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Distribution of Flowering Plants and Cyanobacteria in Relation to Soil Characters in Bahariya Oasis, Egypt

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Abstract: Baharia Oasis in one of the famous Oasses in western desert of Egypt. This study dealt with the distribution of flowering plants and cyanobacteria in the Oasis in relation to each other and to physicochemical characters of soil. Fifty six species of flowering plants and 29 cyanobacterial species were identified in seven different habitats. The data revealed that the flowering plants and algal taxa were controlled by the edaphic factors and physico-chemical characters of the soil. In the present study, both positive and negative correlations between flowering plants and cyanobacterial taxa were obtained confirming the controversial effect of cyanobacterial crust on vascular plants.

Key words: Bahariya Oasis, Western-Desert, correlation, flowering plants, cyanobacteria

INTRODUCTION

The Western desert forms the major part (about 65%) of Egyptian area and the oases are the most prominent features of the region. Bahariya Oasis is located in the heart of the Western desert between latitudes 27° 48' and 28° 30' N and longitudes 28° 32' and 29° 10' E, about 370 km Southwest of Cairo (Fig. 1). The main sources of irrigation are naturally flowing springs and from wells. This type of irrigation 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 and Kehl, 1990). Date palm, Olive, Barely and Lucerne are the main cultivated crops. Like most Oases Bahariya Oasis is characterized by the presence of inland salt marshes. The presence of these salt marshes could be due to the exposure of the underground water, forming lakes of brackish or saline water (Zahran and Girgis, 1970; Zahran, 1972) and the uncontrolled spilling of water and flooding of the plains down to the water table, which is close to the ground (Migahid *et al*., 1960). El-Hadidi (1993) described the salt marsh vegetation with different patches containing different species (or sometimes one species) and sometimes different growth forms.

Studies involving cyanobacteria flora of desert environment has led to an enriched source of microflora that has led to the formation of ecological, physiological and taxonomical information (Hawkes and Flechtner, 2002). Although some investigations have been executed intensify on desert algal flora of different geographical territories in Egypt. Cyanobacterial flora in relation to the distribution of flowering plants inhabiting Bahariya Oasis have not investigated (except, Kobbia and Shabana, 1988) has been carried out. In desert soils, cyanobacteria form the most abundant group of microorganisms (Cameron, 1966) they cover the surface of dry and sandy soil regulates its moisture, provides shelter for seed plants (Fritsch, 1907) and prevents soil erosion (Booth, 1941). Cyanobacteria also contribute significantly to total nitrogen in arid soils after death. Furthermore, the mucilage materials produced by them and act as a binding agent for soil particles, which results in improving the soil texture and increasing the humus content, making it more hospitable for other plants after some years (Apte and Thomas, 1997). For these reasons; making cyanobacteria are important in matured soil (Metting, 1981) and considered as factors in stabilizing and improving the physical and chemical properties of soils (Starks *et al*., 1981; Ibraheem, 2007) they can also be used as indicators of environmental chemistry (Whitton *et al*., 1988). Some researchers highlight the positive effects of biological crusts on germination of vascular plant species in different ecosystems (Eldridge, 1993; Harper and Pendleton, 1993; Marble and Harper, 1989; St. Clair *et al*., 1984). On the other hand negative correlations between the cover of vascular plant species and biological crust have been detected in different crust types, as well as in germination experiments in controlled environments (Eldridge *et al*., 2000; Jeschke and Kiehl, 2008; Keizer *et al*., 1985; Prasse and Bornkamm, 2000; Sedia and Ehrenfeld, 2003; Serpe *et al*., 2006; Van Tooren, 1990).

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The present investigation is an attempt to monitor the floristic composition of the flowering plants and cyanobacterial taxa in relation to soil physicochemical properties and to each other at the investigated study sites of Bahariya Oasis.

MATERIALS AND METHODS

Study area: Bahariya Oasis is located in the heart of the Western desert between latitudes 27° 48' and 28° 30' N and longitudes 28° 32' and 29° 10' E, about 370 km Southwest of Cairo (Fig. 1).

Floristic composition: Field data on the floristic composition (flowering plants and cyanobacteria) was gathered through intensive and extensive field work during March 2006. Seven main habitats were distinguished. These are palm orchard (H_1), olive orchard (H_2), cultivated lands (H_3), salt affected land (H_4), saline habitat (H_5), new reclaimed lands (H_6), found in vast areas around the oasis and canal bank habitat (H_7). A list of species found in an area can often provide interesting information, particularly if the list includes species which were poor colonists of disturbed areas. Seventy homogeneous stands (10×10 m), were selected to cover the different floristic composition, 10 stands for each habitat, were selected. The homogeneity was judged by the general physiognomy of the vegetation and the physiography of the sites. Plant nomenclature was done according to Taeckholm (1974) and was updated following Boulos (1995).

Isolation and culturing of algae: Soil samples were taken by cores (5 cm diameter) from subsurface soil up to 5 cm around the roots of the most common plant species. Cores of all materials were placed in pre-sterilized plastic bags and returned to the laboratory where 2.5 g aliquot of each wet sample was subsequently blended in 20 mL distilled water for identification of the live cells. For the algal culturing, a method recommended by Jurgensen and Davey (1968) was applied. One gram of each soil sample was placed in 99 mL of sterile water and then placed in a shaker for 15 min, species numbers were counted per 100 g soil. Five replicate Petri-dishes were inoculated each with 1 mL of the appropriate dilution and 25 mL of nutrient agar medium (at 45°C) were added. Myers' C medium incubated at 35±1°C was used for isolation of blue-green algae. For nitrogen-fixing species, Allen's free-nitrogen media (Allen and Stanier, 1968) was applied. All were inoculated on a 16/8 h light/dark cycle with a light intensity of 3500-4500 Luxmeter. The cyanobacterial taxa were identified according to Desikachary (1959).

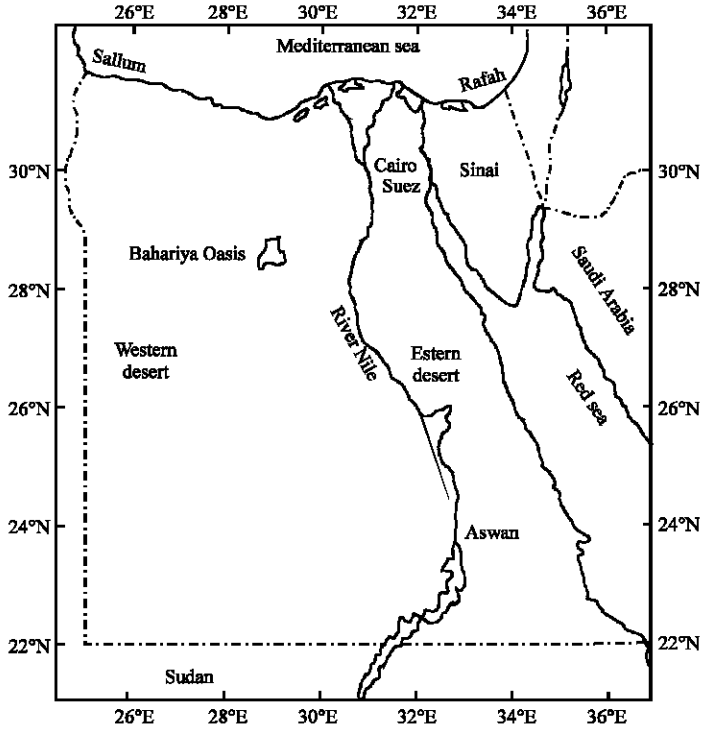

Fig. 1: Location map of Bahariya Oasis, after the Egyptian serving administration

Soil sampling and analysis: Three soil samples (0-20 cm depth) were collected from each stand and were mixed together to form one composite effect of sample. All samples were air dried and sieved through a 2 mm sieve to get rid of debris and coarse gravel. These samples were analyzed for determination of soil texture, with the hydrometer method (Jackson, 1967), providing quantitative data on the percentage of sand, silt and clay. Soil-water extract (1: 5) was prepared for the estimation of total soluble salts (TSS in mS cm^{-1}) using a conductivity meter and of soil reaction, using a pH meter. The concentration of the minerals (Na^+, K^+, Ca^{2+}, Fe^{3+} and Mg^{2+}) were determined by using atomic absorption spectrophotometer, Perkin 403 (Jackson, 1967).

Statistical analysis: Pearson's correlation coefficients were used to evaluate the relationships of flowering plants and cyanobacteria to each other and to soil physicochemical characters, using SPSS statistic programme.

RESULTS

Table 1 shows that 56 species belong to 23 families of the flowering plants were recorded in the seven different habitats. The recorded species represent about 16% of the total reported flora of the Egyptian Oases (Abd El-Ghani and Fawzy, 2006) and lower than that recorded by Abd El-Ghani (1981, 1985). Plants in the families

Table 1: Occurrence of the plant species (>10%) in at least one stand in the studied habitats

No.	Vascular plant species	H_1	H_2	H_3	H_4	H_5	H_6	H_7	Life form
1	*Acacia nilotica* (L.) Delile							11	Ph
2	*Aeluropus lagopoides* (L.) Trin.					23			He
3	*Alhagi graecorum* Boiss.	16	9	6	19	7		14	Ch
4	*Amaranthus graecizans* L.			7	3				Th
5	*Ambrosia maritima* L.							8	Th
6	*Anagallis arvensis* L.	3	4	7					Th
7	*Apium nodiflorum* (L.) Lag.							7	Th
8	*Aster squamatus* (Spreng.) Hieron.	10	11					12	Th
9	*Avena fatua* L.	9		7	12				Th
10	*Bassia muricata* (L.) Asch.				18	13	2		Th
11	*Beta vulgaris* L.	7			15				Th
12	*Bidens pilosa* L.	2	6				1	4	Th
13	*Brassica nigra* (L.) Koch.	8							Th
14	*Calendula arvensis* L.	4	2					8	Th
15	*Carex divisa* Huds.	2	1		3	7		4	Ge
16	*Centaurea calcitrapa* L.							7	Th
17	*Chenopodium ambrosoides* L.	14	10	11					Th
18	*Chenopodium murale* L.	7	4	9			8		Th
19	*Cichorium endivia* L.			12					Th
20	*Convolvulus arvensis* L.			15					Ch
21	*Conyza bonarensis* (L.) Cronquist.	7	11					28	Th
22	*Cressa cretica* L.				17				Ch
23	*Cynanchum acutum* L.							9	He
24	*Cynodon dactylon* (L.) Pers.	11	11	17	25	17		34	Ge
25	*Cyperus rotundus* L.							14	Ge
26	*Desmostachya bipinnata* (L.) Stapf							19	Ge
27	*Dichanthium annulatum* (Frossk.) Stapf							14	Ge
28	*Echinochloa colona* (L.) Link.	5		8	17				Th
29	*Emex spinosa* (L.) Campd.			3				9	TH
30	*Euphorbia peplus* L.	2		14					Th
31	*Fumaria densiflora* DC.			8					Th
32	*Inula crithmoides* L.				14				Th
33	*Imperata cylindrica* (L.) Raeudch.							28	Ge
34	*Juncus rigidus* Desf.					6			Ge
35	*Launea nudicaulis* (L.) Hook.						11		He
36	*Lolium perenne* L.	8							Th
37	*Lotus glaber* Mill.				6			4	Th
38	*Malva parviflora* L.	20		11					Th
39	*Melilotus indicus* (L.) All.	12	11	30	25		2		Th
40	*Mentha longifolia* (L.) Huds.							36	Ch
41	*Oxalis corniculata* L.	30	22						Th
42	*Phragmites australis* (Cav.) Trin. ex Steud.	2	4		14	21		28	Ge
43	*Phyla nodiflora* (L.) Greene	5	3					10	He
44	*Plantago lagopus* L.	7	3	7					Th
45	*Poa annua* L.			11					Th
46	*Polygonum equisetiform* Sm.						1	16	He
47	*Pulicaria crispa* (Frossk.) Oliv.						8		Ch

Table 1: Continued

No.	Vascular plant species	H_1	H_2	H_3	H_4	H_5	H_6	H_7	Life form
48	*Rumex dentatus* L.							25	Th
49	*Sonchus oleraceus* L.			11					Th
50	*Spergularia marina* (L.) Griseb.				13				Th
51	*Stellaria media* (L.) Vill.	8							Th
52	*Tamarix nilotica* (Ehrenb.) Bunge	3			2				Ph
53	*Trifolium resupinatum* L.							33	Th
54	*Typha domengensis*(Pers.)Poir							23	He
55	*Veronica anagallis aquatica* L.		8						Th
56	*Vicia sativa* L.			5					Th

Life-Forms (in accordance with Raunkiaer, 1934), Ph: Phanerophyte, Ch: Chamaephyte, He: Hemicryptophyte, Ge: Geophyte, Th: Therophyte

Table 2: Physicochemical analysis of soil samples collected from the studied habitats of Bahariya Oasis with their life forms

Soil samples	H_1	H_2	H_3	H_4	H_5	H_6	H_7
Sand (%)	69.3± 9.0*	51.1± 4.2	92.9± 4.6	88.3± 7.1	89.0±10.2	91.9±8.5	61.3±4.6
Silt (%)	10.0±1.7	10.2±1.8	2.4±0.5	3.6±0.1	3.3±0.1	3.3±0.1	9.3±0.5
Clay (%)	20.7±2.3	22.1±2.1	4.7±0.3	8.1±0.7	7.7±0.4	4.8±0.1	21.4±0.8
Soil texture	Clay loamy sand	Sandy loamy	Sandy	Sandy loamy	Sandy loamy	Sandy	Sandy loamy
pH	8.2±0.6	7.85±0.8	7.92±0.6	7.88± 0.1	8.77±0.7	7.89±0.4	8.01±0.3
EC (mS cm^{-1})	2.7±0.2	2.5±0.4	1.45±0.2	5.6±0.9	9.2±1.01	0.65±0.1	1.6±0.3
HCO_3^- (mg kg^{-1})	372±23	275±11.2	103.7±1.2	402±13.1	17.4±1.3	19.46±1.5	423±23.5
Cl^- (mg kg^{-1})	5840±52	5642±36	208±23	6785±63	25532±65	18.82±1.3	5124±42
SO^{-4} (mg kg^{-1})	5952±99	5822.7±63	340.8±23	4236±42	8969±85	43.4±12	3945±75
Na^+ (mg kg^{-1})	3661±98	3421±23	158.3±13	4454±74	17178±101	8.37±0.9	2909±85
K^+ (mg kg^{-1})	75.6±13	65.7±9.8	25.8±1.9	1696.5±18	126.8±11	11.6±0.85	1146±63
Ca^{++} (mg kg^{-1})	861.3±63	761.2±30	122±23	260.6±14	218.8±11	17.29±1.3	359.5±41
Mg^+ (mg kg^{-1})	10.9±0.6	11.08±0.3	10.04±1.3	1042.7±40	1784±53	6.18±0.8	227±3.6
Fe (mg kg^{-1})	87.9±25	79.9±5.3	5.62±1.01	83.8±9.4	2.27±0.03	38.3±1.5	18.6±1.2
Total $CaCO_3$ (%)	8.12±0.6	9.6±0.5	12.8±1.3	18.3±1.1	17.61±1.9	13.43±2.0	9.4±0.4

*±SE

Gramineae, Copmositae, Leguminosae and Chenopodiaceae dominated the reported flora and comprised 60% of the total species. Therophytes were the dominant life form constituting 61% of the total recorded species, followed by Geophytes (17%), Chamaephytes (9%), Hemicryptophytes (10%) and Phanerophytes (3%). Canal bank and palm orchard habitats were the richest in species, while saline and new reclaimed habitats showed the lowest number of species. Some species, like *Alhagi graecorum*, *Cynodon dactylon*, *Melilotus indicus* and *Phragmites australis*, were recorded in most of the studied habitats, while other species such as *Ambrosia maritima* and *Typha domengensis*, wet habitats were restricted to certain habitat.

Analysis of the soil samples (Table 2) representing different habitats, demonstrated that the soil texture were mainly sandy soil in all habitats. The main differences appeared in the electrical conductivity which had a bearing on Na^+ and Cl^- ions within the soil. *Aeluropus lagopoides* and *Juncus rigidus* were confined to levels of salinity higher than any habitat.

A total of 29 cyanobacterial species were detected throughout the seven studied habitats (Table 3). Data revealed that the cyanobacterial communities of the investigated sites exhibited variations in the total harvest in response to the habitats (sampling sites). In this respect, olive and palm orchard habitats followed by saline habitats harbored the greatest number of cyanobacterial species which accounted for a total of 18, 13 and 12 species, respectively. The results showed that olive orchard, saline and canal bank habitats were characterized by the presence of filamentous cyanobacterial species only, while palm orchard was characterized by a dominance of some of these species. Meanwhile, the colonial forms were dominant at salt affected, new reclaimed and cultivated habitats, respectively. The present results demonstrated dissimilarities in the microalgal communities throughout the investigated sites (Table 3).

Correlations between flowering plants, cyanobacteria and physico-chemical properties of soil habitats: The distribution of flowering plants and cyanobacterial species throughout the studied habitats at Bahariya Oasis exhibited different Pearson's correlations (p with physico-chemical characters of the investigated soils (Table 4, 5) and with each other (Table 6). Flowering plants showed positive correlation ($p>0.05$), 2-tailed test with potassium and bicarbonates contents in the soil. Most plants showed negative correlations with Fe content, while salt tolerant plants showed a positive correlation with Na^+ and Cl^- content. Cyanobacteria exhibited positive correlations with Ca^{2+} and total CO_3^- content. However, some cyanobacterial species did not reflect any response. Some cyanobacterial species recorded highly significant positive correlation with flowering plants, such as,

Table 3: Quantitative distribution of cyanobacterial species of the studied habitats at Bahariya Oases

No.	Cyanobacterial species	H_1	H_2	H_3	H_4	H_5	H_6	H_7
1	*Anabaena ambigua* C.B. Rao	-	10	-	-	-	-	-
2	*Anabaena anomala* Fritsch	-	2	-	-	-	-	-
3	*Anabaena doliolum* Bharadwaja	6*	14	-	-	-	-	-
4	*Anabaena naviculoides* Fritsch	4	5	-	-	-	-	-
5	*Calothrix parietina* Thuret ex Born et Flah	8	-	2	-	3	-	2
6	*Calothrix thermalis* (Schwabe) Hasngirg	-	-	-	-	8	-	1
7	*Chroococcus limneticus* Lemm	2	-	3	11	-	4	-
8	*Chroococcus minutes* (Kutez) Naeg	5	-	1	7	-	1	-
9	*Gloeocapsa gelatinosa* (Meneghini) Kützing	-	-	5	6	-	6	-
10	*Gloeocapsa stegophila* (Itzigs.) Rabenhorst	-	-	-	3	-	8	-
11	*Gloeocapsa turgida* (Kütz.)	-	-	16	12	-	10	-
12	*Lyngbya dendrobia* Briihl and Bisw	-	12	7	-	11	-	7
13	*Microcoleus acutissimus.* Gardner	-	-	-	1	-	-	-
14	*Nodularia harvenyana* (Thwait.) Thuret	3	16	-	-	5	-	-
15	*Nostoc calcicola* (Bréb.) ex Bornet	9	3	-	-	2	-	-
16	*Nostoc commune* Vaucher ex Bornet and Flahault	8	6	-	-	8	-	-
17	*Nostoc entophytum* Knowlet	-	2	-	6	-	-	-
18	*Nostoc minutum* DESM. ex Boxx	-	15	-	-	-	-	-
19	*Nostoc paludosum* Kützing	-	3	-	-	-	-	-
20	*Nostoc passerianum* Hansg	2	-	-	-	-	-	-
21	*Nostoc punctiforme* (F.T. Kützing) ex Hariot,	1	-	-	-	-	-	-
22	*Oscillatoria acutissima Kuff*	11	8	-	3	5	-	-
23	*Oscillatoria nigroviridis* Thwaites ex Gomont	-	5	-	-	16	-	-
24	*Oscillatoria okenii* Ag. ex Gomont	8	11	-	-	-	-	-
25	*Oscillatoria ornate* Rao fa.	-	2	-	-	6	-	-
26	*Oscillatoria indica* Silva	-	17	-	-	5	-	-
27	*Phormidium corium* (Ag.) Gomont	15	8	-	-	-	-	-
28	*Phormidium tenue* Anagnostidis and Komárek	-	2	-	-	12	-	-
29	*Spirulina major* Kuetzing ex Gomont	-	-	9	-	10	3	-
Total No. of species		13	18	7	8	12	6	3
Total No. of individuals		82	142	43	49	91	32	10
Diversity index		2.4	7.3	0.49	0.83	3.1	0.45	0.18

*Species No. per 100 g soil

Table 4: Pearson's correlation for relationships among the distribution of flowering plants and physico-chemical properties of soil at Bahariya Oasis (Western-desert) Egypt

Vascular plant species	Sand (%)	Silt (%)	Clay (%)	pH	EC (mS cm^{-1})	HCO_3^-	Cl^-	SO^{-4}	Na^+	K^+	Ca^{++}	Mg^+	Fe	Total $CaCO_3$ (%)
						----------(mg kg^{-1})----------								
Acacia nilotica	--		+			+	++			+				
Aeluropus lagopoides	--			++	++	-	+	++	++			++	_	+
Alhagi graecorum	--		+			++	+			++	+		+	
Amaranthus graecizans.	--	++	+											
Ambrosia maritima.			+			+				+				
Anagallis arvensis							++			+				
Apium nodiflorum	+		+			+	+			+		-		
Aster squamatus		++	++			++	+				-		--	+
Avena fatua	++			++	+			+	++	+				
Bassia muricata h.	+	-	-		++				++	++	++		++	
Beta vulgaris.	++					++	++			++		++		
Bidens pilosa		++	+			+	+				-		--	++
Brassica nigra		+					+			++		+	-	
Calendula arvensis	--	++	++			++				+			--	
Carex divisa Huds.				++	++			++	++		++			
Centaurea calcitrapa			+			+	++			+				
Chenopodium ambrosoides							+		-	++	--		--	
Chenopodium murale.	--				--		--	--		--	--			
Cichorium endivia.	--	-	-					-				-		
Convolvulus arvensis		-	-					-				-		
Conyza bonarensis		++	++			++							--	
Cressa cretica	-									++		+	++	
Cynanchum acutum			+			++			++	+				
Cynodon dactylon	--					++				++				
Cyperus rotundus			+			+			++	++				
Desmostachya bipinnata	--		+			+				+				
Dichanthium annulatum	--		+			+				+				

Table 4: Continued

Cyanobacterial sp.	Sand (%)	Silt (%)	Clay (%)	pH	EC (mS cm^{-1})	HCO_3^-	Cl^-	SO^{-4}	Na^+	K^+	Ca^{++}	Mg^+	Fe	Total $CaCO_3$ (%)
						(mg kg^{-1})								
Echinochloa colon									++	++			+	
Emex spinosa	++								+			-		
Euphorbia peplus L.	--		+					_						
Fumaria densiflora		-	+					-				-		
Inula crithmoides	--		++							++		+	++	
Imperata cylindrica	--		++			+				+				
Juncus rigidus				++	++	-	++				++	-	+	
Launea nudicaulis						_		--	++	-				
Lolium perenne	+	+	-							++		+	-	
Lotus glaber						++				++				
Malva parviflora	++		--	-					-		+		-	
Melilotus indicus	+		-											
Mentha longifolia	++		--			+			-	+				
Oxalis corniculata		++							+	++		++	--	+
Phragmites australis					+		++	+		++	++			
Phyla nodiflora	--	++	+			++				+			--	
Plantago lagopus			+							+	-		-	
Poa annua		+						-	++			-		
Polygonum equisetiform						+				+				
Pulicaria crispa	--		+			-		--			-			
Rumex dentatus	--		+			+				+				
Sonchus oleraceus L.		+						-				-		
Spergularia marina										++		+	++	-
Stellaria media.	-	+	++								++		+	
Tamarix nilotica						++			++		+		++	
Trifolium resupinatum	--		++			+				+				
Typha domengensis		+				+			++	+				
Veronica anagallis aquatica	--													
Vicia sativa	--		++											

++: Correlation is significant at 0.01 levels, +: Correlation is significant at 0.05 levels, --: Correlation is significant at 0.01 levels, -: Correlation is significant at 0.05 levels

Table 5: Pearson's correlation for relationships among the distribution of the isolated cyanobacterial species and physicochemical structure of soil at Bahariya Oasis (Western-desert) Egypt

Cyanobacterial sp.	Sand (%)	Silt (%)	Clay (%)	pH	EC (mS cm^{-1})	HCO_3^-	Cl^-	SO^{-4}	Na^+	K^+	Ca^{++}	Mg^+	Fe	Total $CaCO_3$ (%)
						(mg kg^{-1})								
Anabaena ambigua	--	+	+								+			
Anabaena anomala	--	+	+								+			
Anabaena doliolum	--	++	++								++		++	--
Anabaena naviculoides	--	++	++								++			
Calothrix parietina				+							+			
Calothrix thermalis				++	++	-	++	++	++			++	-	+
Chroococcus limneticus	+	-	-							++				++
Chroococcus minutes							+			+			++	
Gloeocapsa gelatinosa	++	--	--	-			-	--	-		--			+
Gloeocapsa stegophila	+	-	-					--			-			
Gloeocapsa turgida	++	--	--	-			-	--	-		--			+
Lungbya dendrobia							+		+					
Microcoleus acutissimus										++			+	++
Nodularia harvenyana	--	+	+					+			++			
Nostoc calcicola		++	+					+			++		+	-
Nostoc commune				++	+		++	++	++	-	++			
Nostoc entophytum						+				++			++	+
Nostoc minutum	--	+	+								+			
Nostoc paludosum	--	+	+								+			
Nostoc passerianum		+									++		+	-
Nostoc punctiforme		+									++		+	-
Oscillatoria acuta	-	++	++					++			++		++	
Oscillatoria nigroviridis				++	++	-	++	++	++			++		
Oscillatoria okenii	--	++	++								++		++	--
Oscillatoria ornate				++	--	-	++	++	++			++		
Oscillatoria salina	--										+			
Phormidium corium	--	++	++								++		++	--
Phormidium tenue				++	++	-	++	++	++				-	+
Spirulina major	++	--	--	++		--	+		+	-	--	+	--	++

++: Correlation is significant at 0.01 levels, +: Correlation is significant at 0.05 levels, --: Correlation is significant at 0.01 levels, -: Correlation is significant at 0.05 levels

Bidens pilosa, *Lolium perenne*, *Inula crithmoides*, *Oxalis corniculata*, *Echinochloa colona* and *Stellaria media*. Others exhibited significant negative Pearson's correlation such as, *Chenopodium murale*, *Calendula arvensis*, *Conyza bonarensis* and *Phyla nodiflora*. Cyanobacteria in the canal bank region did not exhibit any correlation with plants in that region (Table 6).

Table 6: Pearson's correlation for relationships among the distribution of cyanobacterial species and flowering plants located at Bahariya Oasis (Western-desert) Egypt

Cyanobacterial sp.	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Anabaena ambigua								+				++						
Anabaena anomala								+				++						
Anabaena doliolum								++				++					++	
Anabaena naviculoides								++				++	+				++	
Calothrix parietina									++				++				+	
Calothrix thermalis		++							++	+					++			-
Chroococcus limneticus								-		++	++	-		-				
Chroococcus minutes			++							+	++		+					
Gloeocapsa gelatinosa				++				--				--		--	-			
Gloeocapsa stegophila			-			-		-	-								-	
Gloeocapsa turgida				++								--		--	-			
Lungbya dendrobia		+									--		-					
Microcoleus acutissimus			++							++	++							-
Nodularia harvenyana												++						
Nostoc calcicola									+				++				++	
Nostoc commune		+		--					++		-		+					
Nostoc entophytum			++						-	++	++	-						-
Nostoc minutum												++						
Nostoc paludosum												++						
Nostoc passerianum													++				++	
Nostoc punctiforme			-										++				++	
Oscillatoria acuta													++				++	
Oscillatoria nigroviridis		++							++						++			-
Oscillatoria okenii												++	+				++	
Oscillatoria ornate									++						++			-
Oscillatoria salina												++						
Phormidium corium													++				++	
Phormidium tenue		++							++	+					++			-
Spirulina major			--	+					++		-	--						

Cyanobacterial sp.	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Anabaena ambigua																		
Anabaena anomala																		
Anabaena doliolum																		
Anabaena naviculoides																		+
Calothrix parietina																		++
Calothrix thermalis																++		
Chroococcus limneticus			-	++						++				++				
Chroococcus minutes				++						++				++				+
Gloeocapsa gelatinosa			--	+						++				+			+	
Gloeocapsa stegophila						-											++	
Gloeocapsa turgida	++	++	--							++		++	++					
Lungbya dendrobia				-						-				-		+	-	+
Microcoleus acutissimus				++						++				++				
Nodularia harvenyana																		
Nostoc calcicola																		++
Nostoc commune											-					+		+
Nostoc entophytum				++						++				++				
Nostoc minutum																		
Nostoc paludosum																		
Nostoc passerianum																		++
Nostoc punctiforme																		++
Oscillatoria acuta											-							++
Oscillatoria nigroviridis																++		
Oscillatoria okenii																		+
Oscillatoria ornate																++		
Oscillatoria salina																		
Phormidium corium																		++
Phormidium tenue																++		
Spirulina major	++	++	-									+	++			++		

Table 6: Continued

Cyanobacterial sp.	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Anabaena ambigua					+													
Anabaena anomala					+													
Anabaena doliolum					++													
Anabaena naviculoides					++			+						-	+			
Calothrix parietina		++			++			++							++	++		
Calothrix thermalis			-			+												
Chroococcus limneticus	++		++				-							++		+		
Chroococcus minutes	+		+											++	+	++		
Gloeocapsa gelatinosa			+		-		--				+			+				
Gloeocapsa stegophila								-			++							
Gloeocapsa turgida			++		-	-	--		++				++					
Lungbya dendrobia											-			-	-	--		
Microcoleus acutissimus	++		+											++		+		
Nodularia harvenyana					++													
Nostoc calcicola		++			++			++							++	++		
Nostoc commune	-				++										+			
Nostoc entophytum	++		+											++				
Nostoc minutum					+													
Nostoc paludosum					+													
Nostoc passerianum		++			++			++							++	++		
Nostoc punctiforme		++			++			++							++	++		
Oscillatoria acuta		+			++										++	++		
Oscillatoria nigroviridis																		
Oscillatoria okenii					++			+							+			
Oscillatoria ornate																		
Oscillatoria salina																		
Phormidium corium		++			++			++							++	++		
Phormidium tenue																	-	
Spirulina major	-				+				++				++			-		

++: Correlation is significant at 0.01 levels, +: Correlation is significant at 0.05 levels, --: Correlation is significant at 0.01 levels, -: Correlation is significant at 0.05 levels, *No. refers to flowering plant as shown in Table 1

DISCUSSION

The low number of plant and cyanobacterial species recorded in this study is in contrast to earlier studies, mainly because this study covers only winter season. The recorded pattern of life form displays a high resemblance to that given by Abd El-Ghani and Fahmy (1998) and Abd El-Ghani and Fawzy (2006). The hot-dry climates and short time variation of water availability are the main reasons for the dominance of Therophytes. The high species number recorded in Palm orchard could be due to the presence of different shade conditions in palm orchard. Many studies however recorded light penetration of therophytes in 43 to 50% (Bavappa, 1995; Muralidharan, 1980; Wilson and Ludlow, 1990). The recorded dominant families represent the most common in the Mediterranean North African flora (Quezel, 1978). The presence of some species, like *Alhagi graecorum*, *Cynodon dactylon*, *Melilotus indicus* and *Phragmites australis*, in most of the studied habitats shows that they have a wide ecological amplitude (Ahmed and Girgis, 1979). Whereas restriction of some species to particular habitat, like *Ambrosia maritima* and *Typha domengensis* to wet habitats, supports the fact that they require special conditions for growth. Some of the recorded plant species are known to be of economic importance, such as for mats making and good quality paper production (Zahran *et al*., 1979), animal Fodder (Al-Sherif, 2007; Al-Sherif *et al*., 2004), sand dune fixation (Batanouny, 1979) and protection from coastal erosion (Zahran, 1977).

The high presence of the cyanobacterial species in the investigated habitats can be explained by the mechanisms employed to tolerate desiccation and resistances over severe conditions. Such hypothesis conforms with those of Belnap and Gardner (1993), Mazor *et al*. (1996), Liu *et al*. (2001) and Hu *et al*. (2002), who reported that *Microcoleus* sp. is a sheath forming and polysaccharide excreting cyanobacterium with strong ability to stabilize sand grains and with strong resistance to stress conditions. Hu *et al*. (2003) demonstrated that filamentous cyanobacteria such as *Anabaena* sp. possesses a skeleton laced with mineral particles, this skeleton type structure provided a comfortable microenvironment for the organisms underneath. The tolerant and adaptive capacity of cyanophyta may be attributed to its cellular structure. Such assumption is in accordance with that of Kobbia and Shabana (1988), Ahmed (1994) and Ibraheem (2003) who explained the ability of blue-green algae to survive under variable and even adverse conditions on the basis of the properties of cyanobacterial cells. These organisms were found to flourish under pH value of 7 and above and were

intolerant to low pH conditions (El-Attar, 1999; Ibraheem, 2003; Jurgensen and Davey, 1968; Kobbia and Shabana, 1988; Salama and Kobbia, 1982). However, the pH values of the investigated habitats were more than 7 and this may partially explain the wide distribution of cyanobacterial species in most studied habitats.

The obtained variation in cyanobacterial taxa in different habitats was in agreement with those of Metting (1981), Lukešová (1993, 2001) and Ibraheem (2003) who reported that both soil type and vegetation are known to affect cyanobacterial communities. A small variation in soil properties throughout the investigated habitats was also detected. It was clearly established that the cyanobacterial species diversity of olive orchard habitat was higher than other habitats. This positive correlation may be attributed to root exudates of the plants covering this site, which in turn, could reflect the importance of plant cover in the diversity of the algal species. The present finding is in agreement with those of Keeling (1974), who reported that differences in microalgal crusts might be due to quantitative or qualitative differences in root exudates which directly or indirectly influence the quantity or the quality of microflora. The extra metabolites of this root may be alcohol, aldehydes, olefins, volatile organic acids, polysaccharides or plant regulators (Ibraheem, 2003; Vancura and Stotzky, 1971). Also, Evenari *et al.* (1975), also reported that, the desert plant vegetation has a direct effect in selecting and determining the types of algal organisms it will support. Broady (1979), Salama and Kobbia (1982) and Zancan *et al.* (2006) reported that the presence of higher algal populations was recorded at sites with dense plant vegetation which resulted in the enrichment of the soil with organic matter as well as inorganic nutrients. These enrichments return to the surface layers of the soil and become available to surface dwelling algae through the decay and mineralization of dead plants above ground vegetation. Brown and Bold (1964) and Salama and Kobbia (1982) showed that algae in the dense grassy and shrubby sites receive more protection since soil surface is consolidated sufficiently to resist being blown away. In addition, Ariño and Saiz-jimenez (1996) and Chen *et al.* (2006) demonstrated that shrub coverage play a role in limiting Ultra Violet irradiance, sunlight and sand surface temperature necessary for photosynthesis.

The negative correlation between cyanobacteria and some flowering plants may be due to allelopathy leachates from leaves and litter of shrubs reducing seed germination of the surrounding herbs (Hawakes and Flechtner, 2002; Hunter, 1999) thereby decreasing growth and survival of grasses from adjacent communities (Fisher *et al.*, 1994; Richardson and Williamson, 1988).

The high number of cyanobacterial species recorded in saline habitats (H_5) revealed its ability to fix nitrogen as well as their adaptation to the environmental fluctuations such as desiccation or high salinity, thus making them to be the most successful colonizes in low fertility and high pH (Andrea and William, 2006; Costelloe *et al.*, 2005; Englund, 1978; Metting, 1981; Whitton, 1992).

The present study showed that soluble carbonates were depleted from the all studied soil sites. This further supports earlier reports which indicate that the distribution of cyanobacteria is unlimited even in low carbonate environment (El-Attar, 1999; Kobbia and El-Batanony, 1975). Positive and negative correlations between flowering plants and cyanobacterial taxa are obtained confirming the controversial effect of cyanobacterial crust on vascular plants and the difficulty to generalize. Further studies were recommended to know about the interactions between cyanobacteria and vascular plants.

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