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Ecological Studies on the Aquatic Vegetation in North East Nile Delta, Egypt

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Abstract: The present research comprises an investigation of the vegetation analysis, a quantitative assessment of the soil and water characteristics and an evaluation of the relationship between the major identified vegetation groups and the environmental attributes of the canals, drains and their wet shorelines at four governorates in North East Nile Delta, namely: Damietta, El Dakahlya, El Sharkia and Al Qaliopia. Vegetation, soil and water were sampled in 65 representative stands. The floristic categories, life span and life-forms of the recorded species were described. The soil and water characteristics were determined for each stand. The vegetation analysis was carried out using the multivariate techniques. The classification (TWINSPAN) and ordination (DCA) techniques of the stands led to recognition of four vegetation groups: group A codominated by *Veronica anagallis-aquatica*, *Potulaca oleracea* and *Cynodon dactylon*, group B codominated by *Rumex dentatus*, *Phragmites australis* and *Cynodon dactylon*, group C codominated by *Phragmites australis* and *Echinochloa stagnina* and group D codominated by *Phragmites australis* and *Bolboschoenus glaucus.* Canonical Correspondence Analysis (CCA) was applied to detect the main environmental factors influencing the vegetation groups. The electrical conductivity, calcium, sodium, potassium, magnesium, total nitrogen, chlorides and bicarbonates are the most effective environmental variables, which showed significant correlations with the first and second ordination axes. Accordingly, these soil and water variables seem to be the major ecological factors control the distribution of vegetation in the study area.

Key words: Aquatic vegetation, environmental variables

INTRODUCTION

The irrigation and drainage systems of the Egyptian cultivated land comprise approximately 47000 km of waterways (El-Sherbeny, 2003). The canals and drains are infested with most types of aquatic weeds. The increasing spread of aquatic weeds was attributed to the deep penetration of sun-light in water, decrease of water fluctuations and less disturbed habitat was created, increasing fertilization of farm land and pesticides application lead to eutrophication of canals and drains, excess of algal growth leading to deoxygenation of water and increasing pollution from industrial centers and human activities along canals and drains cause environmental physico-chemical alteration (Seiki *et al*., 1991; Edwin, 1996; Khedr and El-Demerdash, 1997; Wang *et al*., 1997). The problems created by these plants are many such as, constituting a health hazard by providing mosquitoes larvae with an ideal breeding place, causing oxygen depletion, 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 (Idso, 1981; Zahran *et al*., 1998). Aquatic plants have received great attention, not only for the magnitude of problems caused by them in the management of water resources, but also for promise they hold as a new source, for such diverse uses as animal feed, compost, paper, fiber, bioenergy and above all the possibility of using them as biofilter for improving water quality and removing heavy metals (Pieterse and Murphy, 1990; Sajwan and Ornes, 1997; Rice *et al*., 1997; Samecka-Cyerman and Kempers, 2001; El-Sherbeny, 2003). Various ecological studies have been concerned with aquatic and canal banks weeds in the Nile Delta as example Shaltout and El-Sheikh (1991) and Shaltout *et al.* (1994) gave information about the vegetation of some canals and drains along Cairo-Alexandria agriculture road. Also, they evaluated the behavior of some common species distributed along canals and drains in the middle of Nile Delta. Shalaby (1995) recorded the flora of canals banks at Kafr El-Sheikh governorate. The vegetation analysis of canals, drains and lacks of northern part of Nile Delta region was studied by Al-Sodany (1998). To evaluate the relationship between the vegetation components of canals, drains and shorelines in Northeast Nile Delta and their environmental conditions, the multivariate techniques (classification and ordination) have been used.

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MATERIALS AND METHODS

Sixty-five sampling stands were selected to cover the irrigation and drainage canals in the study area (Fig. 1). The sampling processes of the plants, soil and water have been carried out during the year 2005-2006. In each stand, the plant species were recorded in five plots (25 m^2 each). The identification and nomenclature of the plants were following Tackholm (1974) and Boulos (1999-2005). The description and classification of life forms were according to Raunkiaer (1937). The soil samples were collected at a depth of 0-20 cm then dried, thoroughly mixed and passed through a 2 mm sieve to be ready for physical and chemical analyses. Soil texture was determined using sieve method for coarse soil and Bouyoucous hydrometer for the heavy soil samples. Moisture content, porosity and water holding capacity were determined according to Piper (1947). Organic carbon was determined using Walkly and Black rapid titration method (Black, 1979). Calcium carbonate was determined as described by Jackson (1962). Soil salinity (EC) and soil reaction (pH) were estimated in 1:5 soil-water extract using the conductivity and pH meters, respectively. Chloride was determined by titration against N/35.5 $AgNO_3$. Sulphate was estimated gravimetrically using 5% barium chloride. Carbonate and bicarbonate were determined using 0.1 N HCl. The cations Na^+, K^+, Ca^{++}, Mg^{++} were estimated using flame photometer as described by Allen *et al.* (1974).

The chemical characteristics of the water samples were determined according to the methods previously applied in the soil analysis.

Two trends of multivariate analysis were applied, namely; classification and ordination. The classification technique applied here was the two-way indicator species analysis TWINSPAN-a fortran program (Hill, 1979; Gauch, 1982). While ordination techniques applied were the Detrended Correspondence Analysis (DCA) and the Canonical Correspondence Analysis (CCA) using CANOCO-a fortran program (Ter Braak, 1987, 1988). The relationships between vegetation gradients and environmental variables can be indicated on the ordination diagram produced by Canonical Correspondence Analysis (CCA biplot), on which points represent species and arrows represent environmental variables. The angle between an arrow and each axis is a reflection of its degree of correlation with the axis. The statistical treatments applied were according to Snedecor and Cochran (1967) and Nie *et al.* (1975).

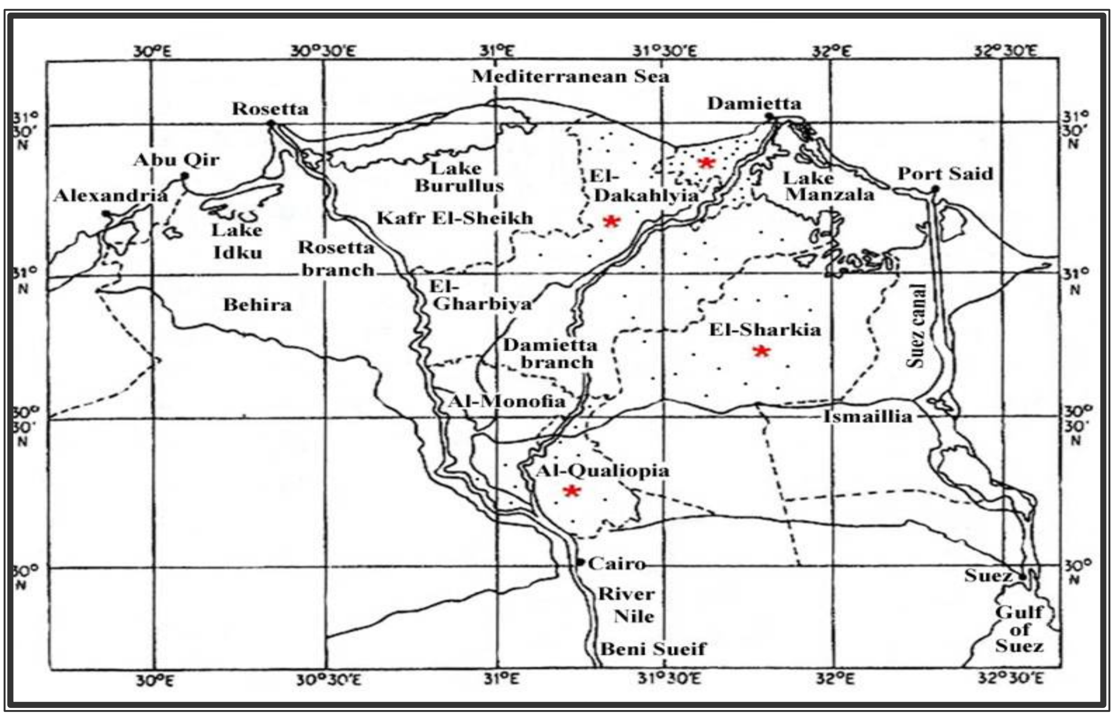

Fig. 1: Location map showing the selected stands (●) of the different governorates (*) in the study area

RESULTS

Floristic composition and features: The vegetation analysis of the selected stands revealed that, the total number of hydrophytic and canal bank species was 116 (Table 1). The recorded species in the different governorates were 71 in Damietta, 49 in El Dakahlyia, 44 in El Sharkia and 62 in Al Qaliopia. These species could be classified into three major groups according to their duration (life span): 67 perennials (57.76%), 5 biennials (4.31%) and 44 annuals (37.93%). Out of the perennials, sixteen species have wide ecological amplitude; they have been recorded in the four governorates. The five biennials have been recorded only in Damietta, El Sharkia and

Table 1: Floristic composition and distribution of the plant life in the study area

				Governorate					
No.	Species	Life form	Floristic category	Dam.	Dak.	Sha.	Qua.	P	P%
Perennials									
1	*Cynanchum acutum* L.	H	ME+IR-TR	+	+	+	+	4	100
2	*Cynodon dactylon* (L.) Pers.	G	COSM	+	+	+	+	4	100
3	*Cyperus alopecuroides* Rottb.	He	PAN	+	+	+	+	4	100
4	*Cyperus rotundus* L.	G	PAN	+	+	+	+	4	100
5	*Echinochloa stagnina* (Retz.) P.Beauv	Th	PAN	+	+	+	+	4	100
6	*Eichhornia crassipes* (Mart.) Solms.Laub	Hy	NEO	+	+	+	+	4	100
7	*Lemna gibba* L.	Hy	COSM	+	+	+	+	4	100
8	*Persicaria lapthifolia* Willd.	G	PAL	+	+	+	+	4	100
9	*Persicaria salicifolia* Brouss ex Willd.	G	PAL	+	+	+	+	4	100
10	*Phragmites australis* (Cav.) Trin. Exsteud	G, He	COSM	+	+	+	+	4	100
11	*Plantago major* L.	H	COSM	+	+	+	+	4	100
12	*Pluchea dioscoridis* (L.) DC	Ph	S-Z+SA-SI	+	+	+	+	4	100
13	*Polypogon viridis* (Gouan) Breistr	H	ME+IR-TR+ER-SR	+	+	+	+	4	100
14	*Saccharum spontaneum* L.	G, He	ME+PAL	+	+	+	+	4	100
15	*Typha domingensis* Pers.	He	PAN	+	+	+	+	4	100
16	*Veronica anagallis-aquatica* L.	He	COSM	+	+	+	+	4	100
17	*Arundo donax* L.	He, G	Cult. and Nat.	-	+	+	+	3	75
18	*Convolvoulus arvensis* L.	H	COSM	-	+	+	+	3	75
19	*Imperata cylindrica* (L.) Beauv.	H	PAL	+	-	+	+	3	75
20	*Leersia hexandra* Swartz	He	PAN	+	+	+	-	3	75
21	*Ludwigia stolonifera* (Guill et Perr)	He	S-Z	+	+	-	+	3	75
22	*Myriophyllum spicatum* L.	Hy	ER-SR+ME+IR-TR	-	+	+	+	3	75
23	*Sorghum virgatum* (Hack) Stapf	G	SA-SI	-	+	+	+	3	75
24	*Symphyotrichum squamatum* (Spreng.) Nesom	Ch	NEO	+	+	+	-	3	75
25	*Alhagi graecorum* Boiss	H	PAL	+	-	-	+	2	50
26	*Brachiaria mutica* (Forssk.) Stapf	H	PAN	+	-	-	+	2	50
27	*Ceratophyllum demersum* L.	Hy	COSM	+	+	-	-	2	50
28	*Cyperus laevigatus* L.	G, He	PAL	+	-	+	-	2	50
29	*Ipomoea carnea* Jacq.	Ch	PAN	-	+	+	-	2	50
30	*Nymphaea lotus* L. var. *aegyptia* Tuzs	Hy	PAL	+	+	-	-	2	50
31	*Panicum repens* L.	G	PAN	+	-	+	-	2	50
32	*Paspalum distichum* L.	G	PAN	+	+	-	-	2	50
33	*Phyla nodiflora* (L.) Greene	Ch	PAN	+	-	-	+	2	50
34	*Ricinus communis* L.	Ph	Cult. and Nat.	-	+	+	-	2	50
35	*Alternanthera sessilis* (L.) DC.	He	PAN	+	-	-	-	1	25
36	*Arthrocnemum macrostachyum* (Moric.) Moris et Delponte	Ch	ME+SA-SI	+	-	-	-	1	25
37	*Atriplex portulacoides* L.	Ch	ME+ER-SR+IR-TR	+	-	-	-	1	25
38	*Bolboschoenus glaucus* (Lam.) S. G. Smith	G	COSM	+	-	-	-	1	25
39	*Bromus catharticus* Vahl	G	ER-SR+ME+IR-TR	-	-	-	+	1	25
40	*Cressa cretica* L	H	ME+PAL	+	-	-	-	1	25
41	*Cyperus articulatus* L.	G, He	PAL	+	-	-	-	1	25
42	*Desmostachya bipinnata* (L.) Stapf	H	S-Z+SA-SI+ME+IR-TR	-	-	-	+	1	25
43	*Dichanthium annulatum* (Forssk.) Stapf	H	PAN	-	-	-	+	1	25
44	*Juncus acutus* L.	He	ME+IR-TR+ER-SR	+	-	-	-	1	25
45	*Juncus rigidus* Desf.	G, He	ME+SA-SI+IR-TR	+	-	-	-	1	25
46	*Leptochloa fusca* (L.) Kunth	G, He	PAL	+	-	-	-	1	25
47	*Limbarda crithmoides* (L.) Dumort.	Ch	ME+IR-TR+ER-SR	+	-	-	-	1	25
48	*Marsilea aegyptiaca* L.	H	PAL	+	-	-	-	1	25
49	*Mentha longifolia* (L.) Huds.	He	PAL	-	-	-	+	1	25
50	*Myrtus communis* L.	Ph	Cult. and Nat.	-	+	-	-	1	25
51	*Oxalis corniculata* L.	H	COSM	-	-	-	+	1	25
52	*Oxystelma esculentum* (L.f.) R.Br.	Ph	S-Z+SA-SI	-	-	-	+	1	25
53	*Paspalidium geminatum* (Forssk.) Stapf.	He	PAL	+	-	-	-	1	25
54	*Pennisetum setaceum* (Forssk.) Chiov.	H	ME+PAL	-	+	-	-	1	25
55	*Persicaria lanigera* (R. Br.) Soják	G	PAL	-	-	-	+	1	25

Table 1: Continued

No.	Species	Life form	Floristic category	Governorate Dam.	Dak.	Sha.	Qua.	P	P%
56	*Pistia stratiotes* L.	Hy	PAN	+	-	-	-	1	25
57	*Polygonum equisetiforme* Sibthi and Sm.	G	ME+IR-TR	+	-	-	-	1	25
58	*Potamogeton nodosus* Poir.	Hy	ME+IR-TR	-	-	-	+	1	25
59	*Schoenoplectus litoralis* (Schrad.) Palla	G	ME+PAL	+	-	-	-	1	25
60	*Sesbania sesban* (L.) Merr.	Ph	PAL	-	-	-	+	1	25
61	*Silybum marianum* (L.) Gaertn	H	ME+IR-TR+ER-SR	-	+	-	-	1	25
62	*Sonchus macrocarpus* Boulus et. C. Jeffrey	Ch	Egypt (endemic)	+	-	-	-	1	25
63	*Sporobolus pungens* (Schreb.) Kunth	G	PAN	+	-	-	-	1	25
64	*Suaeda pruinosa* Lang.	Ch	ME	+	-	-	-	1	25
65	*Suaeda vera* Forssk. ex. J. F. Gmelin	Ch	ME+SA-SI+ER-SR	+	-	-	-	1	25
66	*Tamarix nilotica* (Ehrenb.) Bge	Ph	SA-SI+S-Z	+	-	-	-	1	25
67	*Withania somnifera* (L.) Dunal	Ch	SA-SI+S-Z	-	-	-	+	1	25
Biennials									
1	*Apium graveolens* L.	Th	ME+ER-SR+IR-TR	+	-	-	-	1	25
2	*Chenopodium ambrosioides* L.	Th	COSM	-	-	+	-	1	25
3	*Rorippa palustris* (L.) Besser	Th	ME+ER-SR+IR-TR	-	-	-	+	1	25
4	*Sesbania sericea* (Willd.) Link	Th	PAL	-	-	-	+	1	25
5	*Spergularia marina* (L.) Griseb.	Th	ER-SR+ME+IR-TR	+	-	-	-	1	25
Annuals									
1	*Echinochloa crus-galli* (L.) P.Beauv	G, He	PAL	+	+	+	+	4	100
2	*Eclipta prostrata* (L.) L.	Th	NEO	+	+	+	+	4	100
3	*Ethulia conyzoides* L.	Th	PAL	+	+	+	+	4	100
4	*Malva parviflora* L.	Th	ME+IR-TR	+	+	+	+	4	100
5	*Rumex dentatus* L.	Th	ME+IR-TR+SA-SI	+	+	+	+	4	100
6	*Solanum nigrum* L.	Th	COSM	+	+	+	+	4	100
7	*Sonchus oleraceus* L.	Th	COSM	+	+	+	+	4	100
8	*Chenopodium murale* L.	Th	COSM	+	-	+	+	3	75
9	*Polypogon monspeliensis* (L.) Desf	Th	COSM	+	-	+	+	3	75
10	*Amaranthus lividus* L.	Th	ME+IR-TR	-	+	+	-	2	50
11	*Amaranthus tricolor* L.	Th	PAL	-	-	+	+	2	50
12	*Conyza bonariensis* (L.) Crong.	Th	NEO	+	-	-	+	2	50
13	*Cyperus difformis* L.	Th	PAL	+	-	+	-	2	50
14	*Echinochloa colona* (L.) Link	Th	PAN	-	+	+	-	2	50
15	*Melilotus indicus* (L.) All.	Th	ME+IR-TR+SA-SI	-	+	-	+	2	50
16	*Portulaca oleracea* L.	Th	COSM	-	+	+	-	2	50
17	*Ranunculus sceleratus* L.	Th	ME+IR-TR+ER-SR	+	-	-	+	2	50
18	*Rumex pictus* Forssk.	Th	ME+SA-SI	+	+	-	-	2	50
19	*Senecio aegyptius* L.	Th	ER-SR+ME+IR-TR	-	+	+	-	2	50
20	*Torilis nodosa* (L.) Gaertn.	Th	ME+IR-TR+ER-SR	-	-	+	+	2	50
21	*Amaranthus graecizans* L.	Th	ME+IR-TR	+	-	-	-	1	25
22	*Amarantus hybridus* L.	Th	PAL	-	-	-	+	1	25
23	*Ammania senegalensis* Lam.	Th	PAN	-	+	-	-	1	25
24	*Anagallis arvensis* L. var. *arvensis*	Th	COSM	-	+	-	-	1	25
25	*Atriplex prostrata* DC.	Th	ME+ER-SR+IR-TR	+	-	-	-	1	25
26	*Azolla filiculoides* Lam.	Hy	NEO	+	-	-	-	1	25
27	*Bassia indica* (Wight) A. J. Scott.	Th	S-Z+IR-TR	-	-	-	+	1	25
28	*Bidens pilosa* L.	Th	PAN	-	-	-	+	1	25
29	*Chenopodium album* L.	Th	COSM	-	-	-	+	1	25
30	*Conyza aegyptiaca* (L.) Dryand	Th	ME	-	-	-	+	1	25
31	*Coronopus didymus* (L.) Sm.	Th	COSM	-	+	-	-	1	25
32	*Digitaria sanguinalis* (L.) Scop.	Th	PAN	-	-	-	+	1	25
33	*Euphorbia helioscopia* L.	Th	ME+IR-TR+SA-SI	-	-	-	+	1	25
34	*Euphorbia peplis* L.	Th	ER-SR+ME+IR-TR	-	-	-	+	1	25
35	*Euphorbia prostrata* Aiton	Th	PAN	-	+	-	-	1	25
36	*Lamium amplexicaule* L.	Th	ME+IR-TR+ER-SR	-	+	-	-	1	25
37	*Mesembryanthemum crystallinum* L.	Th	ME+ER-SR	+	-	-	-	1	25
38	*Mesembryanthemum nodiflorum* L.	Th	ME+SA-SI+ER-SR	+	-	-	-	1	25
39	*Oryza sativa* L.	Th	Cult. and Nat.	+	-	-	-	1	25
40	*Phalaris minor* Retz.	Th	ME+IR-TR	-	-	-	+	1	25
41	*Pseudognaphalium luteoalbum* (L.) Hilliard and B. L. Burtt	Th	COSM	-	-	-	+	1	25
42	*Senecio vulgaris* L.	Th	ME+ER-SR+IR-TR	+	-	-	-	1	25
43	*Setaria pumila* (Poir.) Roem and Schutt.	Th	COSM	-	-	-	+	1	25
44	*Suaeda maritima* (L.) Dumort.	Th	ME+ER-SR+IR-TR	+	-	-	-	1	25

Ph = Phanerophytes, Ch = Chamaeophytes, H = Hemicryptophytes, G = Geophytes, He = Helophytes, Hy = Hydrophytes, Th = Therophytes, COSM = Cosmopolitan, PAN = Pantropical, PAL = Palaeotropical, NEO = Neotropical, ME = Mediterranean, ER-SR = Euro-Siberian, SA-SI = Saharo-Sindian, IR-TR = Irano-Turanian, S-Z = Sudano-Zambezian, Nat. = Naturalized, Cult. = Cultivated, Dam. = Damietta, Dak. = El-Dakahlyia, Sha. = El-Sharkia, Qua. = Al-Qualiopia, P = Presence and P% = Presence percentage

Table 2: The principal floristic categories of the families in the study area

Family	Genera	Species	COSM	PAN	PAL	NEO	Pluriregional	Biregional	ME→PAL	ME	SA-SI	S-Z	Endemic	Nat. and Cult.
Gramineae	23	26	4	9	4		3	1	2		1			2
Compositae	11	14	2	1	1	3	4	1		1			1	
Chenopodiaceae	5	10	3				4	2		1				
Cyperaceae	3	7	1	2	3				1					
Polygonaceae	3	6			3		1	2						
Amaranthaceae	2	5		1	2			2						
Euphorbiaceae	2	4		1			2							1
Leguminosae	3	4			3		1							
Convolvulaceae	3	3	1	1					1					
Aizoaceae	1	2					1	1						
Asclepiadaceae	2	2						2						
Cruciferae	2	2	1				1							
Juncaceae	1	2					2							
Labiatae	2	2			1		1							
Solanaceae	2	2	1					1						
Umbelliferae	2	2					2							
Araceae	1	1		1										
Azollaceae	1	1				1								
Caryophyllaceae	1	1					1							
Ceratophyllaceae	1	1	1											
Haloragidaceae	1	1					1							
Lemnaceae	1	1	1											
Lythraceae	1	1		1										
Malvaceae	1	1						1						
Marsileaceae	1	1			1									
Myrtaceae	1	1												1
Nymphaeaceae	1	1			1									
Onagraceae	1	1										1		
Oxalidaceae	1	1	1											
Plantaginaceae	1	1	1											
Pontederiaceae	1	1				1								
Portulacaceae	1	1	1											
Potamogetonaceae	1	1						1						
Primulaceae	1	1	1											
Ranunculaceae	1	1					1							
Scrophulariaceae	1	1	1											
Tamaricaceae	1	1						1						
Typhaceae	1	1		1										
Verbenaceae	1	1		1										
Total	90	116	20	19	19	5	25	15	4	2	1	1	1	4
Percentage (%)			17.24	16.38	16.38	4.31	21.55	12.93	3.45	1.27	0.86	0.86	0.86	3.45

Al Qaliopia. Among the annuals, seven species have been found in all governorates and two species in three governorates. Concerning the life-forms Table 1 show that the recorded species are grouped under five types: therophytes (48 species = 41.38%), cryptophytes comprising geophytes, helophytes and hydrophytes collectively (38 species = 32.76%), hemicryptophytes (14 species = 12.07%), chamaeophytes (10 species = 8.62%) and phanerophytes (6 species = 5.17%).

Floristic analysis: The recorded plant species (116) in the study area are belonging to 90 genera and related to 39 families (Table 2). Gramineae (26 species), Compositae (14 species) and Chenopodianceae (10 species) are represented collectively by 50 species or about 43.1% of the total number of the recorded species. Cyperaceae (7 species), Polygonaceae (6 species), Amaranthaceae (5 species), Euphorbiaceae and Leguminosae (4 species each) and Convolvulaceae (3 species) comprise 25%. The remaining families (30) are either represented by two or one species. Floristically, Table 2 reveals that the most common floristic elements of Gramineae are: Pantropical (9 species), Cosmopolitan and Palaeotropical (4 species each) and Pluriregional (3 species). In compositae, the most common chorotypes are: Pluriregional (4 species) and Neotropical (3 species). The abundant floristic elements in Chenopodiaceae are Pluriregional (4 species) and Cosmopolitan (3 species). In Cyperaceae, Polygonaceae and Leguminosae, The common element is Palaeotropical (3 species each). Other families comprise different types of floristic elements, which are represented by a few numbers of species. The floristic analysis of the study area as shown in Table 2 reveals that 41 species (35.34%) are Mediterranean taxa. They are either pluriregional (25 species), Biregional (14 species) or monoregional (2 species). Also, 63 species of the recorded plants are either Cosmoplitan (17.24%), Pantropical and palaeotropical (16.38% each) or Neotropical (4.31%). The other floristic categories are poorly represented.

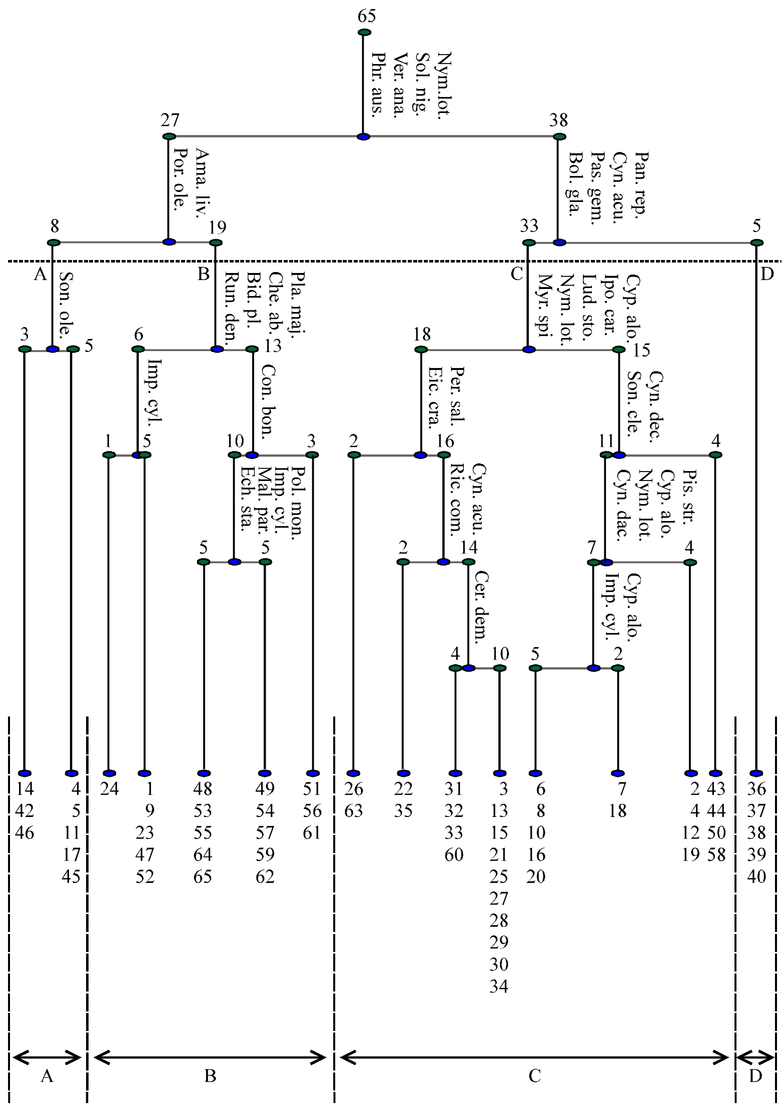

Fig. 2: Two Way Indicator Species Analysis (TWINSPAN) dendrogram of the 65 sampled stands based on the importance values of the 116 species

Vegetation analysis

Classification of stands: The application of TWINSPAN classification led to the recognition of four vegetation groups (Fig. 2). The vegetational composition of these groups is presented in Table 3. Group A comprises 8 stands codominated by *Veronica anagallis-aquatica*, *Portulaca oleracea* and *Cynodon dactylon*. The important species in this group include *Sonchus oleraceous* (indicator species), *Cyperus rotundus* and *Amaranthus lividus*. Group B comprises 19 stands codominated by *Rumex dentantus*, which also identified as indicator species, *Phragmites australis* and *Cynodon dactylon*. The important species in this group comprise *Malva parviflora*, *Sonchus oleraceus*, *Echhornia crassipes* and *Echinochloa stangnina*. Other indicator species are *Plantago major*, *Chenopodium album* and *Bidens pilosa*. Group C includes 33 stands codominated by *Pharagmites australis* and *Echinochloa stagnina*. The most common species in this group are: *Myriophyllum spicatum*, *Cynodon dactylon*, *Cyperus alopecuroides*, *Nymphaea lotus* (indicator species), *Ludwigia stolonifera* and *Ipomoea carnea*. Group D includes 5 stands codominated by *Phragmites australis* and *Bolboschoenus glaucus*. The most important species are *Paspalidium geminatum*, *Cynanchum acutum*, *Leptochloa fusca*, *Panicum repens* and *Atriplex portulacoides*. No indicator species have been identified in this group.

Table 3: Mean value and coefficient of variation (value between brackets) of the importance values of indicator and preferential plants in the different vegetation groups resulting from TWINSPAN classification in the study area

	Vegetation group			
Species	A	B	C	D
Alhagi graecorum	-	0.30(3.30)	-	-
Alternanthera sessilis	-	-	0.09(5.74)	0.38(2.24)
Amaranthus graecizans	-	0.09(4.36)	-	0.34(2.24)
Amaranthus hybridus	-	0.48(3.00)	0.18(5.74)	-
Amaranthus lividus	6.58(0.70)	-	0.25(4.59)	-
Amaranthus viridis	-	0.71(2.37)	0.45(4.11)	-
Ammania senegalensis	-	0.23(4.36)	-	-
Anagallis arvensis	-	0.32(4.36)	-	-
Apium graveolens	-	-	-	1.88(1.42)
Arthrocnemum macrostachyum	-	-	-	3.70(1.05)
Arundo donax	-	1.16(2.02)	0.61(3.24)	-
Atriplex portulacoides	-	-	-	4.18(1.59)
Atriplex prostrata	-	-	0.28(5.74)	1.00(2.24)
Azolla filiculoides	-	-	0.37(4.05)	-
Bassia indica	-	0.08(4.36)	-	-
Bidens pilosa	-	1.72(1.76)	-	-
Bolboschoenus glaucus	-	-	0.18(4.03)	10.48(0.38)
Brachiaria mutica	-	0.60(4.36)	-	1.12(1.48)
Bromus catharticus	-	1.09(2.14)	-	-
Ceratophyllum demersum	-	-	2.11(1.69)	0.34(2.24)
Chenopodium album	-	2.13(1.44)	-	-
Chenopodium ambrosioides	-	0.18(4.36)	0.09(5.74)	-
Chenopodium murale	-	2.88(1.76)	0.18(5.74)	1.30(1.39)
Convolvoulus arvensis	1.66(1.87)	3.29(1.26)	0.55(3.39)	-
Conyza aegyptiaca	-	0.57(3.02)	-	-
Conyza bonariensis	-	0.65(2.14)	0.45(4.09)	-
Coronopus didymus	0.45(2.83)	-	-	-
Cressa cretica	-	-	0.15(5.74)	-
Cynanchum acutum	-	1.28(1.99)	0.77(2.94)	5.50(0.59)
Cynodon dactylon	8.93(0.63)	5.48(1.39)	6.81(0.84)	2.42(1.52)
Cyperus alopecuroides	2.43(1.62)	2.47(1.39)	6.65(0.92)	2.46(1.38)
Cyperus articulatus	-	0.29(3.12)	0.13(5.74)	-
Cyperus difformis	-	-	0.66(4.25)	-
Cyperus laevigatus	-	0.62(3.15)	0.20(4.23)	-
Cyperus rotundus	6.63(1.12)	2.56(1.64)	1.00(2.06)	-
Desmostachya bipinnata	-	0.63(3.60)	-	-
Dichanthium annulatum	-	-	0.08(5.74)	-
Digitaria sanguinalis	-	0.12(4.36)	-	-
Echinochloa colona	5.36(1.00)	-	0.18(4.29)	-
Echinochloa crus-galli	0.74(2.83)	0.47(3.00)	0.38(4.67)	-
Echinochloa stagnina	3.63(1.86)	3.93(0.91)	9.78(0.47)	3.52(1.37)
Eclipta prostrata	0.46(2.83)	0.41(3.06)	0.72(2.99)	-
Eichhornia crassipes	-	4.18(1.38)	5.98(1.18)	-
Ethulia conyzoides	0.93(2.83)	0.75(2.57)	1.29(2.25)	-
Euphorbia helioscopia	-	0.23(4.36)	-	-
Euphorbia peplis	-	0.48(3.00)	0.21(5.74)	-
Euphorbia prostrata	5.71(1.24)	-	-	-
Imperata cylindrica	-	3.69(1.39)	2.97(1.87)	-
Ipomoea carnea	-	0.34(4.36)	2.01(2.16)	-
Juncus acutus	-	-	0.20(5.74)	1.14(2.24)
Juncus rigidus	-	-	-	1.98(1.43)
Lamium amplexicaule	-	0.34(4.36)	-	-
Leersia hexandra	-	0.46(3.38)	0.50(3.23)	1.12(2.24)
Lemna gibba	-	1.42(2.63)	2.00(2.40)	-
Leptochloa fusca	-	-	-	5.20(1.14)
Limbarda crithmoides	-	0.09(4.36)	-	2.54(1.03)
Ludwigia stolonifera	-	0.32(4.36)	4.12(1.49)	0.34(2.24)
Malva parviflora	2.08(1.95)	5.09(1.22)	0.22(4.07)	1.30(1.39)
Marsilea aegyptiaca	-	-	-	0.34(2.24)
Melilotus indicus	-	0.62(3.78)	-	-
Mentha longifolia	-	0.67(3.28)	0.26(5.74)	-
Mesembryanthemum crystallinum	-	0.11(4.36)	-	-
Mesembryanthemum nodiflorum	-	0.11(4.36)	-	-
Myriophyllum spicatum	1.01(2.83)	1.37(2.18)	6.85(1.24)	-

Table 3: Continued

	Vegetation group			
Species	A	B	C	D
Myrtus communis	-	0.22(4.36)	-	-
Nymphaea lotus	-	-	5.90(1.27)	-
Oryza sativa	-	-	0.51(5.74)	-
Oxalis corniculata	-	0.12(4.36)	0.09(5.74)	-
Oxystelma alpine	-	-	0.18(5.74)	-
Panicum repens	-	0.34(3.30)	-	4.28(0.96)
Paspalidium geminatum	-	-	-	6.88(0.63)
Paspalum distichum	-	-	1.22(2.70)	-
Pennisetum setaceum	-	0.23(4.36)	-	-
Persicaria lanigera	-	-	0.27(5.74)	-
Persicaria lapthifolia	1.01(2.83)	0.36(3.44)	0.47(3.68)	-
Persicaria salicifolia	2.51(1.90)	2.81(1.35)	2.98(1.40)	-
Phalaris minor	-	0.59(3.04)	-	-
Phragmites australis	2.43(2.03)	5.78(1.29)	13.7(0.36)	11.22(0.28)
Phyla nodiflora	-	0.11(4.36)	0.45(4.05)	-
Pistia stratiotes	-	-	2.51(2.49)	-
Plantago major	1.55(2.04)	2.03(1.38)	-	0.38(2.24)
Pluchea dioscoridis	-	3.89(1.24)	3.85(1.13)	4.96(0.58)
Polygonum equisetiform	-	0.11(4.36)	-	-
Polypogon monspeliensis	-	3.44(1.20)	0.17(5.74)	0.66(2.24)
Polypogon viridis	3.11(1.39)	1.78(2.50)	0.19(4.00)	-
Portulaca oleracea	9.83(0.59)	-	0.20(5.74)	-
Potamogeton nodosus	-	0.29(4.36)	-	-
Pseudognaphalium Luteo-album	-	0.77(2.49)	-	-
Ranunculus sceleratus	-	0.32(4.36)	0.46(5.74)	0.66(2.24)
Ricinus communis	1.58(1.44)	0.13(4.36)	0.62(3.10)	-
Rorippa palustris	-	0.08(4.36)	-	-
Rumex dentatus	5.13(0.96)	5.87(1.08)	1.25(2.63)	3.60(0.92)
Rumex pictus	-	-	0.19(5.74)	-
Saccharum spontaneum	2.51(1.90)	0.33(3.36)	1.42(2.14)	-
Schoenoplectus litoralis	-	-	-	0.76(2.24)
Senecio aegyptius	-	0.25(4.36)	0.53(3.57)	-
Senecio vulgaris	-	-	-	0.74(2.24)
Sesbania sericea	-	0.27(3.03)	-	-
Sesbania sesban	-	-	0.09(5.74)	-
Setaria glauca	-	0.25(4.36)	-	-
Silybum marianum	-	0.23(4.36)	-	-
Solanum nigrum	1.55(1.43)	3.31(1.01)	0.09(5.74)	-
Sonchus macrocarpus	-	0.09(4.36)	-	0.34(2.24)
Sonchus oleraceus	7.73(0.89)	4.33(1.03)	1.20(2.34)	1.66(1.02)
Sorghum virgatum	1.08(2.02)	0.64(2.52)	0.11(5.74)	-
Spergularia salina	-	-	-	1.38(1.58)
Sporobolus pungens	-	-	-	0.60(2.24)
Suaeda maritima	-	0.18(4.36)	0.38(4.40)	0.60(2.24)
Suaeda pruinosa	-	-	-	0.60(2.24)
Suaeda vera	-	0.54(4.36)	-	-
Symphyotrichum squamatum	0.36(2.83)	-	0.89(2.45)	0.90(1.44)
Tamarix nilotica	-	-	-	2.48(0.99)
Torilis bracteosa	-	1.47(1.85)	-	-
Typha domingensis	0.96(1.85)	1.43(2.26)	0.20(5.74)	3.62(0.94)
Veronica anagallis aquatica	10.66(0.58)	2.90(1.82)	0.23(5.74)	-
Withania somnifera	-	0.16(4.36)	-	-

Ordination of stands: The ordination of the surveyed stands given by Detrended Correspondence Analysis (DCA) is shown in Fig. 3. It is obvious that, the vegetation groups obtained by TWINSPAN classification are distinguishable and having a clear pattern of segregation on the ordination planes. Group A is separated at the right side of the DCA diagram, while group B is separated at the middle position of the DCA diagram. On the other hand, Group C is segregated at the lower left side. And Group D at the upper left side of the DCA diagram.

Variations in soil variables: The soil variables of the four groups of stands which derived from TWINSPAN classification are shown in Table 4, it is notable that most of the soil variables showed a little variation

Table 4: Mean value and standard error (±) of the different soil variables in the stands representing the different vegetation groups obtained by TWINSPAN classification in the study area

	Vegetation group			
Soil variable	A	B	C	D
Sand (%)	87.47±2.20	82.01±3.18	89.33±1.13	88.80±1.68
Silt (%)	11.74±2.36	12.67±2.15	9.55±1.01	10.84±1.60
Clay (%)	0.79±0.28	5.32±1.24	1.12±0.36	0.36±0.17
WHC (%)	56.13±7.07	50.32±3.96	54.26±3.20	47.24±6.02
Porosity (%)	41.20±1.32	40.22±1.59	41.68±1.30	41.57±1.29
$CaCO_3$ (%)	6.31±1.42	8.13±0.96	6.21±0.61	8.40±1.17
OC (%)	1.20±0.20	1.52±0.16	1.62±0.21	1.20±0.34
pH	8.29±0.14	8.17±0.11	8.53±0.07	8.61±0.05
EC (μmhos cm^{-1})	680.13±64.13	1185.42±347.12	1176.64±217.16	2526.00±403.85
Cl^- (%)	0.06±0.02	0.09±0.03	0.05±0.01	0.32±0.06
SO_4^- (%)	0.08±0.01	0.19±0.05	0.12±0.02	0.14±0.03
CO_3^- (%)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
HCO_3^- (%)	0.03±0.00	0.03±0.00	0.03±0.00	0.05±0.00
TN (mg/100 g dry soil)	5.68±0.26	6.07±0.57	6.47±0.50	8.01±1.07
TP (mg/100 g dry soil)	3.04±0.75	4.36±0.65	2.31±0.27	1.97±0.51
Na^+ (mg/100 g dry soil)	0.40±0.10	1.32±0.68	1.19±0.45	1.34±0.29
K^+ (mg/100 g dry soil)	0.10±0.02	0.12±0.03	0.12±0.02	0.34±0.05
Ca^{++} (mg/100 g dry soil)	1.02±0.17	1.14±0.16	1.29±0.12	2.42±0.20
Mg^{++} (mg/100 g dry soil)	1.61±0.16	1.51±0.26	1.71±0.17	2.52±0.47

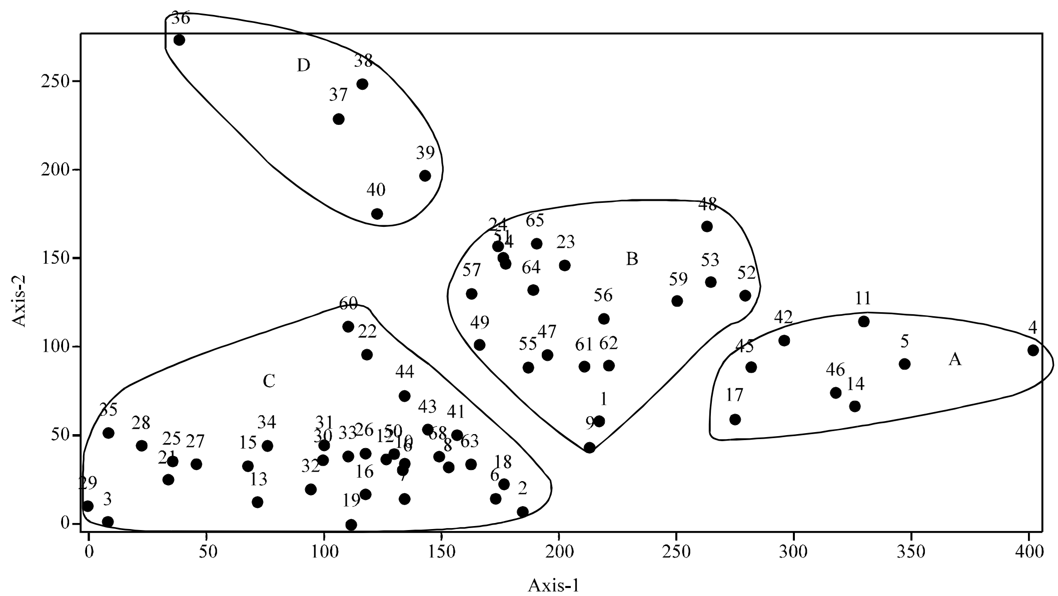

Fig. 3: Detrended Correspondence Analysis (DCA) ordination of the 65 stands

between the different groups of stands. The soils of the four groups have coarse sandy texture with sand fraction more than 80%. The fine fractions (silt and clay) were relatively high in group B than in the other groups. The highest mean value of water holding capacity was attained in group A (56.13%). However, the lowest mean value in group D (47.24%). The mean values of soil pore spaces are obviously comparable at all groups. The percentages of calcium carbonate content are high in groups D and B as compared with the A and C groups. Organic carbon contents are obviously comparable in all groups. The pH values indicate that the soil reaction is slightly alkaline in all groups. It is clear that, the mean values of electrical conductivity, chloride, bicarbonate, total nitrogen content and concentration of extractable cations: Na^+, K^+, Ca^{++} and Mg^{++} are obviously high in group D and low in group A. The phosphate and total phosphorus contents are highly represented in group B.

Variation in water variables: Table 5 shows the means of water variables of the four vegetation groups. It is obvious that the water reaction is weakly alkaline with pH values ranged between 7.98 in group B and 8.68 in group D. Also, it has been found that the highest mean values

Table 5: Mean value and standard error (±) of the different water variables in the stands representing the different vegetation groups obtained by TWINSPAN classification in the study area

	Vegetation group			
Water variable	A	B	C	D
pH	8.50±0.15	7.98±0.13	8.39±0.09	8.68±0.11
EC (μmhos cm^{-1})	641.63±102.62	556.95±58.95	953.12±175.09	5644.00±1317.02
OC (%)	0.30±0.11	0.33±0.06	0.32±0.07	0.60±0.20
DO_2 (%)	38.06±4.27	29.15±2.43	41.19±1.65	43.37±0.75
Cl^- (%)	0.04±0.01	0.40±0.18	0.17±0.07	1.97±0.50
SO_4^- (%)	1.06±0.30	0.57±0.18	0.86±0.11	3.09±0.74
CO_3^- (%)	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00
HCO_3^- (%)	0.02±0.00	0.02±0.00	0.02±0.00	0.07±0.02
TN (mg L^{-1})	0.10±0.05	0.58±0.24	0.99±0.42	5.02±2.24
TP (mg L^{-1})	0.20±0.02	0.19±0.03	0.30±0.05	0.23±0.06
Na^+ (mgL^{-1})	84.70±17.13	79.50±18.17	106.48±13.73	1166.04±361.58
K^+ (mg L^{-1})	5.23±0.85	4.06±0.49	4.32±0.37	26.85±2.81
Ca^{++} (mg L^{-1})	13.94±0.98	20.07±2.76	16.91±1.85	31.56±6.72
Mg^{++} (mg L^{-1})	19.52±1.48	20.18±1.28	27.79±3.49	142.52±35.67

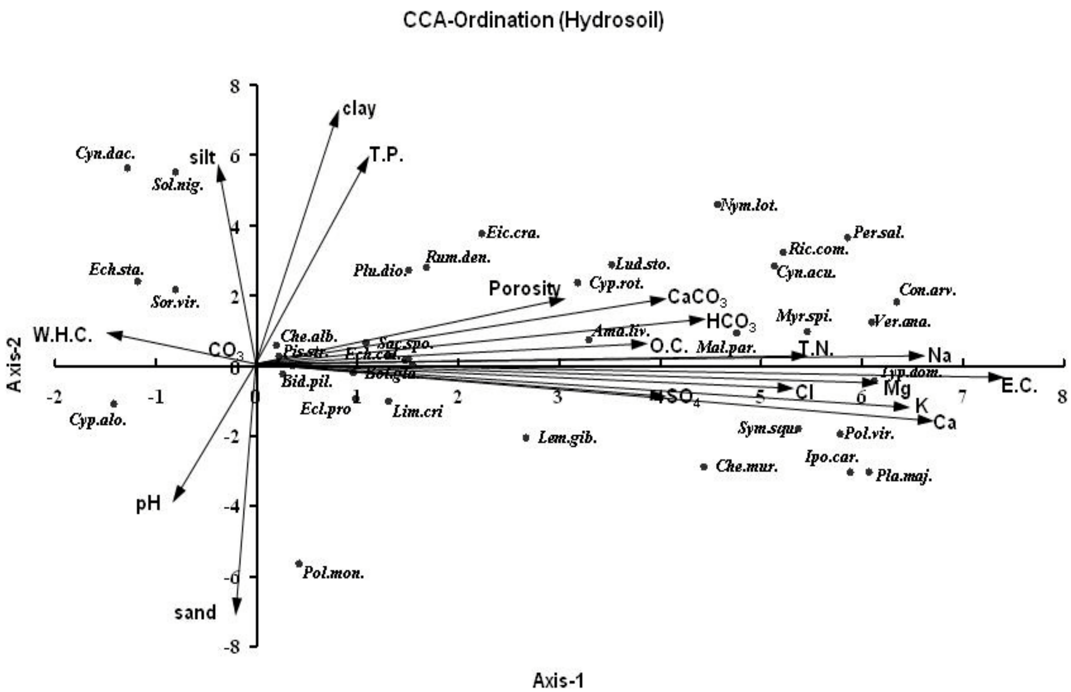

Fig. 4: Canonical Correspondence Analysis (CCA) ordination diagram with hydrosoil variables represented by arrows. The indicator and preferential species are abbreviated to the first three letters of each of the genus and species

of electrical conductivity, dissolved oxygen, chlorides, sulphates, total nitrogen, organic carbon, sodium, potassium, calcium and magnesium are attained in group D. On the other hand, the most mean values of the previous variables are attained in group B except organic carbon, chloride, total nitrogen, calcium and magnesium in group A. The total phosphorous in water reached the highest concentration in group C and the lowest concentration in group B.

Relation between vegetation and environment: The correlation between vegetation and environment is indicated on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot of species-environment as shown in Fig. 4 and 5 for the soil and water, respectively. It is notable that, electrical conductivity, the percentages of calcium, sodium, potassium, magnesium, total nitrogen, chlorides, bicarbonates, calcium carbonates, sulphate, organic

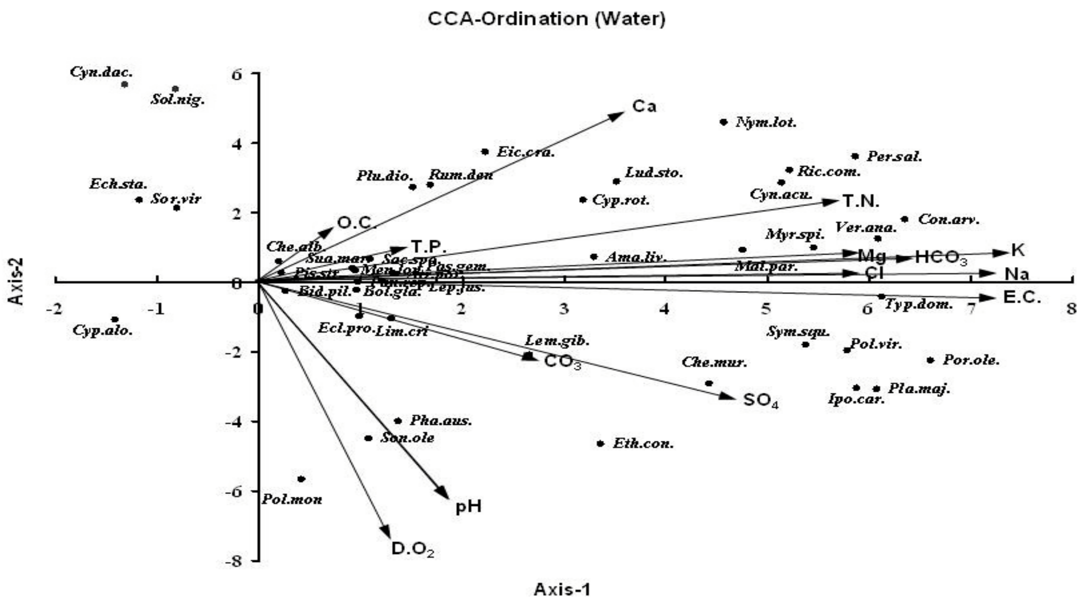

Fig. 5: Canonical Correspondence Analysis (CCA) ordination diagram with water variables represented by arrows. The indicator and preferential species are abbreviated to the first three letters of each of the genus and species

carbon, sand, clay and silt are effective soil variables which show relatively high significant correlations with the first and second axis of CCA ordination diagram. The codominant species of the most identified groups, *Veronica anagllis-aquatica* and *Rumex dentatus* as well as the important species *Cyperus rotundus*, *Amaranthus lividus*, *Malva parviflora*, *Chenopodium album*, *Myriophullum spicatum* (indicator species) and *Eichhornia crassipes* are separated at the upper right side of CCA biplot diagram. These species showed a close relationship with sodium, total nitrogen, bicarbonate, calcium carbonate, organic carbon and porosity. While the codominant species *Bolboschoenus glaucus* as well as the indicator species *Plantago major*, *Bidens pilosa* and *Ipomoea carnea* are segregated at the lower right side of the CCA-bipilot diagram. These species exhibit a clear relationship with electrical conductivity, calcium, potassium, magnesium, chlorides and sulphates. *Cynodon dactylon* as a codominant species in group A and B and as an important species in group C and *Echinochloa stagnina* as a codominant species in group C and as an important species in group B are separated at the upper left side of the CCA-biplot diagram. These species showed a clear relationship with silt and water holding capacity. *Cyperus alopecuroides* as an important species in group C is separated at the lower side of the CCA-biplot diagram and showed a distinct relationship with soil reaction.

It is obvious that, electrical conductivity, potassium, sodium, bicarbonate, chlorides, magnesium, total nitrogen, sulphates, calcium, pH, carbonate and dissolved oxygen are the most important water variables which exhibited a relatively high significant correlation with the first and second axes of the CCA-biplot diagram (Fig. 5). The codominant *Veronica anagallis-aquatica* of group A and *Rumex dentatus* of group B, the important species *Amaranthus lividus* of group A, *Malva parviflora* and *Echhornia crassipes* of group B, *Myriophyllum spicatum* and *Nymphaea lotus* of group C, *Paspalidium geminatum*, *Cynanchum acutum* and *Atriplex portulacoides* of group D, also the indicator species *Chenopodium album* of group B are collectively segregated at the upper right side of the CCA-biplot diagram. These species show a close relation with the high contents of K^+, Na^+, HCO_3^-, Cl^-, Mg^{2+}, total N and Ca^{2+}. However, *Portulaca oleracea*, *Phragmites australis* and *Bolboschoenus glaucus* are in groups A, B, C and D, respectively. And the indicator species *Sonchus oleraceus* in group A, *Plantago major* and *Bidens pilosa* in group B and *Ipomoea carnea* in group C are separated at the lower right side of CCA-biplot and showed a distinct relationship with EC, SO_4^{--}, pH, dissolved O_2 and CO_3^{--}. On the other hand, a few species: *Cynodon dactylon*, *Solanum nigrum*, *Echinochloa stagnina* and *Sorghum virgatum* are obviously segregated at the upper left side, while *Cyperus alopecuroides* alone in the lower left side.

DISCUSSION

The present study reveals that the eastern section of the Nile Dalta, which comprises Damietta, El Dakahlyia, El Sharkia and Al Qaliopia governorates, is rich in its flora on specific generic and families levels. The total number of macrohydrophytes of the irrigations and drainage canals and weeds of its shores is 116 species belonging to ninety genera grouped under thirty-nine families. Graminae, Compositae, Chenopodiaceae, Cyperaceae, Polygonaceae, Amaranthaceae, Euphorbiaceae, Leguminosae and Convolvulaceae constitute the major part of its floristic composition. The cause of interspecific association are varied, but are usually related to similar response of species to the environmental variables. The degree of water availability and the sandy texture of the soil activated the therophytes to maintain predominance over other life forms. Cryptophytes are the second active life form. This could be emphasized through consideration of both its growth habit and the nature of the soil of its habitat. This trend is similar to spectra reported by Mashaly (1987). From the floristic point of view, about 35.34% of the total number of the recorded species are Mediterranean taxa. The other floristic elements are Cosmopolitan, Palaeotropical, Pantropical, Neotropical, Irano-Turanian, Saharo-Sindian, Euro-Seberian and Sudano-Zambesion are represented by varying number of species, reflection their different capability to penetrate the region. Similar investigations have been described by El Ameir (2005). The application of TWINSPAN technique has proved useful in classifying stands, on objective basis, into four vegetational groups, although these groups are not absolutely distinct because the member of some groups are linked together by having one of the dominant species in common. The recognized vegetational groups named after their codominant species as follows: *Veronica anagallis-aquatica*, *Portulaca oleracea* and *Cynodon dactylon* (group A), *Rumex dentatus*, *Phragmites australis* and *Cynodon dactylon* (group B), *Phragmites australis* and *Echinochloa stagnina* (group C), *Phragmites australis* and *Bolboschoenus glaucus* (group D). Comparable groups have been described in the Nile Delta by El Sheikh (1989), Al-Sodany (1992), Khedr and El-Demerdash (1997) and Mashaly *et al.* (2001). The CCA-biplot ordination diagrams indicated that the effective soil and water variables which significantly correlated with the abundance and distribution of vegetation groups in the study area are numerous such as Salinity (EC), soil fractions (sand, silt and clay), pH value, soil fertility (organic carbon, phosphorus and nitrogen contents), dissolved oxygen, calcium carbonate, soluble anions (chlorides and sulphates) and extractable cations (sodium, potassium, calcium and magnesium). Several studies confirmed this trend such as those of El Shiekh (1989) and Shaltout and El Sheikh (1991). *Veronica anagallis-aquatica* as codominant in group A and *Rumex dentatus* as codominant in group B showed a close relationship with sodium, bicarbonate, total nitrogen, calcium carbonate, organic carbon and porosity. However, *Cynodon dactylon* as codominant in group A and B and *Echinochloa stagnina* as codominant in group C exhibited a close relationship with silt and water holding capacity. *Phragmites australis* as codominant in groups B, C and D, *Bolboschoenus glaucus* as codominant in group D and *Portulaca oleracea* as codominant in group A showed a close relationship with electrical conductivity, sulphates, pH value, chlorides, dissolved oxygen. It may be concluded that the most important soil variables which correlated with the distribution and abundance of the aquatic and canal banks weeds in the Nile Delta are: soil salinity (EC), sodium, calcium, potassium, chloride, soil fertility (organic carbon, nitrogen and phosphorus contents) and fine fraction (clay). The most important water variables are salinity, potassium, sodium, bicarbonate, chloride, nitrogen content and pH.

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