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Hydrophytic Vegetation in the Irrigation and Drainage Canal System of the River Nile in Egypt

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Abstract: The present work provides an ecological study on the hydrophytic vegetation in the irrigation and drainage system of the River Nile in Egypt. Eighty sampled stands were selected in the study area representing various water ways, namely, drainage canals, irrigation canals, northern lakes (Manzala, Borollus and Idku), Damietta branch, Rosetta branch and main stream of the River Nile. Vegetation, sediment and water were analyzed in the sampled stands. The application of TWINSPAN classification on the importance values of 70 plant species recorded in 80 sampled stands led to recognition of six vegetation groups dominated by *Phragmites australis*, *Eichhornia crassipes*, *Typha domingensis*, *Arthrocnemum macrostachyum* and *Echinochloa stagnina.* The application of Canonical Correspondence Analysis indicated that, the effective sediment and water variables which significantly correlated with the distribution and abundance of the identified vegetation groups include soil texture, water-holding capacity, electrical conductivity, calcium carbonate, chloride, sulphate, sodium, potassium, calcium and magnesium cations. The vegetation groups in the present work are classified into two main categories: the first category represents the northern lakes Manzala, Borollus and Idku and the second category represents the irrigation and drainage canals, Damietta branch, Rosetta branch and the main River Nile stream.

Key words: Egypt · twinspan · canoco · plant life · sediment and water analysis

INTRODUCTION

The establishment of Aswan High Dam in the most southern part of the River Nile in Egypt has many side effects. The aquatic macrophyte vegetation is growing so rapidly and densely that it represents an acute problem. The River Nile and its irrigation and drainage system canals as well as the northern natural lakes in the Nile Delta are badly infested with aquatic plants. The problems created by the hydrophytes are many such as, constituting a health hazard by providing mosquitoes larvae with an ideal breeding place, causing oxygen depletion, interfering with navigation, obstructing drainage and flow of water in irrigation canals, decreasing phytoplankton production, polluting water supplies, increasing sedimentation by trapping silt particles and causing loss of water through evapotranspiration [1-4]. On the other hand, aquatic plants could be beneficial by providing shelter and nourishment to fish, water fowl and other aquatic organisms by removing toxic compounds from water, by providing source of animal feed, paper pulp, fiber and bioenergy [5].

In Egypt, the total length of canals and drains is approximately 4700 km [6]. These canals and drains are infested by different aquatic weeds. The degree of infestation is affected by environmental factors, including water transparency, depth of water, physico-chemical properties, water quality, water currents and air temperature [7].

The different life forms of hydrophytes were recognized as well as the aquatic vegetation groups were defined in different parts of Egypt by many authors [8-18]. The present study aims at: 1) analyzing water plant vegetation in the major water bodies of the aquatic habitats associated with the River Nile system in Egypt and to assess the vegetation-environment relationship of the identified plant communities.

The study area: The study area is located in some selected governorates in the Nile Delta and Nile Valley subregions of the river system which comprises different types of water bodies supporting the growth of fresh water hydrophytic vegetation. Six types of water bodies were selected: (1) the Nile stream from south of Cairo to

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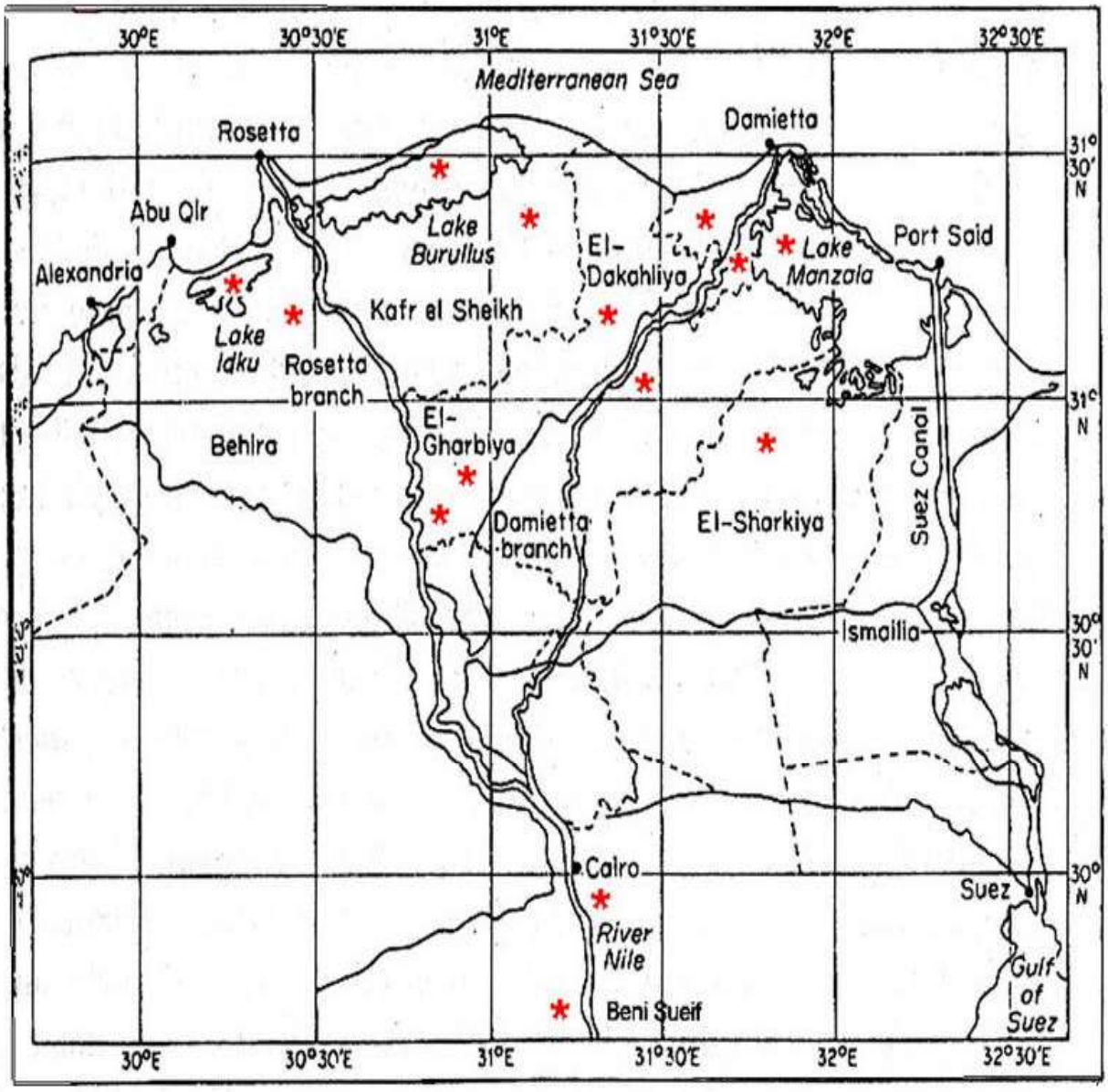

Fig. 1: Location map showing the selected sites (*) in the different riverains of the study area

north of Beny Sueif (Nile Valley), (2) Damietta branch of the River Nile, (3) Rosetta branch of the River Nile, (4) northern Delta natural lakes: Manzala, Borollus and Idku, (5) drainage canals in five representative governorates of the Nile Delta subregion namely Damietta, El-Dakahlyia, Kafr El-Sheikh, El-Gharbia and El-Sharkia and (6) irrigation canals in the same above mentioned Nile Delta governorates (Fig. 1).

MATERIALS AND METHODS

Estimation of species abundance: After regular visits to the different sites in the study area, 80 stands were selected for sampling vegetation in the various water bodies of the River Nile system. In each stand, all plant species were recorded in five plots (25 m^2 each) and the species abundance was estimated in one sampled stand according to Muller-Dombios and Ellenberg [19]. The importance values of the recorded species were expressed by the relative values of frequency calculated for each species. The identification and nomenclature of the recorded species were according to Täckholm [20] and Boulos [21].

Sediment and water analysis: Sediment (hydrosoil) samples were collected from the sampling stands for soil analysis. The texture of hydrosoil samples was determined by Bouyoucos hydrometer method as described by Piper [22]. Special rectangular box (Hilgard pan box) was used for the determination of water-holding capacity (modified method of Piper [22]. Calcium carbonate content was determined according to Jackson [23]. Oxidizable organic carbon was determined using Walkely and Black rapid titration method as described by Piper [22]. Electeric pH-meter (model Lutron pH-206) digital analyzer with glass electrode was used to determine the soil reaction in 1:5 soil extract. Electrical conductivity was measured by YSI Incorporated Model 33 conductivity meter. Estimation of chlorides was carried out by titration method using N/35.5 silver nitrate and potassium chromate indicator [22]. Suphates were estimated gravimetrically using 5% barium chloride solution which precipitated as barium sulphate and ignited in muffle furnace at 700-800 °C. The total dissolved phosphorus was determined by direct stannous chloride method [24], while the total nitrogen was determined by the micro-Kjeldahl method according to Allen *et al.* [25]. The extractable cations of sodium, potassium and calcium were estimated using flame photometer (Model Jenway PEP7) and magnesium using atomic absorption (Atomic Absorption Spectrometer 3110).

Water samples were collected from each sampling stand for water analysis. The water samples were kept in polyethylene bottles from which 1000 cm^3 aliquots, transferred to laboratory, filtered using Whatman 0.45 µm filter paper. The filtrates were acidified to pH 2.0 using nitric acid to preserve the metals in samples. The chemical characteristics of the collected water samples were determined according to the methods previously applied in the sediment analysis.

Data analysis: Two trends of multivariate analysis were applied in the present study: classification and ordination. The classification technique applied here was Two Way Indicator Species Analysis [26]. The matrix of importance values of 70 species was used in the TWINSPAN-classification of the 80 sampled stands. The ordination techniques applied here were Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) [27]. The simple linear correlation coefficient (r) was calculated for assessing the relationships between the estimated different sediment and water variables. The relationships between identified vegetation groups and each of sediment and water variables were carried out by the ordination diagram produced by CCA-biplot. All statistical treatments applied in the present work were according to Snedecor and Cochran [28] and Anonymous [29].

RESULTS

Vegetation classification: The application of TWINSPAN classification of 70 species recorded in 80 sampled stands led to the recognition of six vegetation groups (Fig. 2 and Table 1).

Table 1: Mean and coefficient of variation (value between brackets) of the importance value (out of 100) of indicator and preferential species in the different vegetation groups resulting from TWINSPAN classification of plant communities

	Vegetation groups					
Species	A	B	C	D	E	F
Alhagi graecorum	2.14 (2.24)	-	-	-	1.52 (2.47)	-
Alternanthera sessilis	-	-	0.80 (2.24)	2.44 (1.38)	2.23 (1.37)	0.43 (2.23)
Amaranthus lividus	-	-	4.94 (0.67)	-	1.47 (1.79)	2.93 (2.38)

Table 1: Continue

Arthrocnemum macrostachyum	13.38 (0.58)	9.93 (0.2)	-	1.88 (1.57)	0.12 (6.08)	-
Arundo donax	-	-	-	-	1.35 (1.88)	1.8 (1.96)
Aster squamatus	-	-	-	0.27 (4.47)	1.7 (1.38)	0.89 (2.56)
Atriplex canescens	6.72 (0.58)	3.43 (1.41)	6.45 (1.83)	1.29 (2.56)	0.28 (4.36)	-
Atriplex prostrata	3.44 (1.38)	-	3.6 (2.24)	0.96 (2.18)	0.75 (2.84)	-
Bassia indica	-	-	2.42 (1.49)	1.54 (1.9)	1.78 (2.13)	0.28 (3.32)
Bidens Pilosa	-	-	-	-	0.32 (3.48)	-
Cakile maritima subsp. maritima	1.48 (2.24)	-	-	0.17 (4.47)	-	-
Carthamus tenuis	3.20 (1.37)	-	-	-	-	-
Ceratophyllum demersum	-	7.28 (0.12)	5.08 (1.05)	6.41 (0.59)	3.89 (1.17)	2.02 (1.19)
Chenopodium album	-	-	-	0.63 (3.08)	1.05 (2.19)	1.57 (1.85)
Chenopodium ficifolium	-	-	1.20 (2.24)	0.30 (4.47)	-	0.26 (3.32)
Chenopodium murale	1.82 (2.24)	-	-	0.63 (2.48)	1.39 (1.88)	6.24 (0.65)
Conyza aegyptiaca	-	-	-	-	0.41 (2.63)	-
Conyza bonariensis	-	4.45 (0.58)	3.93 (1.00)	0.85 (2.21)	1.82 (1.67)	0.22 (3.32)
Cynodon dactylon	-	-	2.62 (1.53)	-	1.49 (1.79)	6.11 (0.66)
Cyperus alopecuroides	-	3.34 (1.41)	-	0.74 (2.54)	0.63 (1.06)	5.11 (0.71)
Cyperus articulatus	-	2.63 (1.41)	-	0.52 (1.44)	1.26 (0.91)	0.41 (3.32)
Cyperus difformis	-	-	-	-	0.29 (3.45)	0.43 (3.32)
Cyperus laevigatus	-	-	-	0.32 (4.47)	0.47 (2.73)	0.22 (3.32)
Cyperus rotundus	2.14 (2.24)	-	-	0.66 (3.13)	0.78 (3.09)	0.61 (1.85)
Echinochloa stagnina	-	-	-	6.66 (0.77)	8.82 (0.61)	6.44 (0.69)
Eclipta alba	-	-	-	1.03 (4.47)	1.73 (1.47)	2.00 (1.17)
Eichhornia crassipes	-	6.78 (0.02)	9.16 (0.96)	10.67 (0.43)	8.79 (0.53)	10.10 (0.36)
Elodea canadensis	-	-	-	-	0.08 (6.08)	-
Ethulia conyzoides	-	-	-	-	1.36 (1.72)	0.4 (3.32)
Halocnemum strobilaceum	2.83 (1.38)	-	-	-	-	-
Heliotropium lasiocarpum	2.89 (1.50)	-	-	-	-	-
Imperata cylindrica	-	-	4.91 (1.61)	0.63 (3.08)	4.52 (0.93)	6.57 (1.06)
Ipomoea carnea	-	-	-	0.97 (2.45)	3.01 (1.10)	0.22 (3.32)
Juncus acutus	3.75 (1.37)	6.98 (0.18)	1.00 (2.24)	1.35 (2.11)	0.11 (6.08)	-
Juncus rigidus	1.94 (2.24)	-	-	-	-	-
Juncus subulatus	6.80 (0.79)	4.5 (1.41)	-	-	-	-
Lemna gibba	-	6.58 (0.11)	5.08 (1.05)	4.71 (0.98)	0.67 (2.88)	-
Lemna minor	-	7.28 (0.12)	5.08 (0.99)	4.48 (0.97)	0.75 (0.92)	-
Leersia hexandra	-	-	-	-	0.14 (4.27)	0.22 (3.32)
Limbarda crithmoides	3.19 (1.41)	2.13 (1.41)	3.58 (1.23)	1.46 (2.11)	0.38 (4.26)	-
Ludwigia stolonifera	-	-	2.22 (2.24)	4.79 (0.81)	2.98 (1.27)	0.61 (3.32)
Marsilea aegptiaca	-	1.32 (1.41)	-	0.39 (3.54)	-	-
Mesembryanthemum crystallinum	5.06 (1.57)	-	1.00 (2.24)	-	-	-
Mesembryanthemum nodiflorum	-	-	1.20 (2.24)	-	-	-
Myriophyllum spicatum	-	-	-	-	0.22 (6.08)	1.05 (3.32)
Najas minor	2.83 (1.38)	-	-	0.33 (4.47)	-	-
Nymphaea lotus	-	-	-	-	0.54 (4.33)	-
Panicum repens	-	-	-	-	0.16 (4.46)	-
Persicaria lapathifolia	-	-	1.21 (2.24)	0.15 (4.47)	0.73 (2.65)	3.69 (0.94)
Persicaria salicifolia	-	-	0.40 (2.24)	2.61 (1.13)	4.01 (0.81)	4.23 (0.89)
Phragmites australis	13.54 (0.29)	9.42 (0.41)	13.92 (0.78)	13.93 (0.3)	11.49 (0.34)	9.03 (0.42)
Pistia stratiotes	-	-	-	-	0.47 (4.33)	-
Pluchea dioscoridis	-	2.63 (1.41)	-	0.38 (3.10)	5.29 (0.66)	4.89 (0.74)
Potamogeton crispus	-	-	-	0.74 (2.77)	-	-
Potamogeton nodous	-	-	-	-	0.11 (6.08)	-
Potamogeton pectinatus	6.1 (0.99)	-	-	3.05 (1.9)	-	-
Ranunculus sceleratus	-	-	1.01 (2.24)	0.59 (2.51)	0.09 (6.08)	1.17 (1.43)
Rumex dentatus	-	-	0.80 (2.24)	2.42 (1.48)	2.88 (0.21)	1.98 (1.46)
Saccharum spontaneum	-	2.63 (1.41)	-	2.18 (1.61)	5.07 (1.12)	7.75 (0.55)
Salsola kali	1.43 (2.24)	-	-	-	-	-
Scirpus maritimus	-	-	-	-	0.17 (6.08)	-
Senecio glaucus	1.48 (1.37)	-	2.27 (2.24)	-	-	-
Solanum nigrum	-	-	1.41 (1.57)	-	0.16 (6.08)	5.29 (0.55)
Spergularia marina	-	-	-	-	0.38 (4.26)	-
Suaeda pruinosa	4.27 (1.46)	5.00 (1.41)	4.84 (1.06)	0.51 (2.09)	0.96 (1.99)	0.34 (3.32)
Tamarix nilotica	-	3.95 (1.41)	1.41 (1.39)	2.57 (1.32)	1.87 (1.51)	2.1 (2.37)
Typha domingensis	10.65 (0.72)	9.93 (0.20)	8.47 (1.09)	12.29 (0.44)	3.66 (1.33)	2.47 (1.58)
Veronica anagallis-aquatica	-	-	-	0.17 (4.47)	-	0.61 (2.25)
Vigna luteola	-	-	-	-	0.11 (6.08)	-
Zygophyllum aegyptium	-	-	-	0.28 (4.47)	-	-

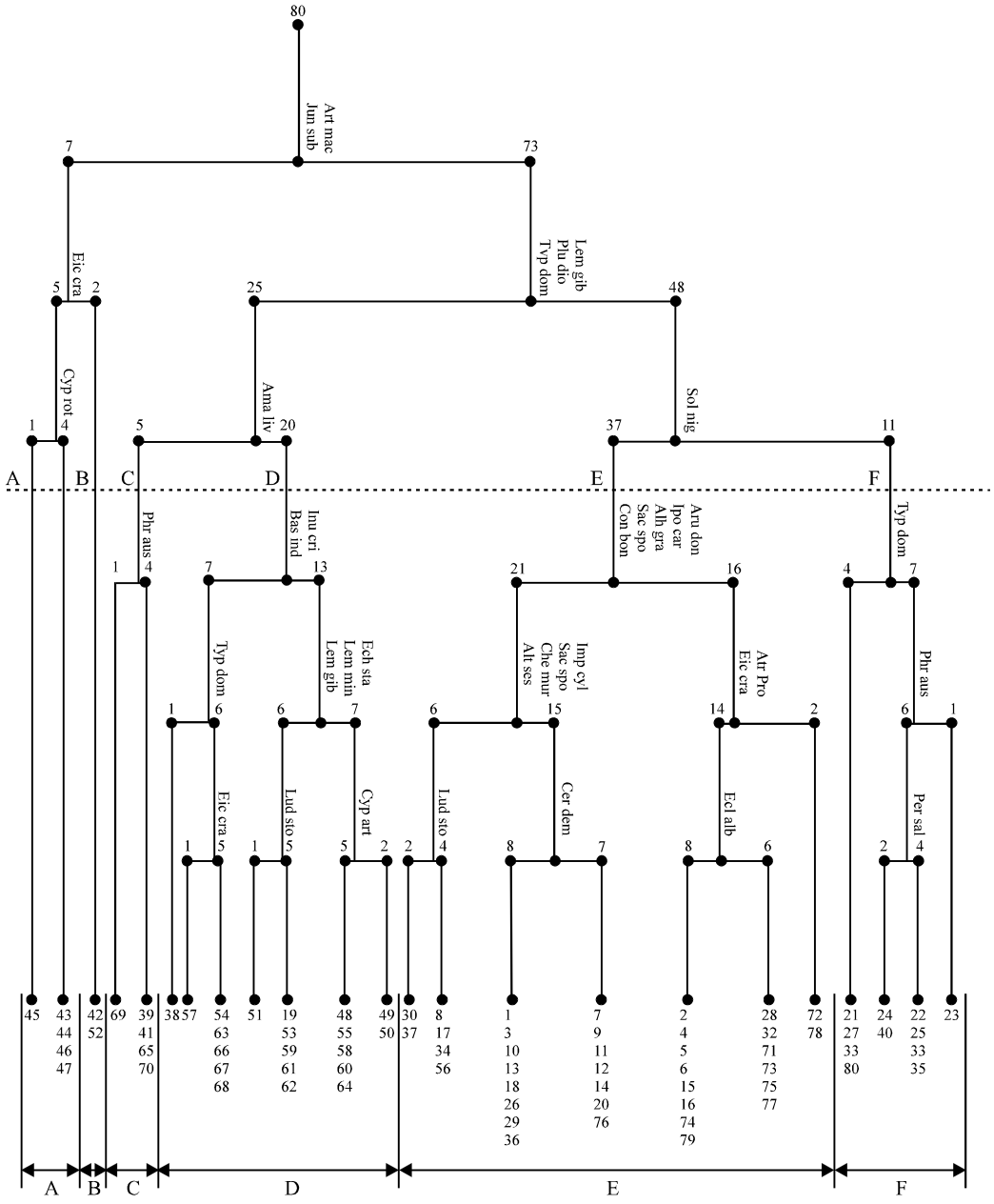

Fig. 2: Two Way Indicator Species Analysis (TWINSPAN) dendrogram of the 80 sampled stands based on the importance values of the 70 species

Group A includes 5 stands codominated by *Phragmites australis* (importance value = 13.54), *Arthrocnemum macrostachyum* (IV = 13.38) and *Typha domingensis* (IV = 10.65). The important species in this group comprise *Juncus subulatus* (IV = 6.80) and *Atriplex canescens* (IV = 6.72), while the indicator species is *Cyperus rotundus* (IV = 2.14).

Group B comprises 2 stands which similarly codominated by *Arthrocnemum macrostachyum*, *Typha domingensis* (IV = 9.93 each) and *Phragmites australis* (IV = 9.42). The important species in this group include *Ceratophyllum demersum*, *Lemna minor* (IV = 7.28 each) and *Juncus acutus* (IV = 6.98), but the indicator species is *Eichhornia crassipes* (IV = 6.58).

Group C consists of 5 stands codominated by *Phragmites australis* (indicator species with IV = 13.92) and *Eichhornia crassipes* (IV 9.16). The most important species in this group include *Typha domingensis*

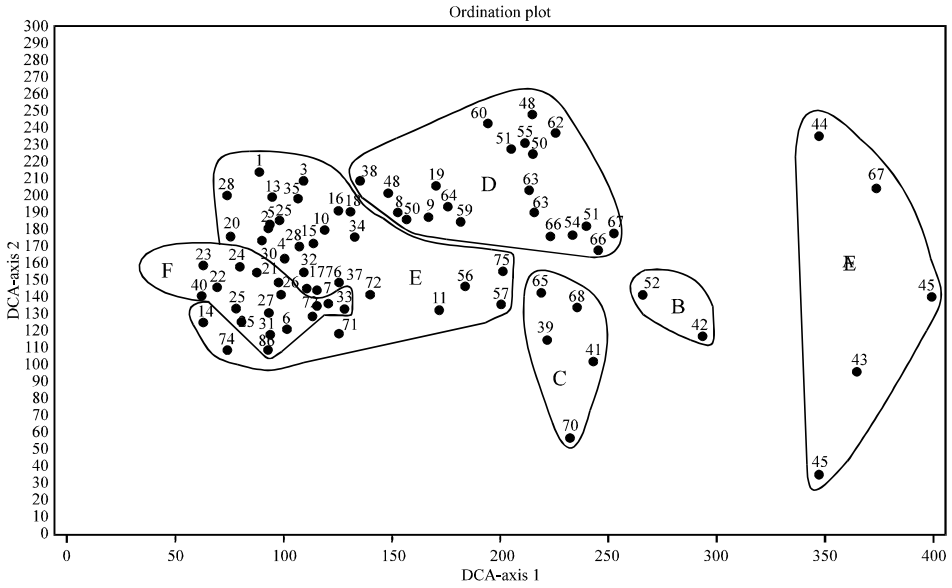

Fig. 3: Detrened Correspondence Analysis (DCA) ordination of the 80 stands with vegetation groups superimposed

Table 2: Mean and standard error of the different sediment variables in the stands representing the different vegetation groups obtained by TWINSPAN classification

	Group					
Soil variable	A	B	C	D	E	F
(%)						
Sand	93.4±3.12	94.00±4.00	94.00±3.35	91.40±1.48	87.70±1.05	87.00±0.98
Silt	5.20±2.96	4.50±3.50	4.80±2.85	7.30±1.48	10.92±1.04	11.27±0.97
Clay	1.40±0.24	1.50±0.50	1.20±0.58	1.30±0.22	1.65±0.12	1.37±0.19
W.H.C	45.27±2.92	46.87±8.47	51.85±11.10	55.03±3.00	57.89±1.54	56.77±3.74
$CaCO_3$	11.60±3.77	14.50±4.50	18.60±2.10	12.43±2.10	8.04±0.89	8.91±1.84
O.C	1.04±0.21	1.50±0.66	0.85±0.18	1.28±0.14	1.19±0.10	1.47±0.28
pH	8.43±0.11	8.36±0.09	8.05±0.19	8.14±0.13	8.20±0.08	8.13±0.14
EC (μmhos cm^{-1})	1494.40±587.12	561.00±216.00	758.74±439.21	1252.52±352.87	618.61±161.24	431.57±114.02
(%)						
Cl^-	0.34±0.11	0.08±0.03	0.17±0.04	0.22±0.07	0.10±0.04	0.04±0.01
SO_4^--	0.29±0.06	0.18±0.06	0.73±0.24	0.54±0.12	0.35±0.06	0.22±0.04
(mg l^{-1})						
T.N	0.32±0.03	0.33±0.15	0.30±0.05	0.36±0.04	0.24±0.02	0.16±0.02
T.P	6.15±1.87	5.77±2.36	2.61±0.68	3.63±0.70	1.60±0.35	1.24±0.15
mg/100 g dry soil						
Na^+	3241.20±1120.7	565.50±76.50	367.90±158.05	1335.64±304.20	385.14±66.19	363.94±138.40
K^+	237.05±74.00	193.35±26.35	94.24±36.99	208.11±53.41	45.38±5.53	31.30±4.42
Ca^{++}	179.40±66.51	359.65±238. 35	56.10±20.49	229.88±69.11	97.05±24.33	40.59±10.49
Mg^{++}	138.22±43.73	55.30±21.90	102.40±24.13	221.17±131.98	79.17±19.90	89.42±53.94
SAR	265.83±55.91	49.81±23.19	40.55±17.40	130.76±38.85	48.79±8.01	43.21±15.75
PAR	18.19±3.16	17.04±7.95	10.50±3.45	19.58 + 5.58	5.37±0.57	4.84±093

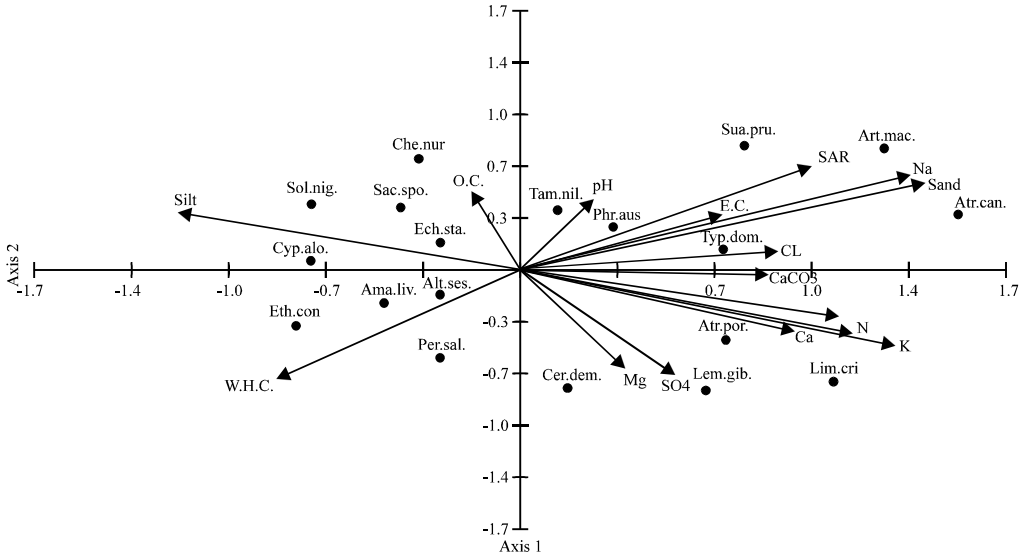

Fig. 4: Canonical Correspondence Analysis (CCA) ordination diagram with sediment variables represented by arrows. The indicator and preferential species are abbreviated to the first three letters of each of the genus and species

(IV = 8.47), *Atriplex canescens* (IV = 6.45) and *Ceratophyllum demersum* (IV = 5.08).

Group D consists of 20 stands codominated by *Phragmites australis* (IV = 13.93), *Typha domingensis* (IV = 12.29) and *Eichhornia crassipes* (IV = 10.67). The important species in this group include *Echinochloa stagnina* (IV = 6.66) and *Ceratophyllum demersum* (IV = 6.41), while the identified indicator species are *Bassia indica* (IV = 1.54) and *Limbarda crithmoides* (IV = 1.46).

Group E includes 37 stands codominated by *Phragmites australis* (IV = 11.49), *Echinochloa stagnina* (IV = 8.82) and *Eichhornia crassipes* (IV = 8.79). The common species in this group comprise *Pluchea dioscoridis* (IV = 5.29) and *Saccharum spontaneum* (IV = 5.07). The indicator species identified in this group are numerous such as *Ipomoea carnea* (IV = 3.01), *Conyza bonariensis* (IV = 1.82) and *Alhagi graecorum* (IV = 1.52).

Group F comprises 11 stands codominated by *Eichhornia crassipes* (IV = 10.10) and *Phragmites australis* (IV = 9.03). The important species in this group include *Saccharum spontaneum* (IV = 7.75), *Imperata cylindrica* (IV = 6.57), *Echinochloa stagnina* (IV = 6.44), *Chenopodium murale* (IV = 6.24) and *Cynodon dactylon* (IV = 6.11), while the indicator species is *Typha domingensis* (IV = 2.47).

Vegetation ordination: The Detrended Correspondence Analysis (DCA) of the sampled stands is shown in Fig. 3. Vegetation group A is separated at the outermost right side of the DCA diagram. Groups B, C and D are segregated at the middle part of the diagram, while groups E and F are segregated at the left side of the DCA diagram. It is obvious that, the vegetation groups A, B and C are markedly distinguishable and having a clear pattern of segregation on the ordination plane, while groups D, E and F are superimposed.

Vegetation-environment relationships: Variation in sediment factors of the vegetation groups: The sediment factors of the six vegetation groups identified by TWINSPIN classification are summarized in Table 2. The soil texture in all groups is formed mainly of sand and partly of silt and clay. The highest mean value of water-holding capacity is recorded in group E and the lowest found in group A. The mean percentages of calcium carbonate were generally higher in groups A, B, C and D than in groups E and F. The organic carbon content was obviously comparable in all groups and the soil reaction was slightly alkaline. The highest mean values of electrical conductivity, chloride, total phosphorus, sodium, potassium and sodium adsorption ratio were attained in group A and the lowest mean values of these variables were attained in group F expect SAR in group C. Sulphate content attained its highest mean value in group C and the lowest one in group B. The highest mean values of total nitrogen and calcium were recorded in group B and the lowest values in group F, while the highest mean values of magnesium and potassium adsorption ratio were recorded in group D.

Table 3: Pearson-moment correlation (r) between the different sediment variables in the stands surveyed in the study area. W.H.C = Water-holding capacity, EC = Electrical conductivity, O.C = Organic carbon, SAR = Sodium adsorption ratio, T.N = Total nitrogen, PAR = Potassium adsorption ratio and T.P = Total phosphorus

Sand	1.000																	
Silt	-0.984	1.000																
Clay	-0.312	0.252	1.000															
W.H.C	-0.476	0.427	0.419	1.000														
O.C	-0.016	0.041	0.210	-0.055	1.000													
$CaCO_3$	0.236	-0.252	-0.024	-0.037	0.000	1.000												
Cl^-	0.177	-0.098	0.258	-0.165	0.341	0.121	1.000											
SO_4^{--}	0.084	-0.016	-0.033	0.078	0.252	0.050	0.428	1.000										
T.N	0.007	0.021	-0.035	-0.018	0.021	0.225	0.169	0.098	1.000									
T.P	0.135	-0.119	-0.080	-0.157	-0.100	0.308	0.222	-0.067	0.462	1.000								
pH	0.041	-0.040	-0.366	-0.322	-0.056	-0.114	-0.154	-0.199	0.102	0.200	1.000							
EC	0.180	-0.121	0.231	0.079	0.364	0.157	0.727	0.609	0.099	0.161	-0.148	1.000						
Na^+	0.047	-0.068	0.062	-0.120	0.044	0.228	0.266	-0.035	0.194	0.551	0.046	0.162	1.000					
K^+	0.257	-0.260	-0.121	-0.040	-0.059	0.204	0.112	0.226	0.196	0.364	-0.050	0.349	0.565	1.000				
Ca^{++}	0.266	-0.296	0.087	-0.125	0.192	0.247	0.278	0.102	0.212	0.105	-0.015	0.234	0.301	0.354	1.000			
Mg^{++}	0.105	-0.104	-0.047	-0.019	-0.005	0.147	-0.031	-0.046	0.196	0.086	-0.126	0.018	0.229	0.570	0.209	1.000		
SAR	-0.107	0.093	0.035	-0.040	-0.002	0.081	0.162	-0.031	0.139	0.466	0.047	0.046	0.880	0.458	0.022	0.019	1.000	
PAR	0.192	-0.184	-0.197	0.012	-0.055	0.078	0.090	0.277	0.067	0.293	-0.016	0.353	0.410	0.855	0.056	0.253	0.448	1.000
	Sand	Silt	Clay	W.H.C	O.C	$CaCO_3$	Cl^-	SO_4^{--}	T.N	T.P	pH	EC	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR

Significant at p = 0.05 = 0.4438, significant at p = 0.01 = 0.5614 and significant at p = 0.001 = 0.6787.

Table 4: Mean and standard error of the different water variables in the stands representing the different vegetation groups obtained by TWINSPAAN classification in the study area

	Group					
Water variable	A	B	C	D	E	F
pH	8.29±0.13	8.07±0.35	8.64±0.28	8.43±0.12	8.25±0.07	8.42±0.14
EC (μmhos cm^{-1})	5752.00±521.66	3550.00±1979.52	1741.60±539.39	2332.38±652.81	1260.19±411.43	1163.21±955.25
(%)						
O.C	0.43±0.04	0.39±0.09	0.76±0.11	0.87±0.21	0.40±0.04	0.64±2.05
DO_2	56.54±2.52	57.90±0.20	68.36±7.58	62.01±2.32	64.41±1.74	68.12±2.05
Cl-	2.99±0.34	1.13±0.48	0.58±0.24	0.31±0.04	0.24±0.02	0.17±0.02
SO_4^--	0.82±0.05	0.42±0.08	0.49±0.09	4.02±0.71	1.29±0.31	0.80±0.17
mg l^{-1}						
T.N	0.26±0.03	0.22±0.13	0.21±0.05	0.71±0.13	0.31±0.12	0.48±0.46
T.P	5.87±1.30	2.41±0.00	2.48±0.58	0.49±0.11	0.34±0.04	0.34±0.09
Na^+	1938.40±292.37	983.00±309.00	270.70±98.69	526.94±124.26	341.78±322.87	341.78±322.87
K^+	75.04±15.15	31.57±12.94	21.62±5.39	34.49±8.42	18.76±10.03	18.76±10.03
Ca^{++}	70.86±7.44	104.50±68.70	17.48±7.97	28.82±7.02	40.58±17.10	40.58±17.10
Mg^{++}	106.38±9.30	73.90±18.60	33.31±10.49	38.85±8.23	28.41±12.44	28.41±12.44
SAR	206.12±31.18	102.51±18.36	55.59±20.10	114.24±36.58	36.60±14.60	33.71±26.47
PAR	7.98±1.66	3.65±1.91	4.73±1.16	7.20±2.15	2.69±0.30	3.16±0.91

The correlation coefficient (r) between the different sediment variables in the sampled stands is presented in Table 3. It showed that, some hydrosoil factors are significantly correlated with each other such as fine fraction (silt), water-holding capacity, total phosphorus, electrical conductivity, sodium, potassium, magnesium, sodium and potassium adsorption ratios. Other hydrosoil characteristics have no correlations with any variables.

Table 5: Pearson-moment correlation (r) between the different water variables in the stands surveyed in the study area. EC = Electrical conductivity, T.P = Total phosphorus, O.C. = Organic carbon, SAR = Sodium adsorption ratio, T.N = Total nitrogen, PAR = Potassium adsorption ratio and DO2 = Dissolved oxygen.

pH	1.000													
EC	0.141	1.000												
O.C	0.242	0.426	1.000											
DO_2	0.254	-0.307	-0.161	1.000										
T.N	-0.140	-0.155	-0.040	-0.262	1.000									
T.P	-0.144	0.255	-0.020	-0.316	0.300	1.000								
Cl^-	0.080	0.712	0.113	-0.266	-0.105	0.384	1.000							
SO_4^{--}	0.199	0.760	0.498	-0.135	-0.184	0.210	0.553	1.000						
Na^+	0.086	0.600	0.056	-0.176	0.026	0.434	0.866	0.442	1.000					
K^+	0.186	0.419	0.177	-0.216	0.061	0.292	0.634	0.296	0.621	1.000				
Ca^{++}	-0.186	0.449	0.130	-0.198	-0.050	0.192	0.572	0.194	0.504	0.455	1.000			
Mg^{++}	0.032	0.461	0.014	-0.342	0.095	0.186	0.661	0.272	0.630	0.594	0.487	1.000		
SAR	0.149	0.458	0.095	-0.071	0.110	0.450	0.645	0.415	0.837	0.508	0.216	0.320	1.000	
PAR	0.265	0.213	0.171	-0.023	0.059	0.185	0.324	0.218	0.369	0.810	0.076	0.149	0.545	1.000
	pH	EC	O.C	DO_2	T.N	T.P	Cl^-	SO_4^{--}	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR

Significant at p = 0.05 = 0.4973, Significant at p = 0.01 = 0.6226 and Significant at p = 0.001 = 0.7420

Variation in water factors of the vegetation groups: The water variables of the identified six vegetation groups are presented in Table 4. The water reaction was slightly alkaline as in the sediment. The highest mean values of electrical conductivity, chloride, total phosphorus, sodium, potassium, magnesium, SAR and PAR were attained in group A, while the lowest mean values of these variables were attained in group F except Na in group C and PAR in group E. The highest mean values of organic carbon, sulphate and total nitrogen were estimated in group D, but the lowest mean values of these factors were attained in group B except total nitrogen in group C. It appears that, the water characteristics of the identified six vegetation groups are obviously in accordance with the sediment characteristics of the same groups.

The correlation coefficient (r) between different water variables in the sampled stands is presented in Table 5. Most water variables are significantly correlated with each other such as chloride, sulphate, sodium, potassium, calcium, magnesium, sodium and potassium adsorption ratios. While the pH value, electrical conductivity, organic carbon, dissolved oxygen, total nitrogen and phosphorus have no correlations with any other water characteristics.

Correlation between sediment factors and vegetation gradients: The relationship between vegetation and sediment variables is indicated on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot of species-sediment factors (Fig. 4). It is clear that, the concentrations of sodium, potassium and calcium as well as the percentages of sand, silt, SAR, PAR, water-holding capacity, chloride, calcium carbonate, electrical conductivity and sulphate were the most effective sediment variables which showed a high significant correlations with the first and second axes of CCA ordination diagram. The codominant species of the most identified groups namely, *Phragmites australis, Typha domingensis* and *Arthrocnemum macrostachyum* as well as the important species *Suaeda pruinosa*, *Atriplex canescens* and *Tamarix nilotica* were separated at the right side of CCA-biplot diagram. These species showed a close relationship with sodium, sand, SAR, chloride, electrical conductivity and pH value. The associated canal bank species *Chenopodium murale*, *Solanum nigrum*, *Cyperus alopecuroides* and *Ethulia conyzoides* were segregated at the left side of the CCA diagram and exhibited distinct relationship with silt, water-holding capacity, clay and organic carbon.

Correlation between water factors and vegetation gradients: The relationship between vegetation and water variables is indicated on CCA ordination diagram (Fig. 5). It is obvious that, chloride, total phosphorus, sodium, SAR, potassium, PAR, magnesium, sulphate, electrical conductivity and calcium were the most important water factors which exhibited a very high significant correlations with the first and second axes of the CCA-biplot diagram. *Phragmites australis* (codominant species in all vegetation groups), *Arthrocnemum macrostachyum*

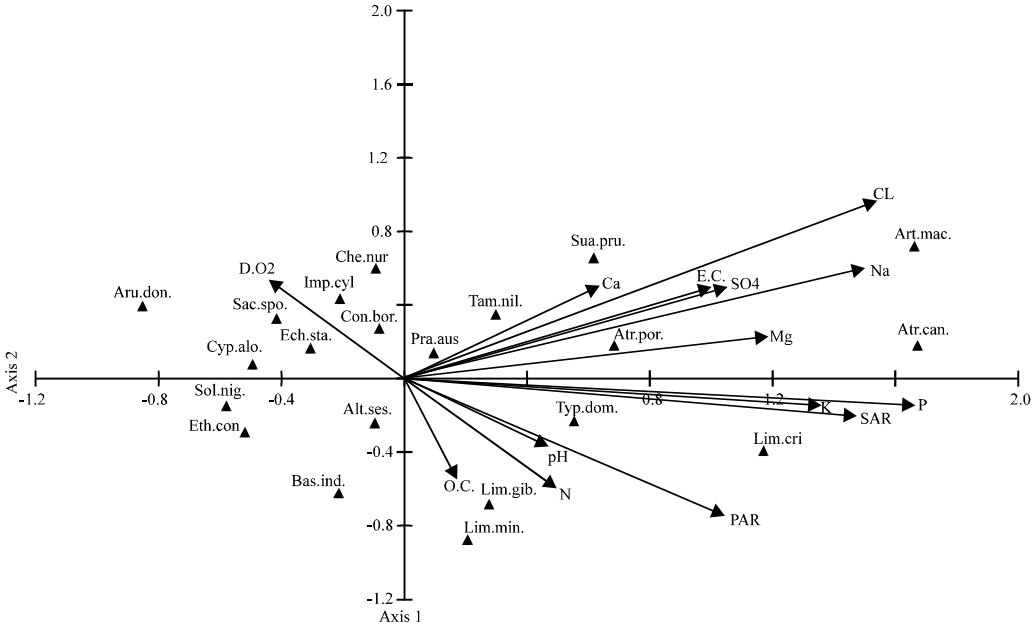

Fig. 5: Canonical Correspondence Analysis (CCA) ordination diagram with water variables represented by arrows. The indicator and preferential species are abbreviated to the first three letters of each of the genus and species

(codominant species in groups A and B), *Atriplex canescens* (important species in groups A and C), *Suaeda pruinosa* (important species in group B), *Tamarix nilotica* (recorded in 5 groups) and *Atriplex prostrata* (indicator species in group E) were collectively separated at the upper right side of the CCA diagram as the same in the sediment CCA diagram. These species are also showed a close relationship with chloride, sodium, magnesium, sulphate, electrical conductivity and calcium. However, *Typha domingensis* (codominant species in groups A, B and D), *Ludwigia stolonifera* (indicator species in groups D and E), *Lemna gibba* and *lemna minor* (indicator species in group D) and *Limbarda crithmoides* (recorded in 5 groups) were segregated at the lower right side of the CCA diagram. These species showed a distinct relationship with total phosphorus, SAR, potassium, PAR, total nitrogen, pH value and organic carbon.

DISCUSSION

The water bodies in the Nile system in Egypt are populated by communities of macrophytes which spread very rapidly and fill up the whole of many water bodies. Thus, water flow is noticeably hampered, so that either chemical, mechanical or biological maintenance is required [4].

The vegetation in the present study is distinguished by TWINSPAN classification into six groups (A-F). These groups are obviously representing a special type of the surveyed water bodies in the Nile region of Egypt. Group A may represent the habitat type of Lake Manzala in which the identified codominant species are a mixture of reeds (*Phragmites australis* and *Typha domingensis*) and halophytes (*Arthrocnemum macrostachyum*), while the indicator species is *Cyperus rotundus*. Group B represents the habitat of Lake Borollus which is codominated by the same vegetation types of group A, but it is characterized by the free floating hydrophyte *Eichhornia crassipes* as an indicator species. Group C represents the habitat of Lake Idku which is codominated by *Phragmites australis* and *Eichhornia crassipes*, the former plant is also identified as an indicator species in this group. Group D may represent the habitats of both Lake Borollus and Lake Idku. This group is codominated by *Phragmites australis*, *Typha domingensis* and *Eichhornia crassipes*. The indicator species in this group are *Limbarda crithmoides* and *Bassia indica*. Group E is the largest among all identified vegetation groups and represents the habitats of the main River Nile stream, irrigation and drainage canals. This group is codominated by the emerged hydrophytes *Phragmites australis* and *Echinochloa stagnina* and floating hydrophyte *Eichhornia crassipes*. The indicator species in this group are numerous canal bank species such as *Ipomoea carnea*, *Arundo donax*, *Alhagi graecorum* and *Conyza bonariensis*. Group F represents the habitats of Damietta

and Rosetta branches of the River Nile which is codominated by *Eichhornia crassipes* and *Phragmites australis*, while *Typha domingensis* is identified as indicator species.

The identified groups in the present work can be classified into two main categories: (a) the first category represents the northern lakes (Manzala, Borollus and Idku) which includes groups A, B, C and D and (b) the second category represents the irrigation and drainage canals, Damietta and Rosetta branches and the main River Nile stream which comprises groups E and F. These six groups can be also categorized according to the floristic association system of Branun-Blanquet [30] into the two classes namely *Phragmitetea* and *Arthrocnemetea*. The first class is adapted to wide moisture gradients extending from canal bank to open water habitats. This class may include most of the communities in the ruderal habitats such as roadsides, railways, waste grounds and abandoned fields in the Nile Delta region. The characteristic species which may be related to class *Phragmitetea* in the present work are *Phragmites australis*, *Typha domingensis*, *Eichhornia crassipes*, *Echinochloa stagnina*, *Cyperus alopecuroides* and *Imperata cylindrica*. The second class (*Arthrocnemetea*) is generally occupying the median positions along the moisture gradients of the brackish and saline water bodies. The characteristic species which may be related to this class in the present study are *Arthrocnemum macrostachyum, Atriplex canescens*, *Limbarda crithmoides*, *Suaeda pruinosa* and *Tamarix nilotica*. The comparison of these two classes (*Phragmitetea* and *Arthrocnemetea*) with the previous related studies indicated that, these classes did not resemble the same classes described by Van Groenendael *et al.* [31] in the study on water bodies in Europe. However, the associations of vegetation in the present study may be related to the associations described by Montasir [32] in his study on Lake Manzala, by Tadros [33] in the study of halophilous communities from Maruit and by Zohary [34] as reviewed in the geobotanical foundations of the Middle East. In recent studies, the vegetation groups identified in the present investigation may be similar to the vegetation groups described by El-Sheikh [35, 36], Al-Sodany [37, 38], Zahran *et al.* [4, 39], Khedr and El-Demerdash [13], Mashaly *et al.* [17], Maswada [40], Shaltout *et al.* [41, 42] and Omar [43].

The ordination of the sampled stands in the present study obtained by Detrended Correspondence Analysis (DCA) indicated that, groups A and B are more or less related to each other, groups C and D are closely related and groups E and F showed the most distinct relationship. These specific relationships between the above mentioned pairs of vegetation groups may be due to the close similarities of their floristic composition and natural habitats. However, CCA biplot ordination diagrams indicated that, *Phragmites australis* as a codominant species in all obtained vegetation groups (A-F) and *Arthrocnemum macrostachyum* as another codominant species in two groups (A and B) showed close relationship with chloride, sodium, magnesium, sulphate, electrical conductivity and calcium. For, *Typha domingensis* as the third codominant species in three vegetation groups (A, B and D) exhibited a distinct relationship with total phosphorus, potassium, sodium and potassium adsorption ratios, total nitrogen, pH value and organic carbon. *Eichhornia crassipes* as an important codominant species in four groups (C, D, E and F) does not show any distinguishable correlation with any of the water or sediment variables. For *Echinochloa stagnina* as a codominant species in only one group (E) showed special type of relationship with dissolved oxygen.

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