INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2006/08–2–249–255
http://www.fspublishers.org

Plant Diversity Around Springs and Wells in Five Oases of the Western Desert, Egypt

MONIER M. ABD EL-GHANI[1] AND AHMED M. FAWZY†
The Herbarium, Faculty of Science, Cairo University, Giza 12613, Egypt
†*The Herbarium, Flora and Phyto-Taxonomy Research, Horticultural Research Institute, Agricultural Research Centre, Dokki, Giza, Egypt*
[1]Corresponding author's e-mail: elghani@yahoo.com

ABSTRACT

This study was conducted to analyse the floristic composition around the wells and springs in five oases (Siwa, Bahariya, Farafra, Dakhla & Kharga) of the Western Desert of Egypt in terms of habitat and species diversity. A total 59 sites were surveyed and distributed as follows: twelve in Siwa, fifteen in Bahariya, twelve in Farafra, eight in Dakhla and twelve in Kharga Oasis. Altogether, 172 species (131 genera & 39 families) of the vascular plants were recorded from the five main distinguished habitats, viz., farmlands (H_1), canal banks (H_2), reclaimed lands (H_3), waste lands (H_4) and water bodies (H_5). The most diversified habitats with high species richness were the farmlands and the canal banks, whereas the least diversified was the water bodies. The ancient irrigation pattern in these oases were studied and described. Bahariya Oasis was the richest in species followed by Siwa, while the lowest number of species was found in Dakhla Oasis, which represents the least affected area by the anthropogenic activities. Forty-three species or 25.1% of the total recorded flora confined to a certain study area: 3 in Siwa, 29 in Bahariya, 3 in Farafra and 8 in Kharga Oasis. Species richness was strongly correlated with the type of bedrock at each oasis. Therefore, it can be concluded that the limestone desert oases (Siwa, Bahariya & Farafra) were richer in species than the sandstone desert oases (Dakhla & Kharga). Differences in species composition were visualised by means of multivariate analysis. TWINSPAN classification of the presence-absence data set of 172 species recorded in 59 sites resulted in four site groups, each of which could easily be linked to a certain study area. On a bedrock gradient basis, the first DCA axis segregated these area into two main groups.

Key Words: Flora; Species distribution; Multivariate analysis; Weeds; Oases; Egypt

INTRODUCTION

The Western Desert covers two-thirds of Egypt (about 681,000 km^2) as it extends from the Mediterranean coast to the Sudanese border for about 1073 km and from the Libyan border to the Nile Valley for about 600-850 km. Precipitation decreases from 150 mm at the coast to practically zero in the south, and southwest Egypt is known as the driest part of the globe. Well-marked drainage systems (*wadis*) comparable to those of the Eastern Desert are not found (Zahran & Willis, 1992). Another salient feature, resulting from arid conditions, is the uniformity of the surface as compared with other parts of North Africa. Though considered barren, the Western Desert supports plants in areas with enough water resources (rainfall & underground). The oases are the most prominent features of the Western Desert of Egypt. They are green patches amidst the surrounding sterile desert. Siwa, Bahariya, Farafra, Dakhla and Kharga are the five inhabited Egyptian Oases (Fig. 1), which contain the largest underground-water reservoir (Nubian Sandstone aquifer) known in the whole desert. The main source of irrigation is naturally flowing springs (some hot) or is pumped from wells. This type of irrigation, though simple, is carried out through a peculiar system of side channels specially designed to cope with insufficient supply of water. Accordingly, agriculture and vegetation in these areas are mainly groundwater-dependent (Bornkamm & Kehl, 1990). Agriculture in the oases follows the general pattern of Egyptian agriculture of summer and winter crops. Date palms (*Phoenix dactylifera* L.) and olives (*Olea europaea* L.) are the principal orchard trees and represent the greatest source of income for the oases. Due to inefficient drainage system, extensive patches of agricultural land have become more and more saline and were abandoned.

With the increased requirement of land for cultivation, reclamation of desert plains has taken place in Dakhla and Kharga Oases (New Valley Project) and also on both sides of the Nile Delta (Tahrir Project). Currently, in the southeastern part of Egypt, Toshka Project is in operation. With the completion of this project (in about 2010), the water of the Nile will be transferred from the Toshka depression (southwest of Aswan) through a long canal crossing the Oases of Kharga, Dakhla and Farafra. The technical methods of irrigation (drip, sprinkle, etc.) and farming processes have had their impact on the plant diversity of these areas.

During the last two decades, plant life of the major inhabited oases (depressions) in the Western Desert have been intensively studied: Bahariya (Abd El-Ghani, 1981), Farafra and Faiyum (Abd El-Ghani, 1985), Kharga and Dakhla (Abu-Ziada, 1980), Qara Oasis (Abd El-Ghani, 1992), Siwa Oasis (Abd El-Ghani, 1994). On the other hand, the flora and vegetation of uninhabited oases from the same desert were also of special interest, e.g., Kurkur (Boulos, 1966), Moghra (Girgis *et al.,* 1971), Nabta (El Hadidi, 1980), Bir Safsaf, El Shab, Nuwaimsa and others (Bornkamm, 1986). The vegetation is poor in species and confined to favourable habitats. In the inhabited oases, the population occupies small villages around the water resources, where agriculture is practiced. Other oases have been abandoned as their water supply has depleted. Frequently, one or more date palm (*Phoenix dactylifera* L.), trees grow near a water resource, well or spring (Aŷn in Arabic), which is clearly marked by the growth of the tall reed *Phragmites australis.*

The present study was therefore initiated with the objectives of analysing the floristic composition around the wells and springs in the five largest and inhabited oases of the Western Desert of Egypt in terms of habitat and species diversity.

The study areas. Siwa Oasis (25° 18’ - 26° 05’ E, 29° 05 - 29° 20’ N) is located in the northern part of the Western Desert, some 65 km east of the Libyan frontier and 300 km south of the Mediterranean coast. Groundwater is one of the Siwa Oasis’ most valuable resource. However, due to the misuse of groundwater, a continuous rise of the level of subsoil water is widespread. Misak *et al.* (1997), in 1962 - 1977 the rate of rise was 1.33 cm year^{-1}, while in 1977 - 1990 it measured 4.6 cm year^{-1}. Consequently, extensive patches are converted into salt marshes as the soils are subjected to deterioration and salinization. The oasis floor (deeper portion) is below sea level: ranges from zero to -18 m, and displays numerous landforms: salt marshes (*Sabkhas*), salt lakes and cultivated lands (orchards). Bahariya Oasis (27° 48’ - 28° 30’ N, 28° 35’ - 29° 10’ E) has an oval shape of ca 1800 km^2 (Fig. 1). Un-like others in the Western Desert, its floor is studded by a number of isolated conical, flat-topped hills. The water resources derived from the extensive Nubian Sandstone aquifer. The depletion of water resources and salinization of land derive towards digging new deep wells and cultivating new land. The Farafra Oasis (26° 20' - 27° 37' N, 29° E) has an irregular, triangle shape cut in a white chalk bed, and bounded by steep cliffs on three sides. Beadnell (1901) dated all the wells of Farafra Oasis to the Roman times. A large number of new deep springs are now active, and the area under cultivation is considerably increased to 3500 Feddans. Dakhla Oasis (28° 48´ - 29° 21´ E, 25° 28´ - 25° 44´ N) located about 120 km west of Kharga Oasis and about 300 km west of the Nile Valley. The lowest point of the oasis is about 100 m above sea level. Formerly, the total area of water discharge cultivated lands was about 75,000 Feddans. Due to land salinization, the area under cultivation is severely decreased to 25,000 Feddans. Kharga Oasis (24° 30’ - 26° N, 30° 07’ - 30° 47’ E) is one of the main oases of the Nubian Desert of Egypt (El Hadidi, 2000), with a total area of about 7200 km^2. Mobile sand dunes, usually of the Barchan type, are of frequent occurrence. Their movement (10 – 20 m year^{-1}) across the floor burries cultivated land, wells, roads, buildings, etc. Cultivation dependent almost entirely on water from artesian old wells (more than 350), dating back to Pharaonic or Roman times. Recently, the Desert Reclamation Regime has drilled a number of extra deep wells (250 – 850 m) that are more efficient and have a bigger discharge. As a result, most of the old wells have been neglected either because of the decrease in their through their overwhelming by drifted sand, or through the decrease in the artesian pressure, which could no longer rise the water to the surface (Himida, 1966).

Climatically the study areas can be classified as arid and hyperarid (Ayyad & Ghabbour, 1986). A hyperarid province with mild winters (10 - 20ºC) and very hot summer (> 30ºC) and includes the south western part of the Western Desert, where Farafra, Dakhla and Kharga Oases are situated. The hyperarid province with mild winter and hot summer (20 - 30ºC), covering the Eastern Desert and the northeastern part of the Western Desert where the Nile Valley up to Qena and the Oases of Siwa and Bahariya are located. Available records of some meteorological data for the studied oases are shown in Table I.

MATERIALS AND METHODS

Field data on the floristic composition was gathered throughout intensive field work during 1978 - 1998, and 2002 - 2004. A total of 59 sites were surveyed, using a stratified sampling method (Müller-Dombois & Ellenberg, 1974). These sites were distributed as follows: twelve in Siwa, fifteen in Bahariya, twelve in Farafra, eight in Dakhla and twelve in Kharga Oasis (Fig. 1). The number of sites in each study area varied according to its agricultural potentialities, and to ensure that all recognised habitats were represented several sampling plots were used from each site. The size of the sample plot varied from one site to another, depending on the total cultivated area, variability in both croplands and habitats. Presence or absence of each species at the sites was monitored, and their frequency was estimated.

Species richness (α-diversity) was calculated as the average number of species per site in that area. Species turnover (β-diversity) was calculated using I-Jaccard’s index of similarity since it provides a way to measure the species turnover between different areas (Magurran, 1988). Fifty % turnover of species composition, termed half change, has been used as the unit of beta diversity (Whittaker, 1960). SPSS version 10.0 for windows was used for all statistical treatments.

Based on a binary presence-absence of species and sites, Two-Way Indicator Species Analysis (TWINSPAN; Hill, 1979) was used for classification. To assure the robustness of the resultant classification, we devised a cluster analysis using Multivariate Statistical Package MVSP for Windows, version 3.1 (Kovach, 1999). Minimum variance as agglomeration criterion (Orloci, 1978) was applied to squared Euclidean distance dissimilarity matrix. This produced nearly identical results to the TWINSPAN analysis. Detrended Correspondence Analysis (DCA), an indirect gradient analysis technique, which plots sites against axes based on species composition and abundance (Ter Braak, 1994) was employed using CANOCO software version 3.12 (Ter Braak, 1987 - 1992). Sites that were more similar in vegetation structure (species composition & abundance) were depicted as being closer together in the diagram. Preliminary analyses were made by applying the default option of the Detrended Correspondence Analysis (DCA) in the CANOCO program, to check the magnitude of change in species composition along the first ordination axis (i.e., gradient length in standard deviation (SD) units). Nomenclature follows Täckholm (1974), Cope and Hosni (1991), Boulos (1995, 1999 - 2002) and El Hadidi and Fayed (1994-95).

RESULTS AND DISCUSSION

Species richness and taxonomic composition. 172 species, 131 genera and 39 families of the vascular plants were recorded in the five surveyed oases. This represents approximately 51% of the total reported flora of the Egyptian oases (Abd El-Ghani, un-published results). Though floristic similarities prevail among these oases (Table II), the floristic composition showed perceptible variations within each area.

Species diversity was un-evenly distributed among taxonomic groups (Fig. 2). Gramineae, Leguminosae, Compositae, Cyperaceae and Chenopodiaceae dominated the flora, and together they comprised more than 50% of the total species diversity. These families represent the most common in the Mediterranean North African flora (Quézel, 1978). Other families were conspicuously less diverse and there were 25 families with a single species. There were a suite of species rich genera, but the majority (101 or 77.1%) of the 131 recorded genera were represented by a single species. Large genera included: *Euphorbia* (5 species), *Cyperus* (4 species), *Avena, Chenopodium, Cuscuta, Medicago, Juncus* and *Tamarix* (3 for each). Such un-equal distribution of species richness among genera was also found in the Feiran Oasis of south Sinai (Abd El-Ghani & Fahmy, 1998) and in Al-Hassa Oasis of eastern Saudi Arabia (Shaltout & El-Halawany, 1993).

Therophytes were the predominant life form and constituted 57% of the total flora, followed by hemicryptophtes (12%), phanerophytes (9%), chamaephytes and geophytes (6% for each). This pattern of life-form spectrum displays a strong resemblance to that given by Abd El-Ghani and Fahmy (1998) in the Feiran Oasis, south Sinai (Egypt), and also by Olsvig-Whittaker *et al.* (1983) in a Negev Desert watershed at Sede Boqer, Israel. Such finding seems to be the response to a more hot and dry climate, topographic variation, human and animal interference and short-time variation of water availability.

Table I. Climatic characteristics averages 1931-78; after Zahran and Willis (1992). Min = Minimum, Max = Maximum

Stations	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
	Min	Max	Min	Max	
Siwa	4	38	42	61	10
Bahariya	4	37	35	51	3
Kharga	6	39	21	46	1

Table II. Sørensen coefficients of floristic similarity (lower half), and the beta diversity (upper half) between the cropland ecosystems in study areas. S = Siwa Oasis, B=Bahariya Oasis, Fr = Farafra Oasis, D = Dakhla Oasis and K = Kharga Oasis. * = *p*<0.05, ** = *p*< 0.01

	S	B	Fr	D	K
S		0.3	0.4	0.3	0.3
B	0.4*		0.3	0.2	0.2
Fr	0.6**	0.5**		0.3	0.3
D	0.4*	0.3*	0.5**		0.5
K	0.4*	0.3*	0.5**	0.7**	
Species richness	79	143	65	18	77

Table III. Sørensen's coefficients of floristic similarity (lower half), together with their beta-diversity (upper half) between the five habitats. ** p<0.001, * p<0.05. For habitat abbreviations H_1-H_5, see text

	H_1	H_2	H_3	H_4	H_5
H_1		0.47	0.41	0.39	0.06
H_2	0.46**		0.37	0.57	0.02
H_3	0.07	0.09		0.25	0.01
H_4	-0.26 *	0.23**	-0.04		0.05
H_5	-0.03	-0.10	-0.06	0.01	
Species richness	143	101	42	87	14

Variation in species richness and β-diversity among the oases. Species richness differed considerably among the five oases (Table II). Bahariya Oasis was the richest in species (143), followed by Siwa (79) even if it is below the sea level. The lowest number of species was found in Dakhla Oasis (18), which represents the least affected oasis by the anthropogenic activities. The long history of agriculture and land use in Bahariya Oasis may contribute to its high species richness. Species richness strongly correlated with the type of bedrock at each oasis (Spearman rank correlation coefficient r = 0.838, p = 0.001). Thus, it may be concluded that the limestone desert oases (Siwa, Bahariya & Farafra) were richer in species than the sandstone desert oases (Dakhla & Kharga).

It was also found that certain species attain their highest ecological and sociological performance in a particular habitat, which referred here to their preferential habitat. In general, five main habitats were distinguished; their preferential species was provided in Table IV, and characteristic features will be outlined below. The farmlands (H_1), are represented by arable land that includes field crops and orchards. They exhibit the typical ancient pattern of agriculture, where usually a 3 -yr crop rotation is applied. Alfa-alfa (*Medicago sativa* L.) is the principal perennial fodder crop that cultivated in the oases. This habitat

Table IV. Habitat preferences of the common species (>50% occurrences) recorded from different oases. Symbols of habitat types: H_1 = farmlands (include irrigated crop-fields and orchards), H_2 = canal banks, H_3 = reclaimed lands, H_4 = waste lands (moist land and abandoned salinized field plots) and H_5 = water bodies

H_1	H_2	H_3	H_4	H_5
Ambrosia maritima	*Centaurium pulchellum*	*Asphodelus tenuifolius*	*Aeluropus lagopoides*	*Lemna gibba*
Avena fatua	*Chenopodium ambrosioides*	*Bassia muricata*	*Alhagi graecorum*	*Ludwigia stolonifera*
Beta vulgaris	*Conyza bonariensis*	*Launaea capitata*	*Bassia indica*	*Ottelia alismoides*
Brachypodium distachyum	*Desmostachya bipinnata*	*Launaea nudicaulis*	*Carex divisa*	*Zannichellia palustris*
Brassica nigra	*Eclipta prostrata*	*Parapholis incurva*	*Cressa cretica*	
Calendula arvensis	*Pseudognaphalium luteoalbum*	*Polygonum equisetiforme*	*Cynanchum acutum*	
Centaurea calcitrapa	*Heliotropium lasiocarpum*	*Prosopis farcta*	*Cyperus laevigatus*	
Corchorus olitorius	*Imperata cylindrica*	*Pulicaria crispa*		
Digitaria sanguinalis	*Mentha longifolia*	*Thesium humile*	*Eleocharis palustris*	
Echinochloa colona	*Oxalis corniculata*		*Juncus hybridus*	
Emex spinosa	*Panicum repens*		*Pycreus polystachyos*	
Euphorbia peplus	*Phragmites australis*		*Scirpus maritimus*	
Lolium perenne	*Phyla nodiflora*		*Spergularia marina*	
Senecio glaucus	*Samolus valerandi*		*Tamarix nilotica*	
Stellaria media	*Sonchus maritimus*			
Trifolium resupinatum	*Veronica anagallis-aquatica*			

occupies the lower levels of the cultivated land, where the underground water is available. Orchards occupy higher levels, and surround the field areas. Canal banks (H_2) vary considerably in their length from one site to the other according to the cultivated area they irrigate. Most of the irrigation canals in the oases are lined with concrete from the terrace to the canal bed; this reduces the growth of plants along their sides. Layering of plant species in this habitat is conspicuous. Reclaimed lands (H_3) cover vast areas of the desert that have been reclaimed, and are under cultivation. Whereas the modern irrigation techniques (such as drip, sprinkle & pivot) were used in the newly reclaimed areas, the inundation type is still used. As this habitat occupies the desert boundaries of the inhabited areas and farmlands, a number of desert plants spread to the arable lands. The waste lands (H_4), occupy areas that were previously productive farmlands but left fallow, and neglected. These include deserted soil areas with dried-up remains of crop plants, sand-filled irrigation canals and traces of previous habitations. The salt-affected areas (not salt marshes) that found either adjacent to the farmlands or around the irrigation canals may be saturated with drainage water including a high amount (2 to 6%) of soluble matter (Zahran, 1972). The water bodies (H_5), include the fresh water streams, irrigation canals, water holes and basins. In certain instances they are devoid of vegetation, while in others an extensive growth of water plants such as *Ottelia alismoides, Zannichellia palustris* and *Lemna gibba* may occur.

A considerable spatial pattern of β-diversity around wells and springs in the 5 studied oases was significantly correlated with the number of sites surveyed at each area ($r = 0.69$, $p = 0.001$), whereas its correlation with other variables (i.e., site bedrock, area, elevation) was weak and not significant ($p > 0.05$). On the other hand, Sørensen's coefficients of floristic similarity between the five habitats were generally low (Table III). Among the significant positive relations were those between the farmlands (H_1) and the canal banks (H_2). They were the more diversified habitats with high species richness. Clearly, the floristic composition of these two habitats was closely related and characterised by the occurrence of many species in common. This may be due to the fact that water of irrigation canals may seep the canal borders and hence increase the soil moisture availability. Not only the reclaimed lands (H_3) and the water bodies (H_5) have the lowest similarities with other ones, but also they were the least diversified habitats. The presence of a highly dominant species in a community results in a general suppression of the less competitive species and hence a decrease in the diversity of that community (Mohler & Liebman, 1987). In the present study, the low alpha diversity and species turnover of water bodies habitat (H_5) may be related to the fact that most of their species were highly specific to the aquatic habitats. This means that the species replacement or biotic change is low in this habitat (Wilson & Shmida, 1984). The high disturbance of its substrate (e.g. cleaning practices & fluctuations of the water velocity) may also explain its low diversity (Grime, 1973; Nilsson *et al.,* 1991). This result coincides with that obtained in AL-Hassa Oasis of eastern Saudi Arabia (Shaltout & El-Halawany, 1993).

Species distribution. The diversity and species distribution in the agro-ecosystem of the Egyptian oases was distinguished from those in the River Nile land (Abd El-Ghani & El-Sawaf, 2004). Climate, particularly temperature and length of dry season, rather than precipitation were important factors in the distribution of species. Batanouny *et al.* (1988) showed the great variability in the distribution of the different photosynthetic types along a geographical gradient from north to the south of the country. They concluded that the oases and the Nile Valley, with high summer temperature, have a relatively high percentages (62 & 63%, respectively) of C_4 grasses, while the Nile Delta and Faiyum region, with mild temperature, have a lower percentage of C_4 grasses (59 & 51%, respectively). In this study, none of the 172 species had been recorded in all the 59 studied sites. However, six species, viz., *Cynodon dactylon, Echinochloa colona, Imperata cylindrica, Juncus*

Table V. Presence estimates of those species (P >10%) confined to a certain oasis. S = Siwa, B = Bahariya, F = Farafra, K = Kharga and D = Dakhla Oases

Species	S	B	F	K	D
Cuscuta pedicellata Ledeb.	25				
Cynanchum acutum L.	50				
Stellaria pallida (Dumort.) Piré	75				
Adiantum capillus-veneris L.		80			
Ammannia auriculata Willd.		33			
Ammannia baccifera L.		27			
Apium nodiflorum (L.) Lag.		87			
Berula erecta (Huds.) Coville		60			
Centaurea calcitrapa L.		100			
Ceratophyllum demersum L.		100			
Cuscuta planiflora Ten.		67			
Cyperus alopecuroides Rottb.		53			
Eichhornia crassipes (C. Mart.) Solms		20			
Eleocharis geniculata (L.) Roem. & Schul.		20			
Eleocharis palustris (L.) Roem. & Schul.		20			
Epilobium hirsutum L.		27			
Equisetum ramosissimum Desf.		13			
Euphorbia arguta Banks & Sol.		33			
Inula crithmoides L.		100			
Juncus fontanesii J. Gay		40			
Juncus hybridus Brot.		13			
Lemna gibba L.		100			
Marsilea minuta L.		13			
Paspalum distichum L.		40			
Persicaria lapathifolia (L.) Gray		67			
Ranunculus sceleratus L.		13			
Schenoplectus senegalensis (Hochst ex Steud.) Palla		40			
Scirpus maritimus L.		33			
Silybum marianum (L.) Gaertn.		27			
Sonchus maritimus L.		60			
Spirodela polyrhiza (L.) Schleiden		33			
Vicia sativa L.		47			
Brachypodium distachyum (L.) P. Beauv.			33		
Ceratonia siliqua L.			25		
Euphorbia forsskaolii J. Gay			33		
Bassia muricata (L.) Asch.				33	
Doellia bovei (DC.) Anderb.				42	
Launaea fragilis (Asso) Pau				17	
Rhynchosia minima (L.) DC.				17	
Saccharum spontaneum L.				17	
Sporobolus spicatus (Vahl) Kunth				67	
Stipagrostis scoparia (Trin. & Rupr.) de Winter				50	
Suaeda aegyptiaca (Hasselq.) Zohary				25	
Cynodon dactylon (L.) Pers.	66	27	50	100	13
Echinochloa colona (L.) Link	33	7	33	42	13
Imperata cylindrica (L.) Raeusch.	83	47	33	100	25
Juncus rigidus Desf.	66	67	17	75	25
Phragmites australis (Cav.) Trin. ex Steud.	92	93	25	83	63
Tamarix nilotica (Ehrenb.) Bunge	42	67	33	100	63

rigidus, Phragmites australis and *Tamarix nilotica* showed the highest species occurrences and have a wide ecological and sociological range of distribution as they had been recorded in the five oases. Forty-three species or 25.1% of the total recorded species demonstrated a certain degree of consistency, where they exclusively recorded in or confined to a certain study area. These species were distributed as follows: 3 in Siwa, 29 in Bahariya, 3 in Farafra and 8 in Kharga Oasis (Table V).

Interestingly, *Equisetum ramosissimum* and *Marsilea minuta* were two ferns known from certain wells in Bahariya Oasis and not elsewhere in the others oases. Their very special habitat along water channels may contribute to their very limited range of distribution. *Sphenoclea zeylanica*, indigenous to the tropics of the Old World, is of recent introduction to Egypt. Its presence may be due to anthropogenic origin, probably with rice grains introduced for cultivation (Abd El-Ghani, 1988). The plant was recorded from rice cultivation in Bahariya Oasis, where it seems to reach its northern limit of distribution in the continent. *Populus euphratica*, a threatened tree not known outside Siwa Oasis. It grows on the sand dunes that surround certain wells at the western stretches of Siwa Oasis. More studies should be paid to this plant. According to Zahran (1972), *P. euphratica* had been introduced to Siwa Oasis to fix the sand dunes during the Alexander the Great Period.

Our results proved the disappearance of some species from the flora of Egyptian oases. For this purpose, several literature were searched, in addition to our surveys for those species whose occurrences were previously very common. The water lily, *Nymphaea caerulea* var. *aschersoniana* is

Fig. 1. Location map of the five studied oases

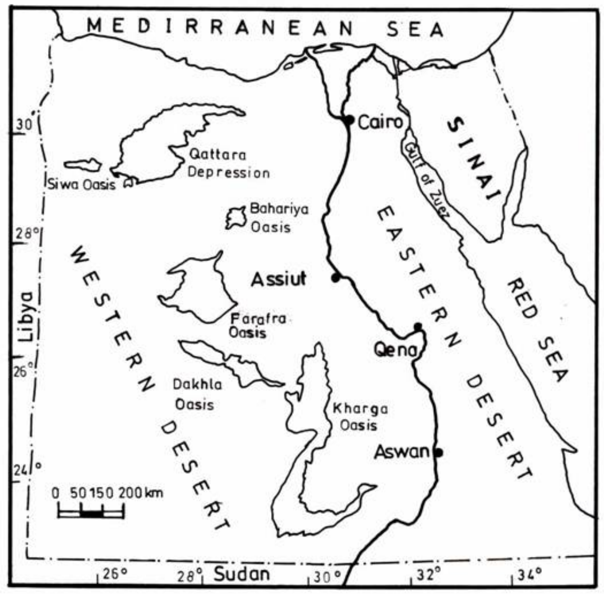
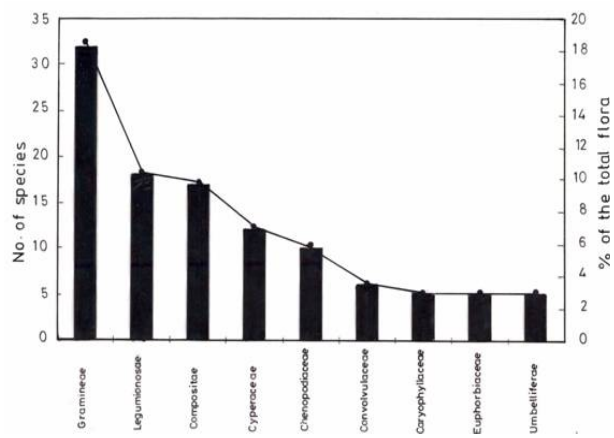


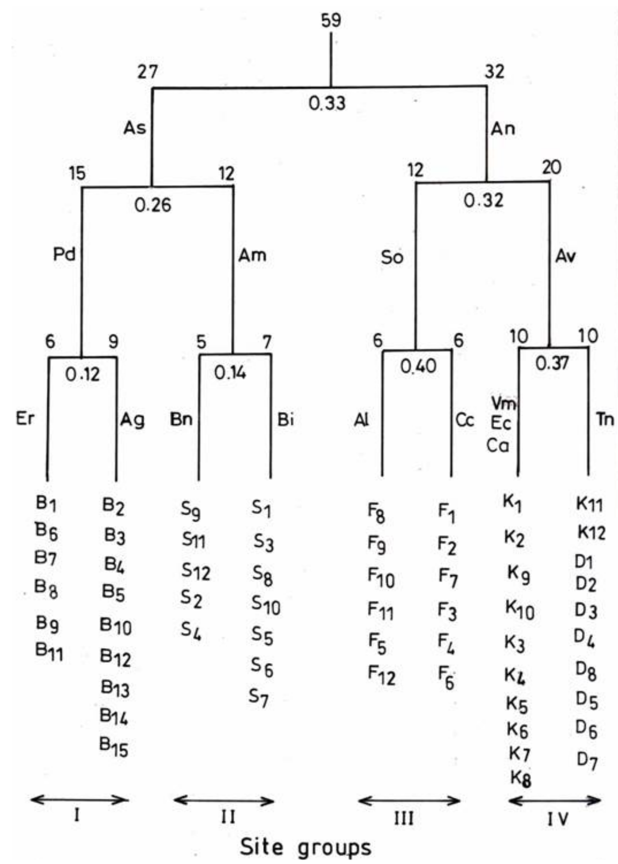
Fig. 2. Relationship between the total number and percentage of plant species in the largest families



known to be endemic to Bahariya Oasis (Ascherson & Schweinfurth, 1887). Collection of the plant during numerous visits made to its type locality and many others, was not possible. It is un-fortunate that this interesting variety is considered as extinct (Abd El-Ghani, 1981). Continuous cleaning and uprooting of the plant from the springs and water channels to get more water for irrigation might be the main reason for its extinction. Similar comment can be made to *Ranunculus rionii*, which can also be considered extinct from the Oases of Egypt. Few populations, or sometimes individuals, of *Gossypium arboretum*, *Rostraria rohlfsii* and *Stipagrostis vulnerans*, recorded in their characteristic habitats may be considered as endangered species. In this context, *Schmidtia pappophoroides, Dianthus cyri, Diplotaxis harra, Ammoides pusilla, Ducrosia ismaelis* and *Melilotus serratifolius,* were of common occurrence but now are occasionally found in the oases. Human activities such as establishment of new settlements, road construction, digging of new wells, land reclamation, new farming processes and overgrazing are among the main reasons of threat. *Ambrosia maritima* and *Aster squamatus* were found to dominate the habitats in the farmland ecosystem of the Egyptian Oases. They grow very rapidly to form dense populations, especially in the orchards habitat that characterized by its shade, cool and humid environment. latter species was recently introduced into Egypt, now completely naturalised and is one of the most common invasive species in the country ((Boulos & el-Hadidi, 1984). Further studies on the environmental correlates of species distribution in these areas are recommended.

Classification and ordination of sites. TWINSPAN classification of the presence-absence data set of 172 species recorded in 59 sites resulted in four site groups (I-IV; Fig. 3), each of which could easily be linked to a certain oasis. At the first hierarchical level, site groups from Bahariya and Siwa Oases (n = 27), were clearly separated from those in the other oases (n = 32). At the left side of the dendrogram, the site groups of Bahariya (I) and Siwa (II) are clearly separated with their indicator species *Aster squamatus, Ambrosia maritima, Paspalum distichum, Alhagi graecorum, Bassia indica* and *Brassica nigra*. The right side of the diagram represents the oases site groups of Farafra (III), and Dakhla and Kharga (IV). *Acacia nilotica, Avena fatua, Sonchus oleraceus, Tamarix nilotica, Echinochloa colona* and *Calendula arvensis* were the indicator species. The latter group (IV) can be inferred to as Dakhla-Kharga complex group, where they have the same origin, and their physiographic features showed high similarity. Floristically, our study confirms the separation of the northern oases (Siwa & Bahariya) from those in the southern (Farafra, Dakhla & Kharga). This separation is also coincides, partly, with the phytogeographical territories that proposed by El Hadidi (2000) for the Western Desert, who included Siwa, Bahariya and Farafra in the Libyan (limestone or white) Desert and the other oases (Dakhla & Kharga) in the Nubian

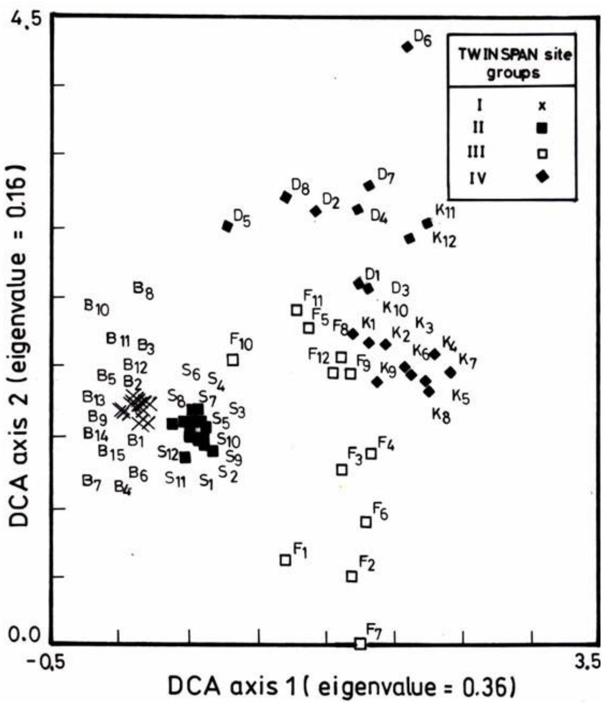
Fig. 3. Floristic classification dendrogram generated by TWINSPAN resulting in four site groups (I-IV), As= *Aster squamatus* (Spreng.) Hieron., An= *Acacia nilotica* (L.) Delile , Pd = *Paspalum distichum* L., Am= *Ambrosia maritima* L., So= *Sonchus oleraceus* L., Av = *Avena fatua* L., Er= *Eichhornia crassipes* (C. Mart.) Solms, Ag= *Alhagi graecorum* Boiss., Bn= *Brassica nigra* (L.) Koch , Bi= *Bassia indica* (Wight) A.J. Scott., Al= *Aleuropus lagopoides* (L.) Trin. ex Thwaites, Cc= *Ceratonia siliqua* L. ,Vm= *Vicia monantha* Retz., Ec= *Echinochloa colona* (L.) Link , Ca= *Calendula arvensis* L., and Tn= *Tamarix nilotica* (Ehrenb.) Bunge.



(sandstone) Desert. Nevertheless, Farafra Oasis seems to be situated at the border between the two deserts.

Fig. 4 shows the ordination results of the DCA analysis of the floristic data set. The 59 site scores were plotted along axes 1 (eigenvalue = 0.36) and 2 (eigenvalue = 0.16), and tend to cluster into four groups (I-IV) that resulted from TWINSPAN analysis. The sites were spread out 4.5 SD units along the first axis, expressing the floristic variation among vegetation groups, and indicating a complete turnover in species composition took place (Hill, 1979). The first and second axes accounted for 13.5% and 5.8%, respectively of the overall floristic variance. This low percentage of variance explained by the axes is attributed to the many zero values in the vegetation data set. Bahariya and Siwa Oases site groups I and II were separated toward the negative end of DCA axis 1, while those of the other oases (groups III & IV) were separated out along the other end.

Fig. 4. DCA ordination of 59 sites on axes 1 and 2 as classified by TWINSPAN



REFERENCES

Abd El-Ghani, M.M., 1981. Preliminary studies on the vegetation of Bahariya Oasis, Egypt. *M.Sc. Thesis*, Cairo University, Cairo, Egypt

Abd El-Ghani, M.M., 1985. Comparative study of the vegetation of Bahariya and Farafra Oases and the Faiyum region, Egypt. *Ph.D. Thesis*, Cairo University, Cairo Egypt

Abd El-Ghani, M.M., 1988. Sphenocleaceae. *In*: El Hadidi, M.N. (ed.), *Flora of Egypt, Taeckholmia add. ser*., 3: 63–8

Abd El-Ghani, M.M., 1992. Flora and vegetation of Qara Oasis, Egypt. *Phytocoenologia,* 21: 1–14

Abd El-Ghani, M.M., 1994. Weed plant communities of orchards in Siwa Oasis. *Feddes Repert.,* 105: 387–98

Abd El-Ghani, M.M. and A.G. Fahmy, 1998. Composition of and changes in the spontaneous flora of Feiran Oasis, S. Sinai, Egypt, in the last 60 years. *Willdenowia*, 28: 123–34

Abd El-Ghani, M.M. and N. El-Sawaf, 2004. Diversity and distribution of plant species in the agro-ecosystem of Egypt. *Syst. Geogr. Pl.*, 74: 319–36

Abu-Ziada, M.A., 1980. Ecological studies on the flora of Kharga and Dakhla Oases of the western desert of Egypt. *Ph.D. Thesis*, P. 342. Mansoura University, Egypt

Ascherson, P. and G. Schweinfurth, 1887. Illustration de la flore d'Egypte. *Mém. Inst. Egypte*, 2: 25–260

Ayyad, M.A. and S.I. Ghabbour, 1986. Hot deserts of Egypt and the Sudan. *In*: Evenari, M., L. Noy-Meir and D.W. Goodall, (eds.), *Ecosystems of the World 12B, Hot Deserts and Arid Shrublands*, pp: 149–202. Amsterdam, Elsevier

Batanouny, K.H., W. Stichler and H. Ziegler, 1988. Photosynthetic pathways, distribution and ecological characteristics of grass species in Egypt. *Oecologia*, 75: 539–48

Beadnell, H.J.L., 1901. *Farafra Oasis*: Its Topography and Geology. Geologic Survey Report, III (1899), Cairo

Bornkamm, R., 1986. Flora and vegetation of some small oases in S-Egypt. *Phytocoenologia*, 14: 275–84

Bornkamm, R. and H. Kehl, 1990. The plant communities of the western desert of Egypt. *Phytocoenologia*, 19: 149–231

Boulos, L., 1966. A natural history study of Kurkur Oasis, Libyan Desert, Egypt. IV. The vegetation. *Postilla*, 100: 1–22

Boulos, L., 1995. *Flora of Egypt.* Check list. Al Hadara Publishing, Cairo, Egypt

Boulos, L., 1999-2002. *Flora of Egypt*. Vols, 1–3. Al Hadara Publishing, Cairo, Egypt

Boulos, L. and M.N. el-Hadidi, 1984. *The Weed Flora of Egypt.* The American University in Cairo Press, Cairo, Egypt

Cope, T.A. and H.A. Hosni, 1991. *A Key to Egyptian Grasses*. Royal Botanic Gardens Kew London, UK

El Hadidi, M.N., 1980. An outline of the planned flora of Egypt. *Taeckholmia Additional Series*, 1: 1–12

El Hadidi, M.N., 2000. *Flora Aegyptiaca*. Vol. 1. Palm press, Cairo, Egypt

El Hadidi, M.N. and A.A. Fayed, 1994/95. Materials for Excursion Flora of Egypt (EFE). *Taeckholmia,* 15: 233

Girgis, W.A., M.A. Zahran, K. Reda and H. Shams, 1971. Ecological notes on Moghra Oasis, Western Desert, Egypt. *A.R.E., J. Bot.*, 14: 147–55

Grime, J.P., 1973. Competitive exclusion in herbaceous vegetation. *Nature,* 242: 344–7

Hill, M.O., 1979. *TWINSPAN* - A Fortran program for arranging multivariate data in an ordered two-way table of classification of individuals and attributes. Ithaca, NY, Cornell University

Himida, I.H., 1966. A quantitative study of artesian water exploitation resources in Kharga and Dakhla Oases, Western Desert, Egypt. *Bull. Inst. Désert d'Egypte*, 16: 31–57

Kovach, W.L., 1999. *A Multivariate Statistical Package for Windows*, version 3.1. Users' Manual. Kovach Computing Services, Pentraeth, Wales, UK

Magurran, A.E., 1988. *Ecological Diversity and its Measurements*. Princeton University Press. Princeton, New Jersey, USA

Misak, R.F., A.A. Abdel Baki and M.S. El-Hakim, 1997. On the causes and control of the waterlogging phenomenon, Siwa Oasis, northern Western Desert, Egypt. *J. Arid Environ.,* 37: 23–32

Mohler, C.L. and M. Liebman, 1987. Weed productivity and competition in sole crops and intercrops of barley and field pea. *J. Appl. Ecol.*, 24: 685–99

Müller-Dombois, D. and H. Ellenberg, 1974. *Aims and Methods of Vegetation Ecology*. Wiley, New York, USA

Nilsson, C., A. Ekblad, M. Gradfjell and B. Carlberg, 1991. Long-term effects of river regulation on river margin vegetation. *J. Appl. Ecol.*, 28: 963–76

Olsvig-Whittaker, L., M. Schachak and A. Yair, 1983. Vegetation patterns related to environmental factors in a Negev Desert watershed. *Vegetatio*, 54: 153–65

Orloci, L., 1978. *Multivariate Analysis in Vegetation Research*. Junk, Den Haag. The Netherlands

Quézel, P., 1978. Analysis of the flora of Mediterranean and Saharan Africa. *Ann. Miss. Bot. Gard.*, 65: 479–534

Shaltout, K.H. and E.F. El-Halawany, 1993. Vegetation analysis of the irrigation and drainage canals in eastern Saudi Arabia. *J. Univ. Kuwait (Sci.),* 20: 261–73

Täckholm, V., 1974. *Students´ Flora of Egypt.* (2nd edn.). Cairo University & Cooperative Printing Company, Beirut

Ter Braak, C.J.F., 1987-1992. *CANOCO - A FORTRAN program for Canonical Community Ordination.* Microcomputer Power, Ithaca, NY

Ter Braak, C.J.F., 1994. Canonical community ordination. Part 1. Basic theory and linear methods. *Ecoscience,* 1: 127–40

Whittaker, R.H., 1960. Vegetation of the Siskiyon Mountains, Oregon and California. *Ecol. Monogr.,* 30: 279–338

Wilson, M.Y. and A. Shmida, 1984. Measuring beta diversity with presence absence data. *J. Ecol.*, 72: 1055–64

Zahran, M.A., 1972. On the ecology of Siwa Oasis, Egypt. *Egypt. J. Bot.*, 15: 223–42

Zahran, M.A. and A.J. Willis, 1992. *The Vegetation of Egypt*. Chapman and Hall, London, UK

(Received 15 November 2005; Accepted 12 February 2006)