taxonomical classification in the study area shows that the plant community is composed of 14 species (belonging to 9 families) of flora of which one is a parasite, the *Cistanche phelypaea*, and two are just present in few observed quadrates, rare in the area, the *Atriplex coriacea* and the *Zygophyllum coccineum*, the rest are 11 perennial shrubs and herbs, and are the species that characterize the natural vegetation of the inhabited area of the Siwa depression.

While the species are limited in number, the bio-diversity of the oasis with its few species represents a unique genetic resource coming from an evolution

of species over thousands and thousands of years in order to adapt to extreme environmental conditions that characterize the Oasis. Each of these flora species plays an important role in the preservation of the ecosystem of the Oasis.

The classification, association and ordination of the species in the different sets demonstrate that the flora of Siwa Oasis is distributed and organized as follows:

- the community that populates the sand environment in the southern area of the depression, represented by 5 species i.e. *Cornulaca monacantha*, *Zygophyllum album*, *Stipagrostis scoparia*, *Calligonum comosum* and *Cistanche phelypaea* which is a parasite on the roots of *Cornulaca monacantha;*
- the community that populates the wet and dry sabkha close to the lakes' edges represented by 4 species *Juncus rigidus*, *Arthrocnemum macrostachyum*, *Phragmites australis* and *Imperata cylindrica* which occurred only in the dry sabkha and has less significant association with the other three species in this group; and,
- there are three species, i.e. *Alhagi maurorum, Tamarix nilotica and Nitraria retusa,* that populate the northern part of the depression and are wide spread in the oasis in different environmental conditions. All three species do not demonstrate any preference of association with other species. The *Alhagi maurorum*, as an invasive plant dominates most of the areas of the oasis specially in proximity with the agricultural area where it replaced and continues to replace other natural spices. It is observed in most of the quadrate samples as reflected in the DFD values.

The results of the study demonstrate that the natural vegetation in Siwa depression is distributed and organized in function and depends directly on the environmental factors. Therefore, any change in the environmental factors will have a direct effect on the vegetation to the advantage or disadvantage of one species or the other. For example, the extended reclamation of the sand sheet in the southern part of the depression directly affects the water table level in this area. The *Alhagi maurorum* which demonstrated higher adaptation ability to habitat changes than other species tends to dominate the area and replace other species such as *Cornulaca monacantha* which originally inhabited the area.

The natural vegetation also plays an important role in preserving the microclimate condition of the oasis. The natural flora conserves the soil surface from erosion and could be considered a natural agent for sand dune fixation as in the case of *Cornulaca monacantha*, *Calligonum comosum* and other species that inhabit the southern areas of the Oasis. The natural flora also contributes to

the stabilization of water table level as it acts as a biological drainage system and it also contributes to the decrease of soil salinification through reducing the water evaporation from the soil surface. The natural flora also contributes to the addition of organic matters that enriches the soil, either directly or indirectly (as a raw material for compost).

Moreover, the natural vegetation provides an economic resource for sustaining the livelihoods of the Siwan people. The Siwan farmers use the *Alhagi maurorum* as natural compost for olive fertilization, *Zygophyllum album* as a medicinal herb, *Calligonum comosum* as animal fodder for camel, *Juncus*, *Phragmites australis* and *Imperata cylindrica* to produce baskets and carpets, etc..

Our generation is the first one that really became aware of the fact that the human activity causes irreparable damage to the planet and to its biological resources. Ours is not the first generation to do damage to the planet, but we are the first to realize the extent of the problem. The study results highlight the importance of the natural vegetation in maintaining the ecological balance and the sustainable development of the Oasis.

A development process that doesn't take in consideration the important role of different environmental variables in an ecosystem, as the one of Siwa Oasis, will lead to the depletion of the unique flora of Siwa, directly or indirectly.

This study leads to the initiation of another investigation to identify the interrelation between different flora species in relation to their variable environmental conditions, and to study the effect of environmental conditions on the genetic constitution of different populations of different species by using the biochemical and molecular genetic analysis techniques.

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الملخص العربي

تمت هذه الدراسة لتحديد التوزيع النسبي والكثافة وشيوع أنواع النباتات البريه في منخفض واحة سيوه خارج المزارع والمناطق المأهولة

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جمهورية مصر العربية

ومن المعروف أن منخفض سيوه يمتد طوليا من الغرب إلى الشرق بطول حوالي ٧٥ كيلو متر وباتساع من الشمال إلى الجنوب يتراوح بين ٥ إلى ٢٥ كيلو متر. ولتنفيذ هذه الدراسة تم تقسيم المنخفض إلى أربعة قطاعات تشمل الأربعة بحيرات الاساسيه بالواحة وهي من الغرب إلى الشرق كما يلي : المراقي ، سيوه ، اغورمي والزيتون. ولقد امتد كل قطاع من الجنوب إلى الشمال شامل أنواع التربةالمختلفه في كل قطاع قاطعا بحيرة كل منطقه . ولقد لوحظ إن القطاعات ألا ربعه تشترك في خصائص التربة من الجنوب إلى الشمال كالتالي:

المنطقة الجنوبية تبدأ بالكثبان الرملية المرتفعة ثم المسطحات الرملية (اقل ارتفاعا) ومع التدرج في لانخفاض تبدأ أراضي السبخة الجافة ثم السبخة الرطبة التي تمثل الشاطئ المباشر لكل بحيرة يلي ذلك في اتجاه الشمال المسطح المائي لكل بحيره. ثم يبدأ لساحل الشمالي بشاطئ من السبخة الرطبة ثم في اتجاه الشمال توجد السبخة الجافة يليها ارض رمليه ذات قاع صخري يحدها من الشمال الجبال الرسوبية التي تحدد الحد الشمالي للمنخفض.

ولقد أخذت البيانات من وحدات مساحية كل وحده مساحتها ١٠٠ متر مربع بطول ضلع ١٠ متر. ولقد شملت الدر اسه ١٤٢ وحده مربعة موزعه علي الأربعة قطاعات . وتتلخص البيانات المأخوذة من كل وحده في حصر وتصنيف الأنواع النباتية المتواجدة وتحديد التكرار النسبي والكثافة والارتباط بين هذا التوزيع ونوع التربة .

ولقد تم حصر وتصنيف أربعه عشر نوعا مختلفا علي مستوي الدر اسه الكلية في هذا البحث موزعه بنسب مختلفة علي مستوي القطاعات ومستوي الوحدات المساحية داخل القطاعات وجميعها أنواع معمره منها ما هو شجيرات وما هواعشاب ووجد نوعا واحدا من الأنواع المتطفلة.

ولقد أظهرت الدراسة أن هذه الأربعة عشر نوعا تتوزع بيئيا طبقا للاقلمه الطبيعية لها لطبيعة التربة النامية عليها وذلك كالتالي

- أنواع تتواجد في الكثبان الرملية والمسطحات الرملية في الجنوب:

Cornulaca monacntha, Stipagrostis scoparia, Zygophyllum album, Zygophyllum coccineum , Calligonum comosum and Cistanche phelypaea

والأخير هو النوع المتطفل والنبات العائل له هو النوع الأول

- أنواع متأقلمة علي الأرض السبخة الجافة أو الرطبة وهي:

Juncus rigidus, Phragmetis australis, Imperata cyllindrica,and Arthrocnemum macrostachyum

- أنواع لها مدي واسع من ألا قلمه علي اختلاف أنواع التربة سواء كانت تربه رمليه أو سبخه جافه أو رطبه او رمليه ذات قاع صخري وهي:

Tamarix nilotica and Nitraria retusa

- نوع واحد اكثر انتشارا وسيادة في جميع البيئات والأكثر شيوعا وتكرارا وهو:

Alhagi maurorum

- نوع واحد اكثر ندره ومتواجد في المنطقة الشرقية في الشمال في التربة الرملية ذات قاع صخري:

Atriplex coriacea