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# Vegetation-environment relationships in south Nile Delta

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The present study aimed at identifying and analysing the plant communities of the different habitats in south Nile Delta. Two hundred and seventy one stands were selected to represent the variation in seven major types of habitat recognized in the study area (terraces, slopes, water edges, open water, gardens and nurseries, croplands and ditches, fallow and flooded lands. One hundred and forty four species belonging to 110 genera, 43 families and 23 orders were recorded. Species-rich families were Gramineae followed by Compositae, Cyperaceae, Euphorbiaceae, Leguminosa, Polygonaceae and Amaranthaceae. Thirteen vegetation groups were recognized after the application of TWINSPAN. Their ordination using DECORANA indicated moisture and human impact gradients. The moisture gradient starts with the xerophytes or drought-tolerant plants that inhabited the dry terraces and slopes of the water courses and ruderal habitats (e.g. *Alhagi graecorum, Imperata cylindrica, Phragmites australis* and *Pluchea dioscorides* groups). Then, passing through the mesophytes that inhabited the ditches, gardens and croplands (e.g. *Chenopodium ficifolium, Cynodon dactylon-Paspalum dilatatum* and *Cyperus rotundus-Cynodon dactylon* groups), and the species that inhabited the water edges (e.g. *Phragmites australis, Pluchea dioscorides, Sorghum bicolor* and *Cyperus articulatus-Cynodon dactylon* groups).The pure aquatic communities that inhabited the open water (e.g. *Eichhornia crassipes-Myriophyllum spicatum, Vossia cuspidata* and *Vossia cuspidata-Eichhornia crassipes* groups) represented the other extreme end. The correlations between the soil and water variables on one hand, and the distribution of common species in the study area on the other hand were assessed.

*Keywords:* Diversity, multivariate analysis, south Nile Delta, species composition.

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## *Introduction*

Weeds represent biologically important components of their environments. Their persistence is remarkable in view of the efforts to eliminate them, and warrants greater attention (Radosevich & Holt, 1984). Management, control and phytosociology of weeds have a great interest all over the world. In Egypt, many studies were carried out on the phytosociology of weeds in different Governorates (e.g. Tadros & Atta, 1958; Springuel, 1981; El-Bakry, 1982; Hussein, 2000; Shehata & El Fahar, 2000 and Goma'a, 2002). Nile Delta with its three sections: north, middle and south, is one of the phytogeographical regions of Egypt, which received great attention for studying their weed phytosociology (El-Shayeb, 1984 and 1989; Shaltout & Sharaf El-Din, 1988; Shaltout & El-Fahar, 1991; Shaltout & El-Sheikh, 1991and 1993; Shaltout *et al*., 1992; Al-Sodany, 1992 and 1998; El-Demerdash *et al*., 1997; El-Halawany, 2000; Sheded & Turki, 2000 and Ahmed, 2003).

The habitats recognized in the study area are: terraces, slopes, water edges and open water of the watercourses, gardens and nurseries of El-Qanatir Public Park, croplands, water ditches, fallow and flooded lands. Watercourse habitats are wide spread due to the presence of the two Nile branches, effluents and the main irrigation canals. On the other hand, croplands are limited and increase northwards. The selected nurseries in the present study lie inside the gardens, so it was considered with the gardens as one habitat. Ditches, fallow lands (adjacent to the croplands and receive their water drainage) and flooded lands (inundated frequently with water of River Nile) are characterized by high moisture content and human impacts all over the year; so, they collectively considered as one habitat.

The establishment of El-Qanatir Public Park was synchronized with the construction of Delta Barrages. In the beginning, it was part of Khedive Said's castle which was constructed at El-Qanatir to be used as fortress against any navy may attack the state through the Nile (Zaki, 1947). Nowadays, The Park represents the northern lung of the greater Cairo and its boundaries in addition to the internal and external tourism. The relatively large green area of the gardens (35 ha) gives it its potentialities as public park.

The weeds of the southernmost part of the south Nile Delta and its surroundings seem to be poorly studied. The objectives of the present study were to determine the structure of the weed vegetation in terms of spatial and temporal variations in the floristic composition and abundance of species in South Nile Delta (El-Qanatir region), to analyze the spatial and temporal variations in the environmental factors (soil, water, climate and human impacts) that affect the species and community distribution and to assess the degree of correlation between the environmental and vegetation variables.

## *Study area*

The study area is located in the most southern sections of the South Nile Delta (between latitude 30º 10' 27'' N to 30º 14' 36'' N and longitude 31º 3' 9'' E to 31º 9' E). It extends from about 20 km north of Cairo northwards to south of Menoufia Governorate and extending from Tawfiky effluent in the east to Behera and Nasery effluents in the west (Fig. 1). In addition to the two branches of the River Nile, the study area is dissected by four effluents. They feed the three divisions of the Delta: the western Behira and Nasery effluents, the central Menoufy effluent and the eastern Tawfiky effluent. On the two branches of the Nile and their effluents, a number of barrages were built for controlling the water discharge budgets. From these watercourses, many irrigation canals are branched.

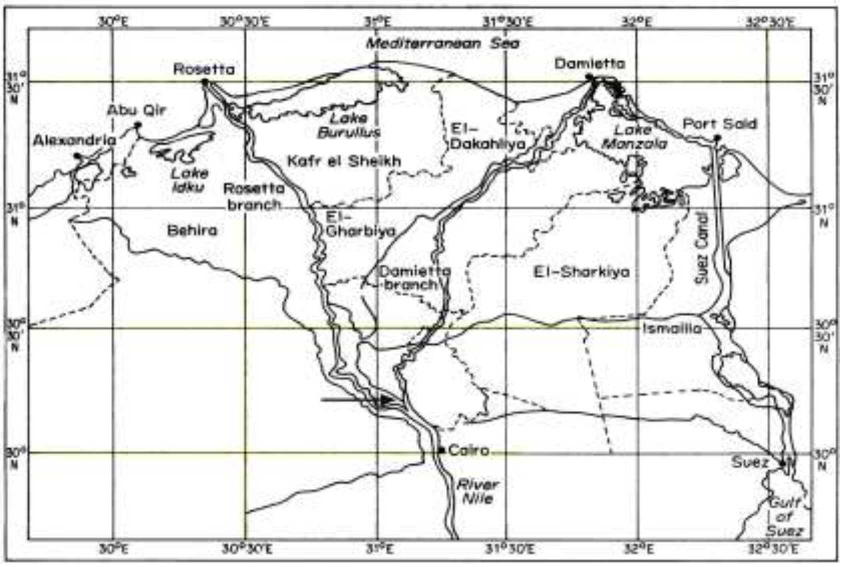


**Fig. 1.** The main features of the Nile Delta (arrow refers to the study area, *c.f.* Zahran & Willis, 1992).

**Table 1.** Long-term annual averages (1960-1975) of the meteorological data of two meteorological stations in the study area (Anonymous, 1980).

| Meteorological variables | BANHA 31° 11` E, 30° 28` N | | CAIRO 31° 15` E, 30° 03` N | |
|---|---|---|---|---|
| | Range | Mean | Range | Mean |
| Max. air temperature (°C) | 19.3 – 34.4 | 27.8 | 19 – 34.9 | 28 |
| Min. air temperature (°C) | 7.6 – 20.8 | 14.4 | 8.8 –21.8 | 15.6 |
| Mean air temperature (°C) | 13.4 – 27.4 | 21.1 | 13.9 – 28.3 | 21.4 |
| Relative humidity (%) | 48 – 75 | 76 | 42 - 61 | 53 |
| Evaporation (mm $day^{-1}$) | 2.9 – 8.4 | 5.2 | 7.4 - 17 | 11.8 |
| Rainfall (mm $year^{-1}$) | - | 1.9 | - | 1.9 |

## *Materials and methods*

### *a) Vegetation*

Two hundred and seventy one stands were selected to represent the apparent variation in the different habitats in the study area which include: terraces, slopes, water edges and open water of the watercourses; gardens and nurseries; croplands; and ditches, fallow and flooded lands. The numbers of stands sampled in each habitat varies between 22 in the ditches, fallow and flooded lands and 62 along the edges of the watercourses (depending on the micro variation in physiography and vegetation physiognomy). The area of each stand was about 20 x 20 m or according to the extension of plant cover and / or the type of the selected habitat.

The following parameters were determined in each stand: seasonal listing of the species indicating the first and second dominant species, visual estimating of the total cover and the cover of each species (%), and the physical changes occurring (grazing, firing, removing of the plants and human impacts). Nomenclature was according to Täckholm (1974), Boulos (1995, 1999, 2000 and 2002).

***b) Soil and water***

Three soil samples were collected from profiles (0 – 50 cm) of each sampled stand. Soil texture was determined by the Bouyoucous hydrometer method. Calcium carbonate was estimated using Bernard's calcimeter. Soil water extracts of 1:5 were prepared for the determination of soil salinity (EC) and soil reaction (pH) using electric conductivity (mS $cm^{-1}$) and pH meters. Chlorides were determined by direct titration against silver nitrate solution using 5 % potassium chromate as an indicator. Soluble bicarbonates were estimated by titration against 0.01N HCl, and sulphates were determined turbidimetrically as barium sulphate at 500 nm. Nitrates were determined using sodium salicylate, $H_2SO_4$ and NaOH as analytical reagents. The sulphanilamide diazotization was used for determination of nitrite in soil extract. Phosphorus was determined in the soil water extract by the direct colorimetric Molybdenum blue method. Ca and Mg were determined by titration against 0.01N-versenate solution using meroxide and erichrome black T as indicators. Sodium and potassium were determined using flame photometer (Allen *et al.,* 1974).

Water samples were collected from the stands of the open water and the edges of the watercourses. Determination of pH, EC and dissolved oxygen were carried out directly after collection. Concentration of dissolved oxygen in water samples (as ppm) was measured using a glass electrode dissolved oxygen meter. Soluble carbonates in water, $NO_3$, $NO_2$, P, $SO_4$, K, Na, Ca, and Mg were estimated using the same methods of soil analysis (Allen *et al.,* 1974).

***c) Data analysis***

Two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) were applied to the matrix of cover estimates of 144 species in 271 stands (Hill, 1979 a,b). The agglomerative clustering techniques were applied to ordinate and classify the zonal vegetation of the habitats based on Sørensen similarity coefficient. The Sørensen similarity matrix was plotted using the Non-Metric Multidimensional scaling (N-MDS) technique (Kruscal, 1964). Species richness for vegetation groups was calculated as the average number of species per stand. Species turnover was calculated as a ratio between the total number of species recorded in a certain vegetation group and its alpha diversity (Whittaker, 1972). Relative evenness of the importance value of species was expressed by Shannon-Wiener index: $\hat{H} = -\sum^{s}_{i=1} Pi (\log Pi)$. The relative concentration of dominance was expressed by Simpson's index: $D = 1/C$, $C = -\sum^{s}_{i=1} (Pi)^2$, where S is the total number of species and Pi is the relative importance value (relative cover) of $i^{th}$ species (Pielou, 1975; Magurran, 1988). Principal Components Analysis (PCA) is a technique used to summarise the relationship between the species of the plant communities and the soil variables in the form of simple figure (Kent & Coker, 1992) in which numbers and squares represent the vegetation groups and lines represent the soil variables. Simple linear correlation coefficient (r) was calculated for assessing the relationship between the estimated soil and water variables on one hand, and the community variables of the vegetation groups on the other hand. The variation in the soil and water variables in relation to the vegetation groups were assessed using one-way analysis of variance (ANOVA). These techniques were according to SPSS Software (SPSS, 1999).

## *Results*

One hundred and forty four species belonging to 110 genera, 43 families and 23 orders were recorded in the study area. The most characteristic families are Gramineae (20.9 %) followed by Compositae (13.9 %), Cyperaceae and Euphorbiaceae (5.6 % for each), Leguminosae and Polygonaceae (4.9 % for each) and Amaranthaceae (4.2 %) (see Tables 2 and 3). The species recorded only along the terraces of watercourses were *Enarthrocarpus lyratus, Tamarix nilotica* and *Trigonella hamosa,* while *Ceruana pratensis* recorded only along the slopes (Table 4). *Lantana camara* and *Persicaria lanigera* recorded only along the water edge, and *Lemna gibba, Potamogeton crispus, P. nodosus* and *P. pectinatus* in the open water. *Commicarpus helenae, Eragrostis cilianensis, Lotus glaber, Mentha piperitta, Allium roseum, Paspalum dilatatum* and *Polygonum equisetiforme* were recorded only in the gardens and nurseries. Some other species were recorded only in the ditches, flooded and fallow lands (e.g. *Abutilon theophrasti*, *Cyperus difformis* and *Fimbristylis bes-umbellata*), and croplands (e.g. *Amaranthus spinosus*, *Cenchrus echinatus, Coronopus squamatus, Eragrostis pilosa,* and *Malvastrum coromandelianum*)

The application of the agglomerative clustering and non-metric multi-dimensional scaling (ordination) technique on the plant communities of the seven habitats (Fig. 2) indicated a distinction of five clusters. The first cluster comprised the terraces and slopes communities, while the second and third clusters represented the communities of the water edges, gardens and nurseries, respectively. The communities of croplands, ditches, fallow and flooded lands were represented by the fourth cluster and that of the open water by the fifth one. The polar ordination revealed these relationships in an impressive manner (Fig. 2b); in which the terrestrial habitats (gardens, croplands and ditches) segregated away from the watercourses habitats. By turn, the watercourses were segregated into three clusters; the open water at the upper left side of the diagram and the terraces and slopes at the lower left side; while the water edges were in transitional position among them.

The life form spectra of the recorded species (Table 5) indicated that therophytes have the highest contribution to the total flora of the study area (58.3 %), followed by the geophytes-helophytes (20.8 %). The variation in relation to the types of habitat indicated that the therophytes have the highest contribution in the croplands (80.8 %), chamaephytes and hemicryptophytes in the terraces (each of 8.4 %), geophytes-helophytes (32.1%) and hydrophytes (28.6 1 %) in the open water.

Seasonal variations in the number of the recorded species per habitat (Table 6) indicated that, generally, the highest number of species (123 species) was recorded in spring season. The open water had the lowest numbers of the recorded species all the year around, while ditches, fallow and flooded lands had the highest numbers of species in spring and summer (71 and 60 species, respectively). Moreover, the water edges had the highest numbers of species in spring (57 species) and winter (58 species). The highest numbers of species per year were recorded in the ditches, fallow and flooded lands (97 species), followed by the water edges (84 species) and croplands (78 species). The distribution of the recorded species in the different seasons showed that 52.1 % of the recorded species were winter active species, 20.8 % were summer active species, 85.4 % were spring active species and 27.1 % are all-year active species.

The application of TWINSPAN classification technique on the cover estimates of 144 species in 271 stands led to the recognition of 38 vegetation groups at level 6 of the classification. The application of DCA on the same set of data indicated a reasonable segregation among these groups along the ordination axes 1 and 2 (Fig. 3). These groups could be categorized at level 3 and 4 of the classification into 13 major groups (Fig. 3, Table 7). These groups were named after their dominant species as follows: (I) *Alhagi graecorum* in the habitat of terraces, slopes and fallow lands, (II) *Persicaria senegalensis–Alhagi graecorum* in the flooded lands, (III) *Pluchea dioscorides* in the water edges, (IV) *Imperata cylindrica* in the slopes, water edges and fallow lands, (V) *Eichhornia crassipes-Myriophyllum spicatum* in the open water, (VI) *Vossia cuspidata-Eichhornia crassipes* in the open water and water edges, (VII) *Vossia cuspidata* in the open water, (VIII) *Phragmites australis* in many habitats, (IX) *Sorghum bicolor* in the water edges (X) *Chenopodium ficifolium* in the croplands, (XI) *Cyperus rotundus-Cynodon dactylon* in the gardens, nurseries, ditches and fallow lands, (XII) *Cynodon dactylon-Paspalum dilatatum* in the gardens and nurseries, and (XIII) *Cyperus articulatus–Cynodon dactylon* in the flooded lands, water edges and terraces of watercourses (Table 7).

Species richness of the vegetation groups varied between 87 species in *Cyperus rotundus-Cynodon dactylon* group (XI) and 3 species in *Sorghum bicolor* group (IX) (Table 8). VG XI had the highest values of species richness (11.6), relative concentration of dominance (37.4) and relative evenness (4.0). The highest value of species turnover (13.1) was recorded in the *Phragmites australis* group (VIII). The *Sorghum bicolor* group (IX) had the lowest values of relative concentration of dominance (3.0) and relative evenness (1.1), while VG II and V had the lowest values of species richness (2.2) and species turnover (1.0), respectively. The relationship between species richness and species dominance was expressed in the form of dominance–diversity curves (Fig. 4). It is clear that most of the curves were steep and the dominance was represented by one or a few species.

Most of the soil variables of the vegetation groups differed significantly according to the one-way ANOVA (Table 9). Soil of *Alhagi graecorum* group (I) had the highest values of EC (5.2 mS $cm^{-1}$), chloride (7 µg $g^{-1}$) and nitrates (6 µg $g^{-1}$). Soil of *Persicaria senegalensis-Alhagi graecorum* group (II) had the highest values of sand (91.9 %), phosphorus (387 µg $g^{-1}$) and pH (7.9), but the minimum of clay (4.1%). Soil of *Vossia cuspidata-Eichhornia crassipes* group (VI) had the highest values of clay (13.3 %), Na (37 µg $g^{-1}$), Ca (3 µg $g^{-1}$) and $CaCO_3$ (6.8 %). In addition, soil of *Phragmites australis* group (VIII) had the highest values of sulphate, while soil of *Chenopodium ficifolium* group (X) had the lowest of chloride, nitrate, phosphorus and sodium. Soil of *Cyperus rotundus-Cynodon dactylon* group (VG XI) had the minimum values of silt and nitrites, while soil of *Cyperus articulatus- Cynodon dactylon* group had the minimum of EC and $CaCO_3$.

**Table 2.** Presence percentages (P %) of the annual species in the study area. The species are arranged in descending order according to their presence percentage in all sampled stands. The habitats are: TE = terraces, SL = slopes, WE = water edges, OW = open water, GR = gardens and nurseries, DI = ditches, fallow and flooded lands and AG = croplands. The vegetation groups are: (I) *Alhagi graecorum*, (II) *Persicaria senegalensis–Alhagi graecorum*, (III) *Pluchea dioscorides*, (IV) *Imperata cylindrica*, (V) *Eichhornia crassipes-Myriophyllum spicatum*, (VI) *Vossia cuspidata-Eichhornia crassipes*, (VII) *Vossia cuspidata*, (VIII) *Phragmites australis*, (IX) *Sorghum bicolar*, (X) *Chenopodium ficifolium*, (XI) *Cyperus rotundus-Cynodon dactylon*, (XII) *Cynodon dactylon-Paspalum dilatatum* and (XIII) *Cyperus articulatus-Cynodon dactylon.*

| Name of species | Family | Habitat | Vegetative group | P % |
|---|---|---|---|---|
| *Rumex dentatus* L. | Polygonaceae | TE,SL,WE,OW,DI,AG | IV, VII, VIII, XI, XII | 16.2 |
| *Amaranthus hybridus* L. | Amaranthaceae | TE,SL,WE,GR,DI,AG | II, VII, VIII, XI | 14.8 |
| *Poa annua* L. | Gramineae | WE,GR,DI,AG | XI, XII | 11.8 |
| *Coronopus niloticus* (Delile) Spreng. | Cruciferae | TE,SL,WE,GA,DI,AG | VII, VIII, XI, XII | 10.3 |
| *Echinochloa colona* (L.) Link | Gramineae | TE,SL,WE,GR,DI,AG | VII, XI, XII, XIII | 10.3 |
| *Portulaca oleracea* L. | Portulacaceae | TE,SL,WE,GR,DI,AG | VII, VIII, XI | 9.6 |
| *Euphorbia peplus* L. | Euphorbiaceae | WE, GR,DI,AG | XI, XII | 9.2 |
| *Chenopodium murale* L. | Chenopodiaceae | TE,SL,WE,GR,DI,AG | VIII, XI, XII | 8.9 |
| *Eclipta prostrata* (L.) L. | Compositae | TE,SL,WE,DI | III, IV, VI, VII, VIII, XII | 8.9 |
| *Chenopodium ficifolium* Sm. | Chenopodiaceae | TE,SL,WE,GR,DI,AG | VII, VIII, X, XI, XII | 8.5 |
| *Rorippa palustris* (L.) Besser | Cruciferae | TE,SL,WE,OW,DI,AG | IV, VII, VIII, X, XI, XII | 8.1 |
| *Pseudognaphalium luteo-album* (L.) Hilliard & B.L. Burtt | Compositae | TE,SL,WE,OW,GR,DI, AG | All except I, II, VI, IX, | 7.7 |
| *Bidens pilosa* L. | Compositae | TE,WE,GR,DI,AG | VIII, XI, XII | 7.0 |
| *Malva parviflora* L. | Malvaceae | TE,SL,WE,GR,DI,AG | VII, VIII, XI, XII | 7.0 |
| *Sonchus oleraceus* L. | Compositae | TE,SL,WE,GR,DI,AG | I, III, VII, XI, XII | 7.0 |
| *Anagallis arvensis* L. | Primulaceae | GR,DI,AG | XI | 6.3 |
| *Bromus catharticus* Vahl | Gramineae | SL,WE,GR,DI,AG | XI, XII | 5.9 |
| *Glinus lotoides* L. | Molluginaceae | TE,SL,WE,OW,DI | III, VII | 5.9 |
| *Polypogon monspeliensis* (L.) Desf. | Gramineae | TE,SL,WE,OW,GR,DI, AG | IV, VII, VIII, XI, XIII | 5.9 |
| *Conyza bonariensis* (L.) Cronquist | Compositae | TE,SL,WE,GR,DI,AG | III, VIII, XI, XII | 4.8 |
| *Lamium amplexicaule* L. | Labiatae | TE,GR,DI,AG | XI | 4.8 |
| *Trianthema portulacastrum* L. | Aizoaceae | TE,SL,GR,DI,AG | VIII, XI, XII | 4.8 |
| *Capsella bursa-pastoris* (L.) Medik. | Cruciferae | WE,GR,DI,AG | XI, XII | 4.4 |
| *Cichorium endiva* subsp. *divaricatum* (Schousb.) P.D. Sell | Compositae | TE,SL,GR,DI,AG | VIII, X, XI, XII | 4.4 |
| *Fimbristylis bisumbellata* (Forssk.) Bubani | Cyperaceae | DI | IV, VIII, XI, XII, XIII | 4.4 |
| *Digitaria sanguinalis* (L.) Scop. | Gramineae | WE,GR,DI,AG | XI, XII | 3.7 |
| *Setaria x verticilliformis* Dumort. | Gramineae | SL,WE,GR,D,AG | VII, VIII, XI, XII | 3.7 |

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|---|---|---|---|---|
| *Urtica urens* L. | Urticaceae | WE,GR,DI,AG | XI | 3.7 |
| *Trifolium resupinatum* L. | Leguminosae | TE,GR,DI,AG | XI, XII | 3.3 |
| *Medicago polymorpha* L. | Leguminosae | TE,SL,WE,GR,AG | X, XI, XII | 3.0 |
| *Sisymbrium irio* L. | Cruciferae | TE,WE,GR,AG | XI, XII | 3.0 |
| *Emex spinosa* L. | Polygonaceae | GR,DI,AG | XI, XII | 2.6 |
| *Setaria viridis* (L.) P. Beauv. | Gramineae | TE,WE,GR,DI,AG | XI, XII | 2.6 |
| *Sorghum bicolor* (L.) Moench. | Gramineae | TE,WE,GR,DI,AG | IX, XI | 2.6 |
| *Amaranthus graecizans* L. | Amaranthaceae | SL,WE,DI,AG | VII, VIII, XI | 2.2 |
| *Eleusine indica* (L.) Gaertn. | Gramineae | TE,SL,GR,DI,AG | XI, XII | 2.2 |
| *Euphorbia heterophylla* L. | Euphorbiaceae | GR,DI,AG | XI | 2.2 |
| *Leptochloa panicea* (Retz.) Ohwi | Gramineae | DI,AG | X, XI | 2.2 |
| *Apium leptophyllum* (Pers.) F. Muell. ex Benth | Umbelliferae | GR,DI,AG | XI | 1.8 |
| *Chenopodium ambrosioides* L. | Chenopodiaceae | TE,SL,WE,DI,AG | VII, VIII | 1.8 |
| *Homognaphalium pulvinatum* (Delile) Fayed & Zareh | Compositae | TE,SL,WE,DI | VII, X, XI | 1.8 |
| *Stellaria pallida* (Dumort.) Pire | Caryophyllaceae | GR,AG | XI | 1.8 |
| *Amaranthus viridis* L. | Amaranthaceae | GR,DI,AG | XI | 1.5 |
| *Dichanthium annulatum* (Forssk.) Stapf | Gramineae | TE,SL,WE,GR,DI | IV, IX, XII | 1.5 |
| *Ethulia conyzoides* subsp. *conyzoides* L. | Compositae | SL,WE | VIII | 1.5 |
| *Euphorbia prostrata* Aiton | Euphorbiaceae | GR,DI,AG | XI, XII | 1.5 |
| *Lolium perenne* L. | Gramineae | GR,DI,AG | XI, XII | 1.5 |
| *Phalaris minor* Retz. | Gramineae | TE,SL,WE,GR,DI,AG | VII, VIII | 1.5 |
| *Tribulus terrestris* L. | Zygophyllaceae | GR,AG | XI | 1.5 |
| *Vicia sativa* L. | Leguminosae | TE,GR,AG | VIII, XI, XII | 1.5 |
| *Ammi visnaga* (L.) Lam. | Umbelliferae | DI,AG | XI | 1.1 |
| *Avena fatua* L. | Gramineae | TE,DI,AG | XI | 1.1 |
| *Senecia aegyptius var. aegyptius* L. | Compositae | TE,SL,WE,DI | VII | 1.1 |
| *Xanthium spinosum* L. | Compositae | TE,SL | VIII, XII | 1.1 |
| *Xanthium strumarium* L. | Compositae | TE,SL,AG | XI | 1.1 |
| *Amaranthus spinosus* L. | Amaranthaceae | DI,AG | XI | 0.7 |
| *Cyperus difformis* L. | Cyperaceae | WE,DI | XIII | 0.7 |
| *Dactyloctenium aegyptium* (L.) Willd. | Gramineae | WE,GR,DI,AG | XI, XIII | 0.7 |
| *Eragrostis pilosa* (L.) P.Beauv. | Gramineae | AG | VIII | 0.7 |
| *Euphorbia hirta* L. | Euphorbiaceae | GR, AG | XI | 0.7 |
| *Matricaria recutita* var. *recutita L.* | Compositae | GR,DI,AG | XI | 0.7 |
| *Melilotus indicus* (L.) All. | Leguminosae | SL,WE,GR,DI,AG | XI | 0.7 |
| *Senecio vulgaris* L. | Compositae | SL,WE | VII | 0.7 |
| *Abutilon theophrasti* Medik. | Malvaceae | DI | XI | 0.4 |
| *Amaranthus lividus* L. | Amaranthaceae | DI,AG | XI | 0.4 |
| *Ammi majus* L. | Umbelliferae | GR,DI,AG | XI | 0.4 |
| *Bergia capensis* L. | Elatinaceae | DI | XII | 0.4 |

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|---|---|---|---|---|
| *Cenchrus echinatus* L. | Gramineae | AG | XI | 0.4 |
| *Ceruana pratensis* Forssk. | Compositae | SL | VIII | 0.4 |
| *Chrozophora plicata* (Vahl) Spreng. | Euphorbiaceae | TE,SL | VIII | 0.4 |
| *Eragrostis cilianensis* (All.) F.T. Hubb. | Gramineae | GR | XI | 0.4 |
| *Euphorbia helioscopia* L. | Euphorbiaceae | SL,WE,DI,AG | XI | 0.4 |
| *Euphorbia indica* Lam. | Euphorbiaceae | AG | XI | 0.4 |
| *Gynandropsis gynandra* (L.) Briq. | Cleomaceae | DI,AG | XI | 0.4 |
| *Lactuca serriola* L. | Compositae | SL,WE,GR,DI | VIII | 0.4 |
| *Malvastrum coromandelianum* (L.) Garcke | Malvaceae | AG | XI | 0.4 |
| *Ranunculus sceleratus* L. | *Ranunculaceae* | SL,WE,OW,DI | VII | 0.4 |
| *Senecio glaucus* subsp. *coronopifolius* L. (Maire) C. Alexander | Compositae | WE,GR,DI,AG | XI | 0.4 |
| *Setaria italica* (L.) P. Beauv. | Gramineae | AG | XI | 0.4 |
| *Coronopus squamatus* (Forssk.) Asch. | Cruciferae | AG | XII | 0.4 |
| *Enarthrocarpus lyratus* (Forssk.) DC. | Cruciferae | TE | XIII | 0.4 |
| *Juncus bufonius* L. var. *bufonius* | Juncaceae | DI | XIII | 0.4 |
| *Potentilla supina* L. | Rosaceae | TE,WE,DI,AG | VII | 0.4 |
| *Trigonella hamosa* L. | Leguminosae | TE | I | 0.4 |

The water of *Phragmites australis* group (VIII) had the highest of EC, bicarbonate, chloride, phosphorus, sodium, calcium and magnesium (Table 10). Water of *Sorghum bicolor* group (IX) had the highest value of sulphate (28.3 mg $l^{-1}$), while the water of *Imperata cylindrica-Pluchea dioscorides* group (IV) had the minimum of sulphate (14.1 mg $l^{-1}$).

The correlation between the vegetation and soil variables was demonstrated by Principal Components Analysis (PCA) ordination biplot (Fig. 5). It was clear that the vegetation group V occupied high position along the gradient of calcium carbonate and electric conductivity, while VG III and X occupied high and intermediate positions along the gradient of nitrate, respectively. Moreover, it was evident that VG VIII and IX occupied high positions along the gradient of clay, while VG VII and XI occurred at high positions along the gradient of sulphates and pH, respectively.

Regarding the pairs of community variables, the total number of species was positively correlated with all the other community variables (Table 11). Also, relative evenness was positively correlated with species richness and species turnover (r = 0.74 and 0.79 respectively), and negatively with relative concentration of dominance (-0.62). Regarding the community versus soil variables, only $CaCO_3$ was negatively correlated with species richness (r = -0.65).

**Table 3.** Presence percentage (P %) of the perennial species in south Nile Delta. The species are arranged in descending order according to their presence percentage in all sampled stands. The habitats are: TE = terraces, SL = slopes, WE = water edges, OW = open water, GR = gardens and nurseries, DI = ditches, fallow and flooded lands and AG = croplands. The vegetation groups are: (I) *Alhagi graecorum*, (II) *Persicaria senegalensis–Alhagi graecorum*, (III) *Pluchea dioscorides*, (IV) *Imperata cylindrica*, (V) *Eichhornia crassipes-Myriophyllum spicatum*, (VI) *Vossia cuspidata-Eichhornia crassipes*, (VII) *Vossia cuspidata*, (VIII) *Phragmites australis*, (IX) *Sorghum bicolar*, (X) *Chenopodium ficifolium*, (XI) *Cyperus rotundus-Cynodon dactylon*, (XII) *Cynodon dactylon-Paspalum dilatatum* and (XIII) *Cyperus articulatus–Cynodon dactylon.*

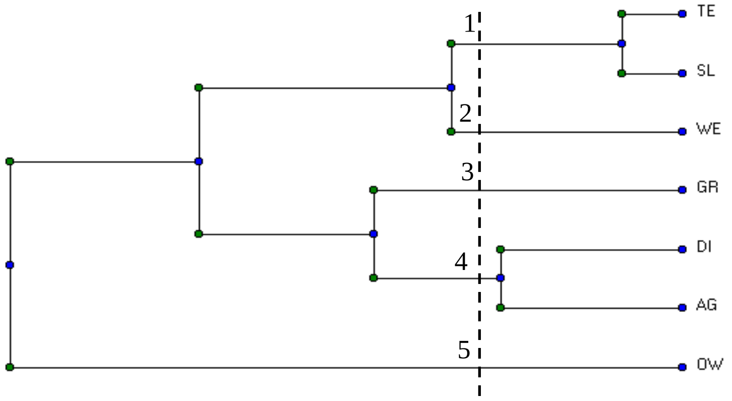
| Name of species | Family | Habitat | Vegetative group | P |
|---|---|---|---|---|
| **Phanerophytes** | | | | |
| *Pluchea dioscorides* (L.) DC. | Compositae | TE,SL,WE,GR,DI,AG | All except I, V, IX, X, XI | 15.9 |
| *Ricinus communis* L. | Euphorbiaceae | TE,SL,WE,OW | IV, VII, VIII | 5.9 |
| *Cynanchum acutum* subsp. *acutum* L. | Asclepiadaceae | TE,SL,WE,OW,GR,DI | VIII, XII | 4.1 |
| *Lantana camara* L. | Verbenaceae | WE | III | 0.4 |
| *Tamarix nilotica* (Ehrenb.) Bunge | Tamaricaceae | TE | I | 0.4 |
| **Chamaephytes** | | | | |
| *Solanum nigrum* L. | Solanaceae | TE,SL,WE,GR,DI,AG | IV, VII, VIII, XI | 3.7 |
| *Symphyotrichum squamatum* (Spreng.) Hieron. | Gramineae | TE,SL,WE,DI | VII, VIII, XII | 2.2 |
| *Withania somnifera* (L.) Dunal | Solanaceae | TE,SL,WE,GR,DI,AG | I, III, IV, VII, XI | 2.2 |
| *Centaurea calcitrapa* L. | Compositae | SL,WE | VII, VIII | 0.7 |
| *Ipomoea carnea* Jacq. | Convolvulaceae | TE,GR,DI | II, VII | 0.7 |
| *Oxystelma esculentum* (L.f.) R.Br. | Asclepiadaceae | TE,SL,WE | VIII | 0.4 |
| *Polygonum equisetiforme* Sm. | Polygonaceae | GR | XI | 0.4 |
| **Hemicryptophytes** | | | | |
| *Convolvulus arvensis* L. | Convolvulaceae | TE,SL,WE,GR,DI,AG | I, IV, VIII, XI, XII | 16.2 |
| *Phyla nodiflora* (L.) Greene | Verbenaceae | TE,SL,WE,GR,DI | IV, VIII, XI, XII | 6.3 |
| *Alhagi graecorum* Boiss. | Leguminosae | TE,SL,WE,DI | I, II, IV, VII, VIII | 5.2 |
| *Plantago major* L. | Plantaginaceae | TE,WE,GR,DI,AG | VII, VIII, XI, XII | 3.0 |
| *Lotus glaber* Mill. | Leguminosae | GR | XI, XII | 2.6 |
| *Silybum marianum* var. *marianum* (L.) Gaertn. | Compositae | TE,SL,WE | VII, VIII | 1.5 |
| *Oxalis corymbosa* DC. | Oxalidaceae | DI,AG | VIII | 0.4 |
| *Spergularia marina* (L.) Griesb. | Caryophyllaceae | TE,SL,WE,DI | VII | 0.4 |
| **Geophytes-Helophytes** | | | | |
| *Phragmites australis* (Cav.) Trin. Ex Steud. | Gramineae | TE,SL,WE,OW,GR,DI | All except III, V, IX, X | 38.4 |
| *Vossia cuspidata* (Roxb.) Griff. | Gramineae | TE,SL,WE,OW,DI | I, V, VI, VII, VIII, IX, XI | 34.7 |
| *Cynodon dactylon* (L.) Pers. | Gramineae | TE,SL,WE,GR,DI,AG | IV, VII, VIII, XI, XII, XIII | 34.3 |
| *Echinochloa stagnina* (Retz.) P. Beauv. | Gramineae | TE,SL,WE,OW,DI | IV, VI, VII, VIII, XI | 31.7 |

| | | | | |
|---|---|---|---|---|
| *Persicaria senegalensis* (Meisn) Sojak | Polygonaceae | TE,SL,WE,OW,DI | I, II, V, VI, VII, VIII, XIII | 17.3 |
| *Cyperus alopecuroides* L. | Cyperaceae | TE,SL,WE,OW,DI | V, VI, VII, VIII, XI | 16.2 |
| *Cyperus rotundus* L. | Cyperaceae | TE,SL,WE,GR,DI,AG | VII, VIII, XI, XIII | 14.4 |
| *Persicaria salicifolia* (Willd.) Assenov | Polygonaceae | TE,SL,WE,OW,DI | VI, VII, VIII, XIII | 10.3 |
| *Oxalis corniculatus* L. | Oxalidaceae | GR,DI,AG | IV, VIII, XI, XII | 9.6 |
| *Paspalum dilatatum* Poir. | Gramineae | GR,AG | XII | 7.7 |
| *Imperata cylindrica* (L.) Raeusch. | Gramineae | TE,SL,WE,GR,DI,AG | I, IV, VII, VIII, XI, XII | 7.4 |
| *Mentha longifolia* (L.) Huds. | Labiatae | TE,SL,WE,DI | IV, VIII, XII | 5.9 |
| *Panicum repens* L. | Gramineae | TE,SL,WE,GR,DI,AG | IV, VII, VIII, XI, XII, XIII | 4.4 |
| *Arundo donax* L. | Gramineae | TE,SL,WE,OW | VII, VIII | 3.7 |
| *Cyperus articulatus* L. | Cyperaceae | TE,SL,WE, DI | VII, VIII, XIII | 3.7 |
| *Paspalidium geminatum* (Forssk.) Stapf | Gramineae | SL,WE,OW,GR,DI,AG | I, VII, VIII | 3.7 |
| *Persicaria lapathifolia* (L.) Gray | Polygonaceae | TE,SL,WE | VII, VIII | 3.7 |
| *Typha domingensis* (Pers.) Poir. ex Steud. | Typhaceae | SL,WE,OW | VIII | 3.7 |
| *Paspalum distichum* L. | Gramineae | TE,SL,WE,DI | VII, VIII, XII, XIII | 3.0 |
| *Desmostachya bipinnata* (L.) Stapf. | Gramineae | TE,SL,WE | I, IV, VII, VIII | 2.2 |
| *Commicarpus helenae* (Schult.) Meikle | Nyctaginaceae | GR | XII | 1.5 |
| *Cyperus longus* L. | Cyperaceae | TE,SL,WE,GR, ,AG | VII, XI | 0.7 |
| *Leptochloa fusca* (L.) Kunth | Gramineae | WE,DI,AG | VIII, X | 0.7 |
| *Veronica anagallis-aquatica* L. | Scrophulariaceae | SL,WE,DI | XII | 0.7 |
| *Veronica persica* Poir. | Scrophulariaceae | SL,GR,DI | XI, XII | 0.7 |
| *Allium roseum* L. | Alliaceae | GR | XI | 0.4 |
| *Alternanthera sessilis* (L.) DC. | Amaranthaceae | SL,WE,DI | II | 0.4 |
| *Mentha piperita* L. | Labiatae | GR | XI | 0.4 |
| *Persicaria lanigera* (R.Br.) Sojak | Polygonaceae | WE | VII | 0.4 |
| *Cyperus papyrus* L. | Cyperaceae | WE | III | 0.4 |
| **Hydrophytes** | | | | |
| *Eichhornia crassipes* (C. Mart.) Solms | Pontederiaceae | SL,WE,OW | V, VI, VII, VIII, XIII | 14.0 |
| *Ludwigia stolonifera* (Guill. & Perr.) P.H. Raven | Onagraceae | SL,WE,OW | V, VI, VII, VIII, XI | 10.0 |
| *Myriophyllum spicatum* L. | Haloragidaceae | WE,OW | V, VI, VII | 7.0 |
| *Lemna gibba* L. | Lemnaceae | OW | VIII | 1.8 |
| *Potamogeton nodosus* Poir. | Potamogetonaceae | WE,OW | VI, VII, XI | 1.8 |
| *Ceratophyllum demersum* L. | Ceratophyllaceae | OW | V, VI, VII | 1.1 |
| *Potamogeton pectinatus* L. | Potamogetonaceae | OW | VI, XI | 0.7 |
| *Potamogeton crispus* L. | Potamogetonaceae | OW | V | 0.4 |
| **Parasites** | | | | |
| *Orobanche crenata* Loefl. | Orobanchaceae | AG | XI | 0.7 |
| *Cuscuta pedicellata* Ledeb. | Convolvulaceae | WE,GA,DI,AG | VIII | 0.4 |

**Table 4.** Unique species recorded in only one of the 7 habitats identified in south Nile Delta. TE = terraces, SL = slopes, WE = water edge, OW = open water, GR = gardens & nurseries, DI = ditches, fallow & flooded lands and AG = croplands.

| Species | Habitat type | | | | | | |
|---|---|---|---|---|---|---|---|
| | TE | SL | WE | OW | GR | DI | AG |
| *Enarthrocarpus lyratus* | + | | | | | | |
| *Tamarix nilotica* | + | | | | | | |
| *Trigonella hamosa* | + | | | | | | |
| *Ceruana pratensis* | | + | | | | | |
| *Lantana camara* | | | + | | | | |
| *Persicaria lanigera* | | | + | | | | |
| *Lemna gibba* | | | | + | | | |
| *Potamogeton crispus* | | | | + | | | |
| *Potamogeton nodosus* | | | | + | | | |
| *Potamogeton pectinatus* | | | | + | | | |
| *Allium roseum* | | | | | + | | |
| *Commicarpus helenae* | | | | | + | | |
| *Eragrostis cilianensis* | | | | | + | | |
| *Lotus glaber* | | | | | + | | |
| *Mentha piperita* | | | | | + | | |
| *Paspalum dilatatum* | | | | | + | | |
| *Polygonum equisetiforme* | | | | | + | | |
| *Abutilon theophrasti* | | | | | | + | |
| *Bergia capensis* | | | | | | + | |
| *Cyperus difformis* | | | | | | + | |
| *Cyperus papyrus* | | | | | | + | |
| *Fimbristylis bisumbellata* | | | | | | + | |
| *Gynandropsis gynandra* | | | | | | + | |
| *Juncus bufonius* | | | | | | + | |
| *Amaranthus spinosus* | | | | | | | + |
| *Cenchrus echinatus* | | | | | | | + |
| *Coronopus squamatus* | | | | | | | + |
| *Eragrostis pilosa* | | | | | | | + |
| *Euphorbia indica* | | | | | | | + |
| *Malvastrum coromandelianum* | | | | | | | + |
| *Orobanche crenata* | | | | | | | + |
| *Setaria italica* | | | | | | | + |
| **Total** | **3** | **1** | **2** | **4** | **7** | **7** | **8** |

**(a) Agglomerative clustering**




(b) **Polar ordination**

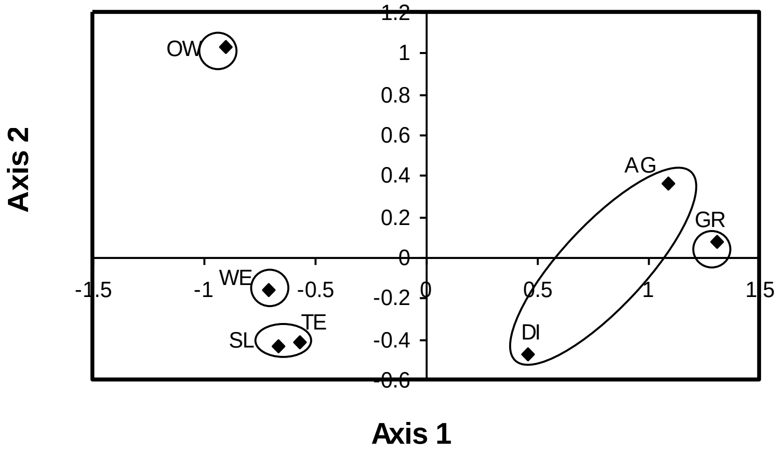



**Fig. 2.** The dendrogram resulting from the agglomerative clustering technique (a), and the similarity ordination according to Sørensen 1948 (b) of the plant communities of the 7 habitats in south Nile Delta. The habitats are: TE = terraces, SL = slopes, WE = water edge, OW = open water, GR = gardens & nurseries, DI = ditches, fallow lands & flooded lands and AG = croplands.

**Table 5.** Life forms of the recorded species in the 7 habitats in south Nile Delta. A: actual number of species, R: relative number of species, TE = terraces, SL = slopes, WE = water edge, OW = open water, GR = gardens & nurseries, DI = ditches, fallow & flooded lands and AG = croplands. The maximum and minimum values are underlined.

| Life form | | Habitat | | | | | | | Total species |
|---|---|---|---|---|---|---|---|---|---|
| | | TE | SL | WE | OW | GR | DI | AG | |
| Phanerophytes | A | 4 | 3 | 4 | 3 | <u>1</u> | 2 | 1 | 5 |
| | R | 5.6 | 4 | <u>4.8</u> | 12.5 | 1.3 | 2.1 | <u>1.3</u> | 3.4 |
| Chamaephytes | A | 6 | 6 | 6 | 1 | 4 | 6 | 2 | 7 |
| | R | <u>8.4</u> | 8.1 | 7.1 | <u>4.1</u> | 5.4 | 6.2 | 2.6 | 4.8 |
| Hemicryptophytes | A | 6 | 6 | 6 | --- | 6 | 5 | 3 | 8 |
| | R | <u>8.4</u> | 8.1 | 7.1 | --- | 8 | 5.2 | <u>3.8</u> | 5.5 |
| Geophytes –heleophytes | A | 15 | 19 | 19 | 9 | 13 | 19 | 7 | 30 |
| | R | 21.1 | 25.7 | 22.6 | <u>37.5</u> | 17.5 | 19.6 | <u>9</u> | 20.8 |
| Hydrophytes | A | 1 | 2 | 4 | 8 | --- | --- | --- | 8 |
| | R | <u>1.4</u> | 2.7 | 4.7 | <u>33.3</u> | --- | --- | --- | 5.5 |
| Therophytes | A | 39 | 38 | 45 | 7 | 50 | 65 | 63 | 84 |
| | R | 54.9 | 51.3 | 53.6 | <u>29.1</u> | 67.6 | 67 | <u>80.8</u> | <u>58.3</u> |
| Parasites | A | --- | --- | --- | --- | 1 | 1 | 2 | 2 |
| | R | --- | --- | --- | --- | 1.3 | <u>1</u> | <u>2.6</u> | <u>1.4</u> |
| Total | | 71 | 74 | 84 | 24 | 74 | 97 | 78 | 144 |

**Table 6.** Seasonal variation in the recorded species in the 7 habitats in the south Nile Delta.

| Habitat | Spring | Summer | Autumn | Winter | All the year |
|---|---|---|---|---|---|
| Terraces | 48 | 44 | 45 | 43 | 71 |
| Slopes | 53 | 49 | 46 | 50 | 74 |
| Water edges | 57 | 46 | 52 | 58 | 84 |
| Open water | 18 | 15 | 16 | 21 | 24 |
| Gardens & nurseries | 61 | 38 | 39 | 38 | 74 |
| Ditches, fallow & flooded lands | 71 | 60 | 48 | 53 | 97 |
| Croplands | 56 | 39 | 41 | 45 | 78 |
| Total species per season | 123 | 106 | 98 | 103 | 144 |

(a)

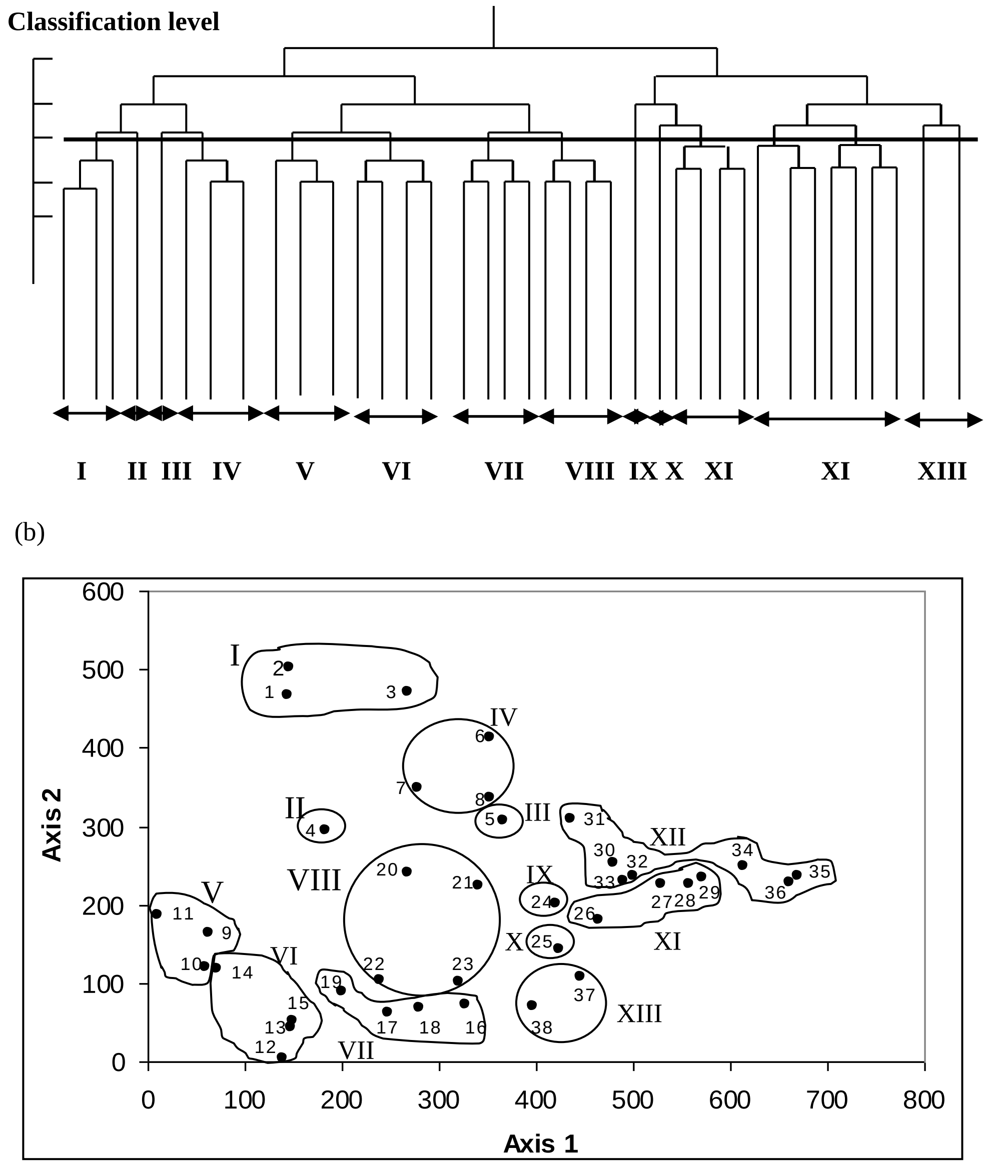



**Fig. 3.** The relationship between the 13 groups generated after the application of TWINSPAN classification technique on 271 sampled stands in the different habitats (a), and the position of their cluster centroids on the first and second axes of DCA.

**Table 7.** Characteristics of the 13 vegetation groups derived at levels 3and 4 after the application of TWINSPAN on 271 sampled stands in the different habitats in south Nile Delta. N: number of stands, G/P: ratio of the stands representing each vegetation group to the total sampled stands (%). The habitats are: TE= terraces, SL= slopes, WE= water edges, OW= open-waters, GR= gardens & nurseies, DI=: ditches, fallow & flooded lands and AG= croplands. P: presence percentage (%), Co: relative cover (%).

| VG. | N | G/P | | | | | | | | 1st dominant species | P | Co | 2nd dominant species | P | Co |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TE | SL | WE | OW | GR | DI | AG | | (%) | | | (%) | |
| I | 7 | 2.6 | 57.1 | 28.6 | - | - | - | 14.3 | - | *Alhagi graecorum* | 100 | 76.3 | *Imperata cylindrica* | 28.6 | 16.4 |
| II | 1 | 0.37 | - | - | - | - | - | 100 | - | *Persicaria senegalensis* | 100 | 45 | *Alhagi graecorum* | 100 | 34 |
| III | 2 | 0.73 | - | - | 100 | - | - | - | - | *Pluchea dioscorides* | 100 | 43.3 | *Conyza bonariensis* | 100 | 10.4 |
| IV | 12 | 4.4 | 33.3 | 41.7 | 8.3 | - | - | 16.7 | - | *Imperata cylindrica* | 100 | 40 | *Pluchea dioscorides* | 83.3 | 11 |
| V | 11 | 4.1 | - | 9 | - | 91 | - | - | - | *Eichhornia crassipes* | 81.8 | 69 | *Myriophyllum spicatum* | 63.6 | 23.6 |
| VI | 28 | 10.3 | - | 3.6 | 10.7 | 85.7 | - | - | - | *Vossia cuspidata* | 96.4 | 50 | *Eichhornia crassipes* | 71.4 | 40 |
| VII | 61 | 22.5 | 9.8 | 24.6 | 52.5 | 11.5 | - | 1.6 | - | *Vossia cuspidata* | 80.3 | 37.2 | *Echinochloa stagnina* | 60.7 | 9.2 |
| VIII | 68 | 25.1 | 22.1 | 33.8 | 29.4 | 10.3 | 4.4 | - | - | *Phragmites australis* | 89.7 | 51.3 | *Echinochloa stagnina* | 44.1 | 13.7 |
| IX | 1 | 0.37 | - | - | 100 | - | - | - | - | *Sorghum bicolar* | 100 | 58 | *Vossia cuspidata* | 100 | 26 |
| IX | 2 | 0.73 | - | - | - | - | - | 50 | 50 | *Chenopodium ficifolium* | 100 | 66 | *Rorippa palustris* | 50 | 11 |
| XI | 42 | 15.5 | 2.4 | 2.4 | 4.8 | - | 21.4 | 11.9 | 57.1 | *Cyperus rotundus* | 76.2 | 7 | *Cynodon dactylon* | 66.7 | 9.1 |
| XII | 31 | 11.4 | 9.7 | 3.2 | - | - | 67.7 | 19.4 | - | *Cynodon dactylon* | 100 | 25.1 | *Paspalum dilatatum* | 67.7 | 15.3 |
| XIII | 5 | 1.8 | 20 | - | 20 | - | - | 60 | - | *Cyperus articulatus* | 100 | 52.4 | *Cynodon dactylon* | 100 | 21.3 |

**Table 8.** Variation in some diversity indices calculated for the 13 vegetation groups derived after the application of TWINSPAN on 271 stands in the different habitats in south Nile Delta. The maximum and minimum values are underlined.

| VG | Total species | Species richness | Species turnover | Relative conc. of dominance | Relative evenness |
|---|---|---|---|---|---|
| **I** | 10 | 2.4 | 4.2 | 6.2 | 2 |
| **II** | 7 | 7 | <u>1</u> | 7 | 2 |
| **III** | 8 | 7 | 1.1 | 22.5 | 2 |
| **IV** | 22 | 5.3 | 4.1 | 12.1 | 2.7 |
| **V** | 8 | <u>2.2</u> | 3.6 | 4 | 1.6 |
| **VI** | 14 | 4 | 3.7 | 7.1 | 2.1 |
| **VII** | 55 | 6.6 | 8.3 | 21 | 3.4 |
| **VIII** | 64 | 5 | <u>13.1</u> | 17.5 | 3.4 |
| **IX** | <u>3</u> | 3 | 1 | <u>3</u> | <u>1.1</u> |
| **1X** | 8 | 4.5 | 2 | 36 | 2 |
| **XI** | <u>87</u> | <u>11.6</u> | 7.5 | <u>37.4</u> | <u>4</u> |
| **XII** | 54 | 7.7 | 7 | 23 | 3.5 |
| **XIII** | 16 | 6 | 2.7 | 15.5 | 2.6 |
| **Mean** | 27.4 | 5.6 | 4.6 | 16.3 | 2.5 |

## *Discussion*

Comparing the recorded species in the present study (144 species) with those recorded in the north and middle Delta, it was found that 61.8 % of them were recorded in the study of Al-Sodany (1998) along the watercourses of north Nile Delta, and 45.4 % in the study of El-Sheikh (1996) in the ruderal habitats of the Nile Delta. On the contrary, all the halophytic and desert plants in the north Delta were not recorded in the present study. Moreover, some aquatic plants that were recorded in the study of Al-Sodany (1998) were not recorded in the present study (e.g.

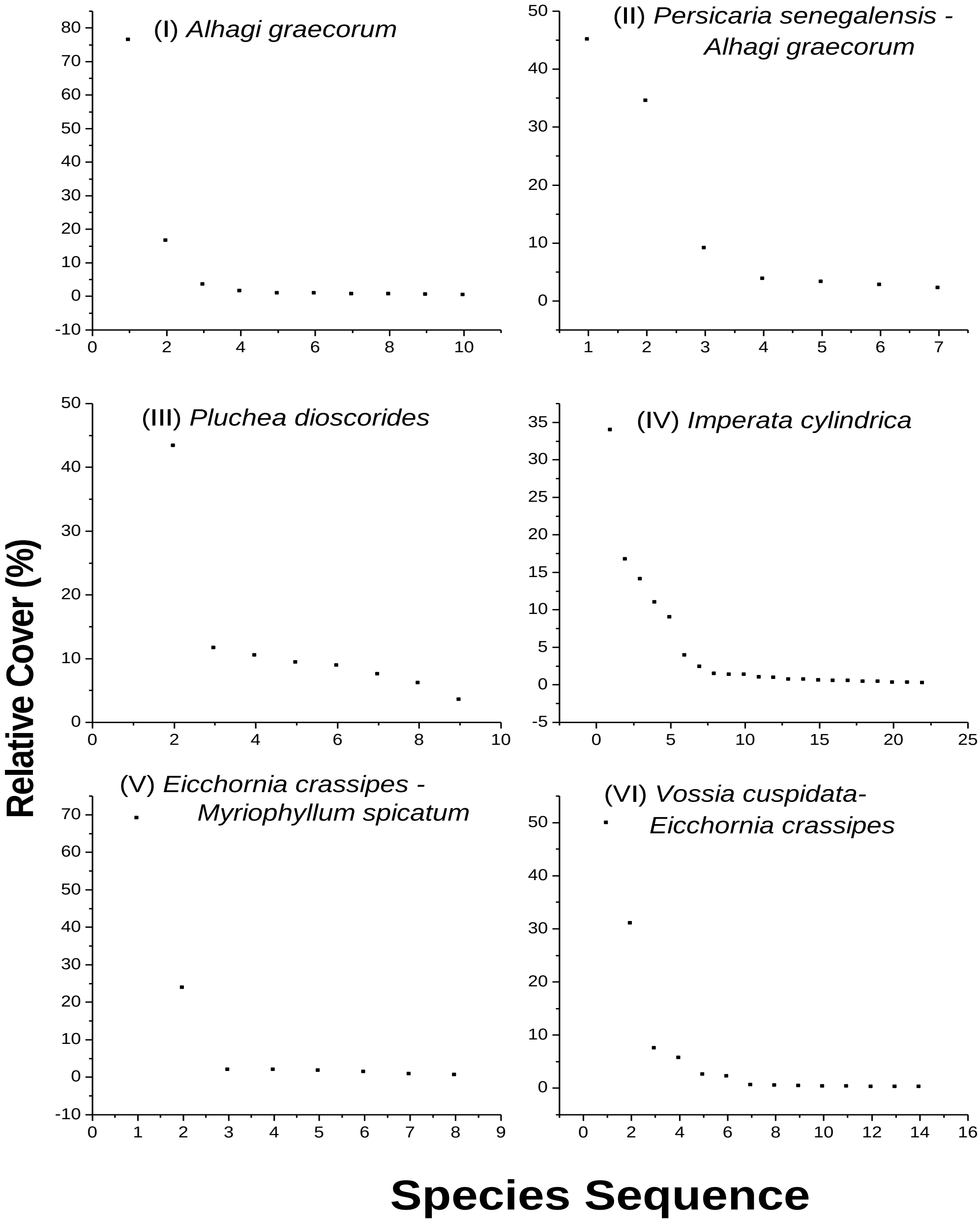



**Fig. 4.** Dominance diversity curves of the 13 vegetation groups identified in south Nile Delta (1 - 13).

**Fig. 4.** Continue

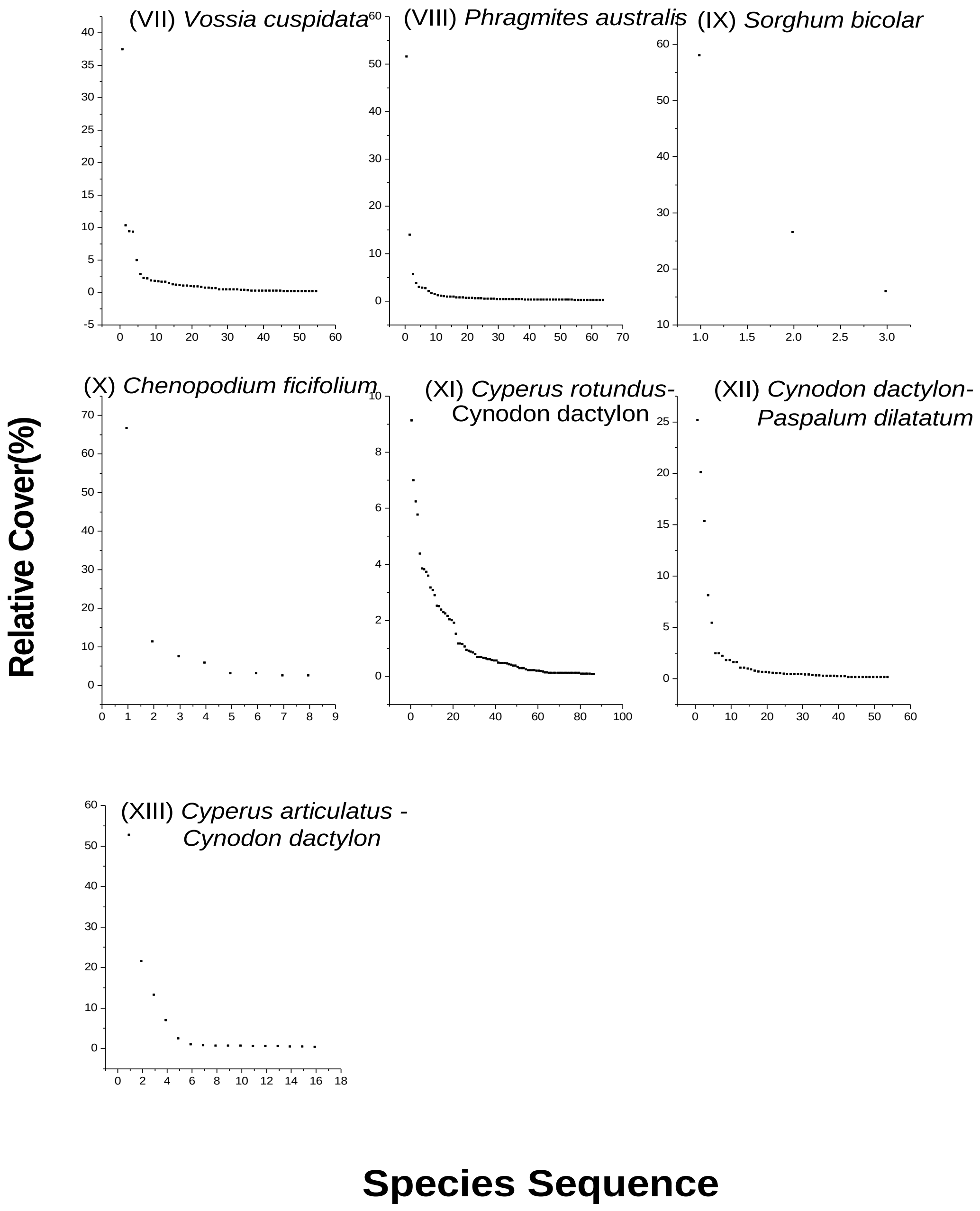


**Table 9.** Mean (± standard deviation) of the soil characteristics of the 13 vegetation groups generated after the application of TWINSPAN. The maximum and minimum values are underlined. The F-values and its probability are indicated. *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001.

| Soil characteristics | | Vegetation group | | | | | | | | | | | Mean ± SD | F-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | IV | V | VI | VII | VIII | X | XI | XII | XIII | | |
| Sand | % | 83.0 | 91.9 | 80.4 | 86.7 | 76.7 | 88.7 | 78.4 | 79.4 | 76.0 | 79.1 | 91.0 | 82.8 ± 5.8 | 2.8** |
| Silt | % | 10.3 | 4.0 | 14.9 | 6.0 | 10 | 6.9 | 16.6 | 14.0 | 19.2 | 15.7 | 4.0 | 11.1 ± 5.3 | 1.7** |
| Clay | % | 6.7 | 4.1 | 4.7 | 7.3 | 13.3 | 4.4 | 5.0 | 6.6 | 4.9 | 5.2 | 5.1 | 6.1 ± 2.6 | 1.6 |
| pH | | 7.3 | 7.9 | 7.7 | 7.9 | 6.8 | 7.7 | 7.8 | 7.6 | 7.8 | 7.8 | 7.7 | 7.6 ± 0.3 | 2.5** |
| E.C (mS $cm^{-1}$) | | 5.2 | 5.2 | 3.1 | 1.7 | 2 | 2.1 | 2.3 | 0.3 | 0.9 | 1.3 | 0.3 | 2.2 ± 1.7 | 4.5*** |
| $HCO_3$ | µg $g^{-1}$ | 0.2 | 0.1 | 0.2 | 0.1 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.14 ± 0.09 | 3.3*** |
| Cl | µg $g^{-1}$ | 7 | 7 | 7 | 2 | 2.5 | 2 | 3 | 0.4 | 1 | 1 | 0.5 | 3.04 ± 2.7 | 3.6*** |
| $SO_4$ | µg $g^{-1}$ | 0.2 | 0.4 | 0.2 | 0.1 | 0.9 | 0.2 | 4 | 0.2 | 0.2 | 0.2 | 0.1 | 0.61 ± 1.15 | 1.1*** |
| $NO_3$ | µg $g^{-1}$ | 6 | 0.0 | 5 | 2 | 2 | 2 | 3 | 1 | 3 | 2 | 3 | 2.63 ± 1.7 | 5.4 |
| $NO_2$ | µg $g^{-1}$ | 223 | 44 | 251 | 111 | 552 | 105 | 132 | 100 | 64 | 104 | 64 | 159.1 ± 145.2 | 2.3*** |
| P | µg $g^{-1}$ | 232 | 387 | 245 | 90 | 159 | 134 | 144 | 89 | 151 | 172 | 122 | 175 ± 86.0 | 6.0* |
| Na | µg $g^{-1}$ | 9 | 9 | 5 | 2 | 37 | 3 | 4 | 1 | 1 | 2 | 0.2 | 6.65 ± 10.5 | 1.2*** |
| K | µg $g^{-1}$ | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 ± 0.006 | 5.2 |
| Ca | µg $g^{-1}$ | 1 | 2 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 0.0 | 1.2 ± 0.75 | 6.7*** |
| Mg | µg $g^{-1}$ | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 0.0 | 1.1 ± 0.7 | 0.0*** |
| $CaCO_3$ (%) | | 5.0 | 2.1 | 3.3 | 3.8 | 6.8 | 2.5 | 2.5 | 2.6 | 2.8 | 2.6 | 1.7 | 3.2 ± 1.5 | 2.3** |

*Nymphaea coerulea*, *Ottelia alismoides*, and *Najas armata*). Eighteen species (12.5 %) recorded in the present study were not recorded neither by Al-Sodany (1998) nor by El-Sheikh (1989): e.g. *Vossia cuspidata, Persicaria lanigera*, *Commicarpus helenae*, *Malvastrum coromandelianum, Amaranthus spinosus*, *Homognaphalium pulvinatum*, *Paspalum dilatatum, Oxalis corymbosa* and *Rorippa palustris.* In addition, most of these species were not recorded in the study of Hussein (2000) in the greater Cairo (southern border of the study area).

**Table 10.** Mean (± standard deviation) of water characteristics of the 13 vegetation groups generated after the application of TWINSPAN. The maximum and minimum values are underlined. F-values and its probability are indicated.

| Water characteristics | | Vegetation group | | | | | | | | Mean ± SD. | F-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | III | IV | V | VI | VII | VIII | IX | XI | | |
| **pH** | | 9.2 | 11.0 | 9.7 | 9.5 | 9.9 | 9.9 | 7.7 | 7.8 | 9.3 ± 1.1 | 1.7 |
| **E.C (mS $cm^{-1}$)** | | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.9 | 0.3 | 0.3 | 0.4 ± 0.2 | 5*** |
| **$HCO_3$** | **Mg $l^{-1}$** | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.4 | 0.2 | 0.2 | 0.2 ± 0.08 | 4.4*** |
| **Cl** | | 0.02 | 0.02 | 0.002 | 0 0.02 | 0.01 | 0.1 | 0.03 | 0.02 | 0.03 ± 0.03 | 5.5*** |
| **$SO_4$** | | 16.2 | 14.1 | 19.5 | 18.1 | 18.8 | 24.7 | 28.3 | 16.4 | 19.5 ± 4.73 | 3.5*** |
| **$NO_3$** | | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 ± 0.0 | 1.8 |
| **$NO_2$** | | 0.4 | 0.4 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.6 | 0.5 ± 0.08 | 1.1 |
| **P** | | 13.4 | 13.6 | 1.4 | 13.4 | 13.6 | 2.0 | 13.9 | 13.6 | 10.6 ± 5.5 | 4*** |
| **Na** | | 0.04 | 0.04 | 0.04 | 0.04 | 0.09 | 1.1 | 0.03 | 0.03 | 0.17 ± 0.36 | 4.5*** |
| **K** | | 0.003 | 0.003 | 0.004 | 0.01 | 0.005 | 0.01 | 0.003 | 0.02 | 0.007 ± 0.36 | 1.5 |
| **Ca** | | 1.1 | 1.4 | 1.0 | 1.2 | 1.2 | 2.7 | 1.4 | 1.0 | 1.4 ± 0.006 | 4.3*** |
| **Mg** | | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 1.2 | 0.6 | 0.3 | 0.51 ± 0.56 | 3.4*** |
| **$CO_3$** | | 0.01 | 0.0 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 ± 0.03 | 0.7 |
| **Dissolved Oxygen (ppm)** | | 3.3 | 3.5 | 5.7 | 6.9 | 5.7 | 4.4 | 4.1 | 11.2 | 5.6 ± 11.6 | 0.5 |

The life form spectrum indicated that therophytes were highly represented, followed by geophytes-helophytes and hydrophytes. This is in accordance with the study of Al-Sodany (1992) in North Delta and the general trend of Egyptian flora (Shaltout & El-Halawany, 1993). Croplands, gardens and nurseries had the highest number of therophytes, while the open water had the lowest. This may be due to that therophytes are not adapted to grow in or above the water surface and inherently do not develop subterranean perennating organs which fix the plant to the bottom soil of the water body as in the case of perennial sedges and rushes (Al-Sodany, 1998). Geophytes-helophytes and hydrophytes were well represented along the slopes, water edges and open water more than the other habitats. This is due to the nature of these life forms, which often produce perennating organs to resist the external disturbances and impacts on the habitats or due to their water demands. Similar conclusions were reported by El-Demerdash (1984);

Shaltout & Sharaf El-Din (1988); El-Sheikh (1996) and Shaltout & El-Halawany (1993) in their studies on the vegetation along the irrigation and drainage canals in Nile Delta.

**Table 11**. Simple linear correlation coefficient (r) between the pairs of soil and community variables.

| Pairs of variables | | r | P |
|---|---|---|---|
| A- community variables | | | |
| Total species | x Species richness | 0.70 | 0.001 |
| | x Species turnover | 0.84 | 0.001 |
| | x Relative concentration of dominance | 0.58 | 0.001 |
| | x Relative evenness | 0.94 | 0.001 |
| Relative evenness | x Species richness | 0.74 | 0.001 |
| | x Species turnover | 0.79 | 0.001 |
| | x Relative conc. of dominance | -0.62 | 0.01 |
| **B- Community vs soil variables** | | | |
| $CaCO_3$ | x Species richness | - 0.65 | 0.05 |

The highest numbers of species per year were recorded in the ditches, fallow and flooded lands followed by the water edges and croplands. Winter and spring seasons were the flourishing seasons of the year in which most of the species were grown (52.1 % were winter active species and 85.4 % were spring active species). This may reflects the effect of climatic factors and water stress on the seasonal existence of species.

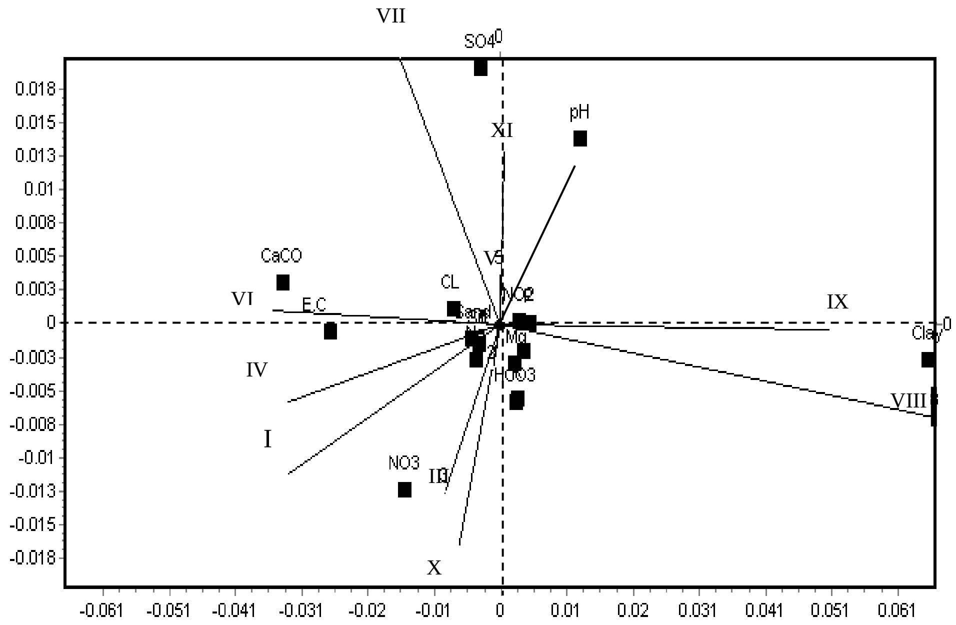



**Fig. 5.** PCA ordination diagram of the 13 vegetation groups generated after application of TWINSPAN (represented by numbers & squares) with respect to soil variables (represented by lines).

According to TWINSPAN, thirteen vegetation groups were generated and their ordination using DCA represents a complex gradient of moisture started with the open water communities while the gardens and nurseries communities located at the opposite direction. Positions that represent the water edges were located between that of the open water in one side, and gardens and nurseries in the other side. The moisture gradients started with the plant communities inhabited the terraces and slope of the watercourses and subjected to heavy human impacts (*Alhagi graecorum, Imperata cylindrica*, and *Pluchea dioscorides* groups). The moisture gradient and human impacts increased gradually in the plant communities that colonized the ditches and flooded lands (e.g. *Persicaria senegalensis-Alhagi graecorum, Chenopodium ficifolium,* and *Cyperus articulatus-Cynodon dactylon*). Similar conclusions were reported by El-Sheikh (1996) and Al-

Sodany (1998) in their studies on irrigation canals and drains in Middle and North Delta, respectively.

The mesophytes dominating plant communities in the gardens, nurseries and croplands include: *Chenopodium ficifolium*, *Cynodon dactylon-Paspalum dilatatum* and *Cyperus rotundus-Cynodon dactylon* groups. Wetland plants that characterize *Phragmites australis, Pluchea dioscorides, Sorghum bicolor* and *Cyperus articulatus-Cynodon dactylon* groups, usually inhabited the edges of the watercourses. The moisture gradient ends with the plant communities of the open water (e.g. *Eichhornia crassipes-Myriophyllum spicatum, Vossia cuspidata* and *Vossia cuspidata-Eichhornia crassipes* groups). The aquatic plants recorded in the present study have certain features in common, such as vegetative reproduction and relatively high rapid growth (Murphy *et al.*, 1990). Other plants may tolerate physical disturbances by being strong and flexible (Spink, 1992). It was also observed that most of the plant communities, especially in terrestrial and aquatic habitats, were often overwhelmingly dominated by one species. The presence of plant community dominated by one species, results in the suppression of the less competitive species, and hence the decrease in the species diversity of that community (Mohler & Liebman, 1987). Similar conclusions have been made by Shaltout *et al*. (1995) and Shaltout & El-Sheikh (2003) in their studies on the vegetation of the Mediterranean region of Nile Delta and that of the urban habitats in the Nile Delta region.

It is interesting to compare the aquatic plant communities in the present study ith those of the other related studies in the north (Al-Sodany, 1998) and middle Delta (El-Sheikh, 1989). Three vegetation groups have a common occurrence in north, middle and south Delta (*Eichhornia crassipes, Echinochloa stagnina* and *Phragmites australis*). Each region has its characteristic plant communities. Obviously, the present study area has its unique vegetation groups (e.g. *Vossia cuspidata, Vossia cuspidata-Eichhornia crassipes* and *Eichhornia crassipes–Myriophyllum spicatum* groups). Moreover, *Ceratophyllum demersum-Potamogeton crispus, Potamogeton pectinatus* and *Azolla filliculoides* were either completely absent from the study area or exist in a very low cover. It was reported by Fayed (1985), Springuel (1987) and Springuel & Murphy (1990) that *Myriophyllum spicatum* invaded the Nile Valley in the southern provinces of Egypt. Northwards, in the Nile valley, El-Kholi (1989) recorded *Myriophyllum spicatum* in the River Nile and irrigation canals from Aswan to Giza, but he did not record it in the Nile Delta including the northern

Lakes. In Nile Delta, Serag (1991); Zahran & Willis (1992); Shaltout & El-Sheikh (1993) and Shaltout *et al.* (1994) did not refer to the presence of *Myriophyllum spicatum.* Recently, Khedr & El-Demerdash (1995) and Khedr & Zahran (1999) recorded *Myriophyllum spicatum* in the east of the Nile Delta and Lake Manzala (*c.f.* Zahran & Willis 2003). Two vegetation groups of the present study (*Cyperus rotundus-Cynodon dactylon* and *Cynodon dactylon-Paspalum dilatatum*) were represented with their first dominant species in the study of El-Sheikh (2004) in El-Qanatir Public Park. A total of 67 species was recorded as weed vegetation in the study of El-Sheikh (2004) (74 species in the present study).

The lowest values of diversity indices were that of the plant communities of the open water. Some of the plant communities that occupy the gardens, nurseries, croplands, ditches, fallow and flooded lands had high diversity indices (e.g. *Cynodon dactylon–Cyperus rotundus* and *Cynodon dactylon*). In general, it was noted that the diversity indices of the plant communities in south Nile Delta were lower than that in North Delta and middle Delta (see Al-Sodany, 1998 and Shaltout *et al.* 1994). Steep dominance-diversity curves (geometric series) showed strong dominance of some species and confirm the hypothesis of niche-pre-emption, which often exhibited by vascular plants with a low diversity (Whittaker, 1972 and Al-Sodany, 1998). As an example for the strong dominance of species in the water edge and the open water communities were *Pluchea dioscorides, Vossia cuspidata* and *Phragmites australis.* Moreover, There was a strong dominance of *Alhagi graecorum* and *Imperata cylindrica* along the terraces and slopes of watercourses, and *Chenopodium ficifolium* in the croplands, ditches, fallow and flooded lands. Some plant communities were dominated by two species while the other species were weakly represented such as: *Eichhornia crassipes-Myriophyllum spicatum, Vossia cuspidata-Eichhornia crassipes* (in the open water) and *Cynodon dactylon-Paspalum dilatatum* (in the gardens and nurseries).

Principal Components Analysis revealed a degree of correlation between some soil variables and plant communities. It indicated a high correlation between *Vossia cuspidata* (VG VII) and *Cyperus rotundus-Cynodon dactylon* (VG XI) with the soil pH and sulphate contents. Shehata (1994) reported that *Vossia cuspidata* dominated in water with low alkaline pH (7-8.9), total soluble salts between 2.12-5.9 mg $L^{-1}$ and sulphates between 0.7-1.16 mg $L^{-1}$. This may explain the vigorous and weak growth of the plant in fresh and saline water, respectively. It also revealed that *Phragmites* *australis* (VG VIII) and *Sorghum bicolar* (VG IX) were positively correlated with clay content. This explains the abundance of the two species along the water edges as well as in all the watercourse habitats.

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