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Species richness and phenology of vegetation along irrigation canals and drains in the Nile Delta, Egypt

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Abstract

This study evaluates the species richness, phenology and effect of environmental factors on the composition of canal and drain vegetation in the Nile Delta, Egypt. Altogether, 365 stands were sampled along the terraces, slopes, littoral zones and water zones of 28 canals and 10 drains. Smooth species compositional changes were found in the first three zones. The slope plant community has the highest total number of species and species richness and a medium value of species turnover. The water zone has the lowest values of these variables.

The number of species with seedlings and vegetative plants had two peaks: one in winter and the second in summer, which was related to the contrasted behaviour of the winter and summer weeds. The number of species with vegetative and fruiting plants was relatively higher, while the number with dormant plants was relatively lower in the canal vegetation when compared to that of the drains. The number of species with vegetative, flowering and fruiting plants increased with the decrease of canal-drain width.

Nomenclature: Täckholm, V. (1974). Students Flora of Egypt. Cairo Univ. Press.

Introduction

Aquatic weeds can cause problems with navigation, agriculture, fisheries and public health. However the aquatic vegetation can also be benificial by providing shelter and nourishment to fish, waterfowl and other aquatic organisms; by removing toxic compounds from water; by preventing erosion along the banks of water bodies; and by providing source of animal feed, paper pulp, fiber and bioenergy. Multiple uses of this resource requires the management of aquatic vegetation in a way that all interests are fulfilled (Zon 1982).

Almost all the Egyptian cultivated land is irrigated by the River Nile through a network of canals and drained by a similar network of drains. Most of these canals and drains were dug in the last 150 years (Hurst 1952). The total length of both networks (excluding private ditches and drains) exceeds 47 000 km: >31 000 km of canals and >16 000 km of drains (Khattab & El-Gharably 1984). This irrigation system has been subjected to many of large scale alterations. The most recent is the Aswan High Dam (1960–1968) which brings the River Nile under the full flood control. Due to this, many serious ecological problems have arisen. Among them is the spread of aquatic weeds (Khattab & El-Gharably 1984).The reduction of the Nile's annual flood-load of sediments that the river brought to its delta is causing serious erosion (Kassas 1971) with undoubted effect on the riparian vegetation of the irrigation system.

The factors that govern the richness of the vegetation along the banks of rivers and other water bodies are still poorly understood (Nilsson *et al.* 1989). In Egypt, such studies have received little attention. Among the previous studies, are those of Simpson (1932), Hassib (1951), and Batanouny and El-Fiky (1984).The present study in the Nile Delta evaluates the diversity and phenology of canal and drain vegetation and the effect of the environmental factors on this vegetation.

Study area

The Nile Delta is a classic triangular delta with an inconstant system of distributaries. Its surface is relatively even in the south compared to the north (Abu Al-Izz 1971). The soils of Nile Delta are heavy in texture, rather compact at the surface and rich in humus. Except for the Mediterranean coastal region, soils are man-made variants of Gleysols and Fluvisols (El-Gabaly *et al.* 1969). Summer air temperatures range between 20 °C and 30 °C, and winter between 10 °C and 20 °C (Anon. 1977). Most of rain falls in winter and ranges between 72 mm/year at Kafr El-Sheikh in the north and 36 mm/year at Shebin El-Kom in the south (Fig. 1).

Methods

One hundred sites were selected along 28 canals and 10 drains, distributed in 8 locations within the study area (Fig. 1). They were selected to represent the apparent physiognomic variations in vegetation and edaphic features, as well as three width classes of canals and drains (<5, 5–10, >10 m). Each site was divided into 4 main zones: terrace, slope, littoral, and water. Each zone was sampled using a long rectangular plot. Its length and width varied according to the extension of plant cover and/or width of the selected canal or drain. The total number of stands sampled was 365: 251 for canals and 114 for drains. A list of species and their life forms (sensu Raunkiaer 1937) was made in each stand indicating the dominant and the sub-dominant species (visual estimates). Nomenclature follows Täckholm (1974). The percent presence of each species, the mean number of species/stand (species richness), and the species turnover (total number of species/ mean species richness) (Wilson & Shmida 1984) of each canal and drain zone were calculated. Wisconsin polar ordination (Bray & Curtis 1957) of the vegetation of the 4 zones of canals and drains, based on Sorensen similarity coefficient, was also carried out.

The seasonal variation in the phenological state (PS) of the plant community of each width class of canals and drains was calculated as follows: $PS = (N/TN)100$, where N is the number of species in a certain community that have a given phenological state (seedling, vegetative, flowering, fruiting, and dormancy), and TN is the total number of species of that community.

Soil profile samples (0–50 cm) were collected from terrace and slope stands, and water samples were collected from the water surface down to 50 cm at a distance of 1.5 m from the shore. Texture, organic matter, and $CaCO_3$ of soil samples were estimated using Bouyoucos hydrometer, loss-on-ignition, and calcimeter, respectively. Soil salinity (EC) and soil reaction (pH) were estimated in 1:5 soil-water extracts using the conductivity and pH meters, respectively. The determination of alkalinity, chlorides, and sulphates of water samples were carried out using the titration against HCl, titration against $AgNO_3$, and gravimetric with ignition of residue, respectively. Some nutrients (P, K, Ca, Na, Mg) were estimated in soil extracts of 2.5% v/v glacial acetic acid, and the filtered water samples. K, Ca, and Na were

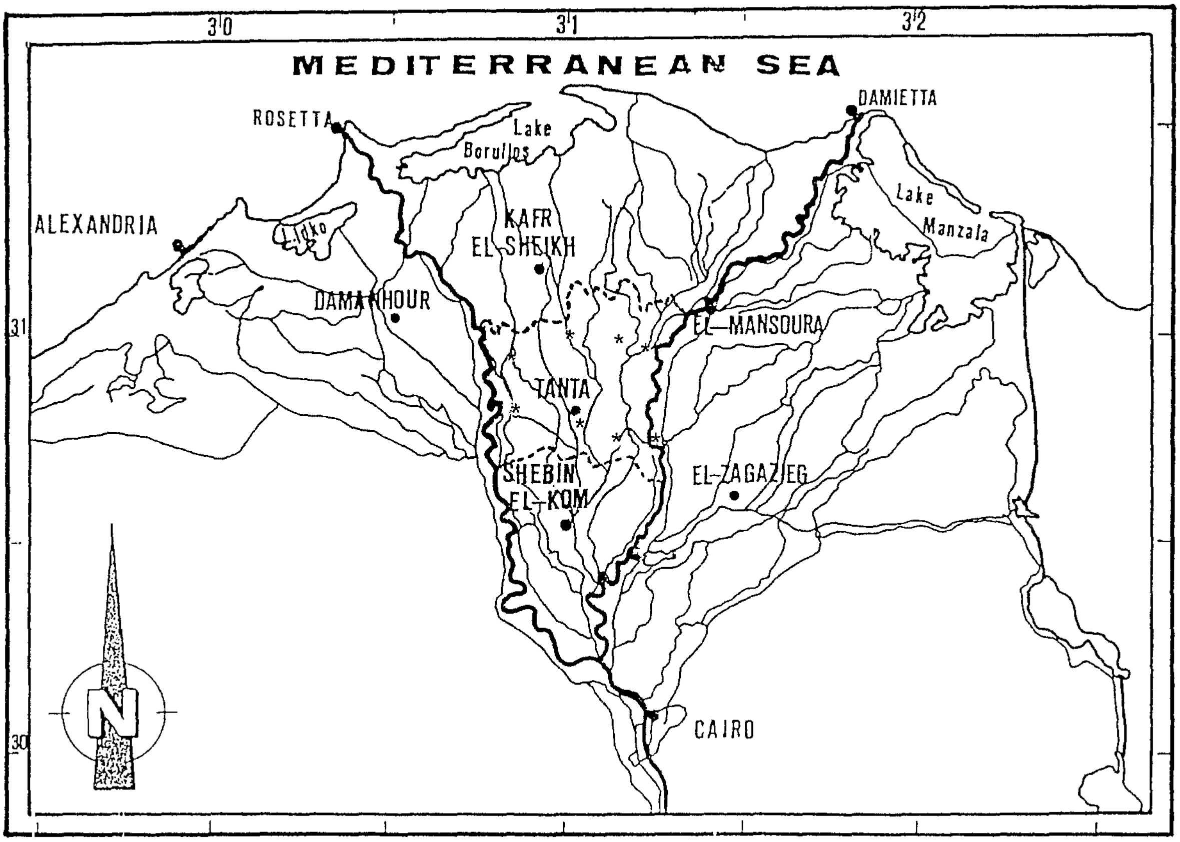

Fig. 1. The main canals and drains in the Nile Delta region. The study area is bounded by dashed lines. * Denotes the 8 studied locations.

estimated using flame photometer, P and N using spectrophotometer, and Mg using atomic absorption. All these procedures are outlined by Allen *et al.* (1974) and Anon. (1985).

Results

The total number of species recorded was 178: 56 were found only along canals and 15 along drains. The others 107 were found along both. Some species have higher presence with increasing soil moisture from the terrace to the water zone (e.g. *Paspalum paspaloides* and *Echinochloa stagninum*), while others are restricted to either the dry or wet ends of this gradient (Table 1). As expected there is a high similarity between the floristic composition of the first three zones in contrast with the water zone. However there are differences between canal and drain vegetation (Fig. 2).

Therophytes are the most frequent life form for all zones except the water zone where the cryptophytes (geophytes-helophytes and hydrophytes) are dominant. In general, phanerophytes and geophytes-helophytes are relatively more common in canals than drains, while the other life forms show a reverse trend. The plant community of the slopes has the highest total number of species and species richness and a medium species turnover value, while that of the water zone has the lowest values of these variables (Table 2).

In general, the number of species with seedling and vegetative plants had two peaks: one in winter (the highest) and the second in summer. On the other hand, the peak number of species with dormant plants was in autumn. The number of

Table 1. Percent presence of the species that have > 10% in at least one zone along the canals (C) and drains (D).

Species	Terrace		Slope		Littoral		Water	
	C	D	C	D	C	D	C	D
Mentha microphylla	12.8	12.5	36.0	13.0	11.6			
Cynanchum acutum	1.5	12.5	0.7		0.4			
Arundo donax	8.0		10.0		1.8			
Oxalis corniculata	12.1	0.5	8.9	1.4	0.2			
Ethulia conyzoides	0.2		22.4	0.9	17.0			
Conyza discoridis	16.0	7.4	38.8	34.2	15.7	19.4		
Ricinus communis	2.8	1.4	10.0	1.9	1.3	0.5		
Aster squamatus	30.3	15.5	50.0	30.0	26.3	24.3		
Convolvulus arvensis	18.2	33.0	13.8	35.5	1.6	1.4		
Vigna luteola	1.4	2.3	10.0	5.1	2.3	3.2		
Cyperus rotundus	26.0	23.0	18.5	13.0	6.8	2.8		
Imperata cylindrica	19.4	13.7	13.5	23.2	2.9	1.4		
Panicum repens	25.2	28.5	30.0	30.0	16.7	6.8		
Amaranthus viridis	31.0	11.5	18.0	24.0	4.3	9.9		
Corchorus olitorius	3.4	4.2	11.5	4.6	3.1	0.5		
Chenopodium murale	17.4	23.0	18.1	30.5	2.4	9.0		
Conyza linifolia	4.8	2.3	15.0	10.0	7.4	4.4		
Eclipta alba	1.1	0.9	21.9	19.7	9.4	17.3		
Kochia indica	0.8	27.3	0.9	0.9	0.4	7.1		
Malva parviflora	12.7	21.2	5.6	7.9	0.7	1.9		
Poa annua	5.1	0.5	11.0	0.9	3.1	0.5		
Polypogon monspeliensis	11.2	9.9	19.8	14.5	16.1	18.5		
Polypogon semiverticillatus	8.3	0.9	12.4	5.8	10.6	2.3		
Portulaca oleracea	6.1	7.7	10.1	6.3	3.4	2.8		
Rumex dentalus	30.0	27.0	58.0	37.0	22.1	29.3		
Sonchus oleraceus	18.6	15.6	25.0	27.0	5.0	14.3		
Sonchus asper	2.3	3.5	10.5	10.0	1.6	0.9		
Solanum nigrum	9.0	3.2	23.1	24.6	4.5	4.9		
Torilis arvensis	3.4	1.9	10.0	2.8	1.6	0.5		
Verbena officinalis	9.5	0.5	16.0	4.6	3.1	1.9		
Beta vulgaris	4.7	10.0	1.7	3.7	0.4	0.5		
Sida alba	3.0	4.6	10.0	5.6	0.4	0.5		
Echinochloa colonum	3.7	1.4	10.0	1.9	6.2	1.4		
Alternanthera sessilis	4.0		10.0	0.5	13.0	0.9		
Cyperus articulatus	0.2		10.0		7.2	0.9		
Inula crithmoides		12.5		6.3		3.1		
Ranunculus sceleratus				3.1		12.5		
Brachiaria mutica	6.6	12.5	9.8	27.0	11.3	17.1	0.4	
Cynodon dactylon	79.0	62.5	82.2	51.7	34.5	31.3	0.9	
Cyperus dives	0.9		10.0		8.5		0.4	
Paspalum pspaloides	18.1	3.2	42.0	15.0	42.0	18.0	6.6	9.0
Echinochloa stagninum	4.9	17.0	25.0	26.0	36.0	31.0	16.0	30.3
Phragmites australis	16.3	32.0	23.5	45.1	10.0	47.0	0.7	1.9
Polygonum salicifolium	8.0	1.4	56.2	34.0	52.0	39.0	6.2	8.6
Scripus tuberosus	1.5	13.0	6.3	0.5	3.6	20.1	0.7	2.8
Typha domingensis	1.7	7.1	1.5	9.4	13.4	32.0	0.9	9.8
Leersia hexandra	1.9		18.3	6.7	21.2	25.4	0.4	6.3
Cyperus alopecroides	11.2	1.8	28.0	21.3	33.0	33.0		1.4
Echinochloa crus-galli	4.0	4.0	3.0	1.9	7.0	10.0		0.9
Ceratophyllum demersum					28.4	8.8	33.0	12.0
Eichhornia crassipes					20.0	22.0	16.0	19.0
Lemna gibba					2.3	38.0	9.4	22.0
Potamogeton crispus					12.0	6.3	17.0	20.0
Spirodela polyrrhiza					3.0	5.8	13.4	5.6
Potamogeton nodosus					3.1		30.4	

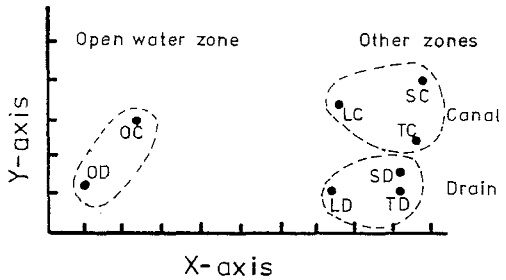

Fig. 2. Two dimension polar ordination of the four zones of canals and drains based on the similarity of their species composition. TC, SC, LC and OC are the terrace, slope, littoral and water zones of canals, respectively. TD, SD, LD and OD are the similar zones of drains.

species with vegetative and fruiting plants were relatively more common in canal vegetation than in drain vegetation throughout the year. The reverse is true for dormancy (Fig. 3). There is a tendency for more species with vegetative, flowering and fruiting plants and fewer dormant plants with decreasing the width of canals and/or drains (Table 3).

There is a general increase of the fine fractions (silt and clay), organic matter, N, and K of the terrace and slope soils with the decrease of the canal and, to some extent, drain width. A decrease of the drain width, is associated with an increase in soil salinity (EC), while an increase in canal width is associated with increase in soil salinity. In general, the soils of terraces and slopes of canals have higher contents of sand, N, K and Ca, and lower contents of fine fractions, EC, P and Mg than those of drains (Table 4). The water of the narrow canals (< 5 m) and drains (5–10 m) is slightly more saline and have more dissolved elements than the wider ones. In comparison with drain water, canal water was less saline (Table 5).

Discussion

Smooth species compositional changes occur between the terrace, slope and littoral zones of both canals and drains, in contrast with the transition to water zone. Comparing the recorded species in the present study (178 species) with those of related studies, we found that about half of them are considered weeds in the Nile Delta region (EL-

Table 2. Life form spectrum, species richness and species turnover in the four zones along canals (C) and drains (D). A and R are the actual and relative (%) number of species, respectively.

Life form		Terrace		Slope		Littoral		Water	
		C	D	C	D	C	D	C	D
Phanerophytes	A	6	2	6	3	5	2		
	R	4.9	2.0	4.5	2.9	4.5	2.4		
Chamaephytes	A	6	8	6	7	4	6		
	R	4.9	8.0	33	4.5	6.9	3.6	7.1	
Hemicryptophytes	A	11	10	11	9	11	8		
	R	9.0	10.0	8.2	8.8	9.8	9.4		
Geophytes and	A	24	14	25	17	30	17	16	8
Helophytes	R	19.7	14.0	21.6	16.7	26.8	20.0	57.1	44.4
Hydrophytes	A					10	7	12	9
	R					8.9	8.2	42.9	50.0
Parasites	A		1	4	1				
	R		1.0	2.9	0.9				
Therophytes	A	75	65	78	65	52	45		1
	R	61.5	65.0	58.2	63.7	46.4	52.9		5.6
Total species		122	100	134	102	112	85	28	18
Species richness		6.9	7.8	13.0	12.0	10.0	8.5	2.9	3.2
Species turnover		17.7	12.8	10.3	8.5	11.2	10.0	9.7	5.6

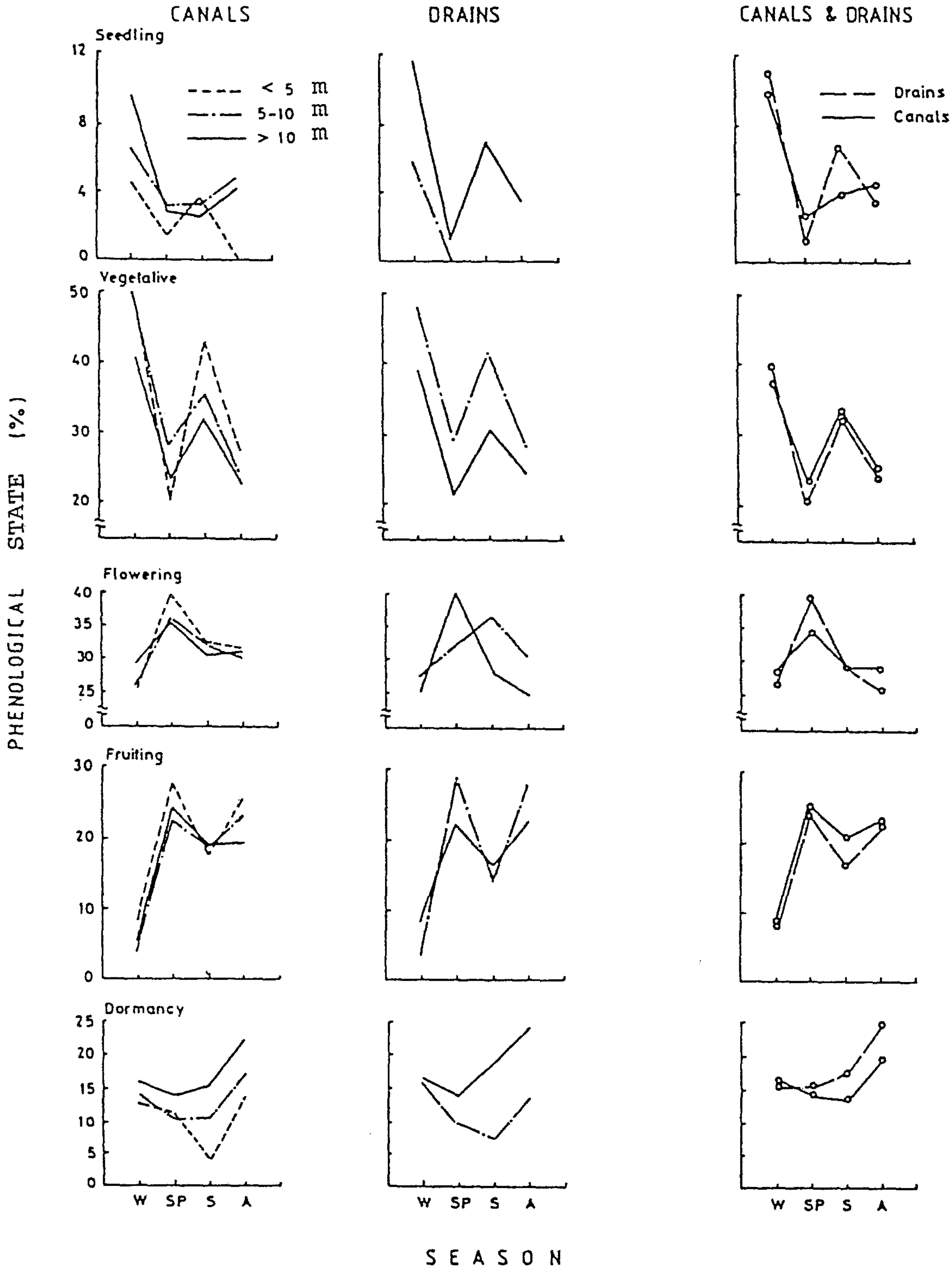

Fig. 3. Seasonal variation in the phenological states (%) of the species in the vegetation of all zones along canals and drains.

Table 3. The mean phenological states (%) of the vegetation of canals and drains. Means with common letters are significantly different according to t-test (P: 0.05–0.01).

Phenological stage	Canal width		Drain width		
	< 5 m	5–10 m	> 10 m	5–10 m	> 10 m
Seedling	2.3	4.5 a	4.8 b	1.5 abc	5.9 c
Vegetative	35.0	34.0 a	29.5 ab	36.3 bc	28.6 c
Flowering	32.3	31.3	31.4	32.0	29.6
Fruiting	20.0	16.9	17.3	19.0	17.6
Dormancy	10.8	13.4 ab	17.0 a	11.6	18.4 b

Fahar 1989). Many others are found in urban habitats within the Nile Delta (Hejny & Kosinova 1977; Shaltout & Sharaf El- Din 1988). About two thirds of the recorded species in the study of Simpson (1932) on the vegetation of the Egyptian irrigation channels were found in the present study. *Aster squamatus* and *Kochia indica* were common species in the present study. Both spe-

Table 4. Mean and standard error (SE) of some soil characters of the terraces and slopes of canals and drains. SD: sand, ST: silt, CY: clay, OM: organic matter.

Canal-drain width	SD	ST	CY	OM	$CaCO_3$	EC	pH	N	P	K	Na	Ca	Mg
	(%)					μmohs/cm	mg/100 gm						
Terrace zone													
Canal													
< 5 m	37	42	21	7.4	3.0	916	7.9	273	6.9	131	253	1693	281
5–10 m	47	45	8	5.4	3.0	1678	7.9	241	8.2	102	293	2608	229
> 10 m	52	41	7	6.4	4.4	1976	7.5	232	9.6	102	277	1639	280
Mean	45	43	12	6.3	3.4	1523	7.7	249	8.2	111	274	1980	263
SE	4	1	4	0.5	0.9	325	0.1	13	0.7	11	13	274	17
Drain													
5–10 m	45	51	4	7.4	2.3	2522	7.7	206	13.6	81	352	1433	296
> 10 m	38	43	19	6.3	5.5	2436	7.9	203	10.2	87	329	1659	306
Mean	42	47	11	6.8	2.9	2479	7.8	204	11.8	84	340	1546	301
SE	4	4	7	0.5	0.8	140	0.1	32	1.4	9	24	98	11
Slope zone													
Canal													
< 5 m	37	46	17	8.5	2.8	336	7.8	305	8.4	107	153	1895	292
5–10 m	42	45	13	5.6	1.8	355	7.9	222	7.6	76	140	1437	261
> 10 m	50	44	6	6.3	1.6	563	7.6	222	7.3	66	147	1385	218
Mean	43	45	12	6.8	2.1	418	7.8	256	7.7	80	137	1572	257
SE	3	1	3	0.8	0.3	77	0.0	24	0.4	12	9	145	19
Drain													
5–10 m	46	44	10	9.0	2.6	3163	7.8	245	14.3	96	431	1658	385
> 10 m	36	42	22	6.6	2.1	1144	7.9	173	8.7	53	264	1377	309
Mean	41	43	16	7.7	2.3	2154	7.9	209	11.4	75	384	1518	322
SE	6	3	7	1.1	0.2	1111	0.1	30	2.7	18	86	140	11

Table 5. Mean and standard error (SE) of some water characters of the canals and drains. Alka.: alkalinity.

Canal-drain width	EC µmohs/cm	pH	N	P	K	Na	Ca	Mg	Alka.	Cl^-	$SO_4^=$
		mg/L									
Canal water											
<5 m	380	7.5	1.0	0.5	20.0	89.0	45.0	9.6	217.0	56.0	421.0
5–10 m	335	7.8	2.9	0.4	16.2	73.7	36.0	8.2	160.0	74.0	311.0
>10 m	337	7.7	0.9	0.5	15.8	77.4	37.5	9.9	172.0	56.0	271.0
Mean	350	7.7	1.6	0.5	17.3	80.0	39.5	9.2	183.0	62.0	334.3
SE	14	0.1	0.7	0.0	1.3	4.2	2.7	0.5	16.9	5.7	44.4
Drain water											
5–10 m	1585	7.5	0.4	0.5	11.5	158.0	59.0	9.7	300.2	264.0	423.0
>10 m	1185	7.7	2.5	1.4	27.1	157.8	55.0	15.0	300.0	200.0	306.0
Mean	1385	7.6	1.4	1.0	19.3	157.9	57.0	12.3	300.1	232.0	364.5
SE	196	0.1	1.0	0.4	7.8	1.1	1.6	2.6	0.1	31.2	56.7

cies were absent in the earlier studies by Simpson (1932) and Hassib (1951). According to Täckholm (1974), the first species is of American origin and is naturalized in Egypt. *Kochia indica* was introduced to Egypt in 1945 as a promising fodder plant in the north western desert, after that it began to invade the Nile Delta and Valley (Drar 1952). As in the whole Egyptian flora (Hassib 1951), the therophytes are the most common life form in the present study. The decrease of this life form along the moisture gradient from the terraces to the water zones indicates that the aridity favours the annuals. The cryptophytes are the second most common life form (26%), exceeding that of the whole Egyptian flora (15%) and even the Egyptian Nile region (16%) (Hassib 1951), and the arable weed flora in the Nile Delta (11%) (Shaltout & El-Fahar 1991), but it is comparable to that of urban habitats (29%) (Shaltout & sharaf El-Din 1988). The unstable conditions along the banks of the rivers and the other water bodies (in the present study, erosion, cleaning practices, repeatable change in the water level and excessive human disturbance play the major role) may inhibit establish of plants from seed, but favour the colonization by creeping growth (Roberts & Ludwig 1991).

The high species richness and the medium species turnover of the slope plant community in the present study may be related to its intermediate position along the prevailing environmental gradient, thus it acts as a transitional community which is usually rich in species. Such zone is characterized by medium disturbance comparing with the terrace (trampling, grazing, cutting, firing) and water zones, thus the high diversity of this community consists with the medium disturbance hypothesis (see Nilsson *et al.* 1991). On the other hand, the low species richness and species turnover of the water zone may due to the fact that most of its species are highly specific to the aquatic habitat and the same species occur at nearly all the sites. This means that the species replacement or biotic change is low in this zone (Wilson & Shmida 1984).

The bimodality in the phenological state of the present vegetation may be partially due to the contrasted behaviour of the winter and summer weeds (Kosinova 1975; Shaltout & El-Fahar 1991). The relative increase of vegetative, flowering and fruiting plants in relation to the decrease of canal-drain width could be related to the increase of soil fertility (organic matter, N and P) with the decrease of canal-drain width. On the other hand, dormant plants were relatively lower, while the vegetative and fruiting plants were relatively higher along the canals than along the drains throughout the year. This may be due to the higher salinity of the soils and water of the drains than those of canals.

References

Abu Al-Izz, M. S. 1971. Land forms of Egypt. The American Univ. in Cairo Press. Dar Al-Maaref, Cairo.

Allen, A. E., Grimshaw, H. M., Parkinson, J. A. & Quarmby 1974. Chemical analysis of ecological materials. Blackwell Scientific Publications.

Anon. 1977. Map of the world distribution of arid regions. UNESCO, MAB Technical Notes 7.

Anon. 1985. Standard methods for the examination of water and waste water. APHA, Washington.

Batanouny, K. H. & El-Fiky, A. M. 1984. Water hyacinth in Egypt: distribution and magnitude. Proc. of the Inter. Conf. on Water Hyacinth. Hyderabad, India. U. N. Envir. Prog.

Bray, R. J. & Curtis, J. T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecol. Mono. 27: 325-349.

Drar, O. 1952. A report on *Kochia indica* Wight in Egypt. Bull. Inst. Fouad I du Desert 1.1.

El-Fahar, R. A. 1989. A phytosociological study on weed vegetation in the Nile Delta region. M. Sc. Thesis, Tanta Univ.

El-Gabaly, M., Gewaifel, I. M., Hassan, M. N. & Rozanov, G. 1969. Soil map and land resources of the United Arab Republic. Res. Bull. 22: 1–14.

Hassib, M. 1951. Distribution of plant communities in Egypt. Bull. Fac. Sci. Fouad I Univ. 29: 59–261.

Hejny, S. & Kosinova, J. 1977. Contribution to synanthropic vegetation of Cairo. Publications from Cairo Univ. Herbarium 7–8: 273–286.

Hurst, H. E. 1952. The Nile. Constable, London.

Kassas, M. A. 1971. The river Nile ecological system, a study towards an international programme. Biol. Conser. 4: 19–25.

Khattab, A. F. & El-Gharably, Z. A. 1984. The problem of aquatic weeds in Egypt and methods of management. Proc. EWRS Third Symp. on Weed Problems in the Mediterranean: 335–344.

Kosinova, J. 1975. Weed communities of winter crops in Egypt. Preslia 47: 85–74.

Nilsson, C., Ekblad, A., Gardfjell, M. & Carlberg, B. 1991. Long-term effects of river regulation on river margin vegetation. J. App. Ecol. 28: 963–987.

Nilsson, C., Grelsson, G., Johansson, M. & Sperens, U. 1989. Patterns of plant species richness along river banks. Ecol. 70: 77–84.

Raunkiaer, C. 1937. Plant life forms. Clarendon, Oxford.

Roberts, J. & Ludwig, J. A. 1991. Riparian vegetation along current-exposure gradients in floodplain wetlands of the River Murray, Australia. J. Ecol. 79: 117–127.

Shaltout, K. H. & El-Fahar, R. A. 1991. Diversity and phenology of weed communities in the Nile Delta region. J. Veg. Sci. 2: 385–390.

Shaltout, K. H. & Sharf El-Din, A. 1988. Habitat types and plant communities along a transect in the Nile Delta region. Feddes Repert. 99: 153–162.

Täckholm, V. 1974. Students flora of Egypt. Cairo Univ. Press.

Simpson, N. D. 1932. A report on the weed flora of the irrigation channels in Egypt. Ministry of Public Works, Government Press, Cairo.

Wilson, M. V. & Shmida, A. 1984. Measuring Beta diversity with presence absence data. J. Ecol. 72: 1055–1064.

Zon, van, J. C. J. 1982. Aquatic weeds. In: Biology and Ecology of Weeds, eds. W. Holzner & N. Numata. Junk Publishers 449–456.