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Invasive Plant Communities in the Nile Delta Coast

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Abstract: Plant communities dominated by the invasive species *Heliotropium curassavicum, Bassia indica* and *Chenopodium ambrosioides* were investigated in fallow land, coastal desert land, newly reclaimed land, canal banks and old reclaimed land in the Nile Delta Mediterranean coast. A total of 19 common species were recorded in this study. They constituted 12 annual and 7 perennial species. The vegetation was classified by the Two Way Indicator Species Analysis (TWINSPAN) into five vegetational groups representing different habitat types. Detrended Correspondence Analysis (DCA) demonstrates the separation of TWINSPAN groups of different habitat types into five vegetational groups along the plane of the first and second axes. Canonical Correspondence Analysis (CCA) demonstrates that soil factors especially $CaCO_3$, organic carbon and soil texture contribute significantly to the distribution of species. The Shannon diversity index (*H′*) of the five vegetational groups showed parallel results to those obtained in case of species richness. The highest species richness value was attained in the fallow land and desert, then lower values obtained in canal bank and newly reclaimed land, followed by the minimum value obtained in the old reclaimed land. The highest value of evenness attained in the fallow land while the minimum value recorded in the old reclaimed land.

Key words: Plant-soil relationships . multivariate analysis . species diversity . mediterranean coast

INTRODUCTION

The increase in human population of Egypt necessitates the expansion of the cultivated lands. This was achieved during the last few decades by the reclamation of desert areas [1]. This human interference causes the weedy species to replace the wild plant species in these reclaimed areas [2], which are considered as transitional habitats between the old cultivated land and desert. The invasive species in the new agricultural lands cause serious problems that require attention to be paid to the negative impacts of plant invasions on ecosystems and native gene pools [3].

Despite the many studies undertaken on desert vegetation in Egypt [4, 5], yet, studies on the vegetation of the reclaimed land in Egypt are still limited [1]. One of these studies was that carried out by [6] and concerned with the vegetation of the reclaimed areas northeast of the Nile Delta. It has been estimated that the farm management practices such as application of herbicides [7], crop rotation [8], tillage practices [9] and use of fertilizers [10] contribute to the expansion and diversity of the weed communities, where each management practice exerts a different selection pressure on weed species [11]. The many factors involved in the formation of weed communities make it difficult to evaluate the relative importance of each individual factor [12]. Furthermore, diversity of weed communities has little been investigated [13] and most of the diversity studies on weeds focus on the impact of the management practices on the diversity of weed communities [14]. Vegetation studies on invasive weeds provide the quantitative information required in developing comprehensive weed community management strategies and supply the baseline information for measuring any changes in the weed flora [15].

The present study deals with the investigation of vegetation dominated by the three target invasive plant species; *Heliotropium curassavicum, Bassia indica* and *Chenopodium ambrosioides* in the Nile Delta coast. The main objective is to study vegetation and species diversity in the invasive plant communities in relation to habitat types.

MATERIALS AND METHODS

Vegetation analysis: A total of 15 stands were located over summer and winter growing seasons during the period (2003-2005). The stands covered the different habitat types in five sites of the study area namely; fallow land, desert, newly reclaimed land that was previously cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, canal bank and old reclaimed land cultivated with *Citrullus lanatus.*

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Stands and sites were selected so as to represent the variation of invasive plant vegetation and edaphic characteristics prevalent in the area. Voucher specimens of plant material were collected, identified following [16] and deposited in Cairo University Herbarium (CAI).

For every stand, a floristic list and plant counts were taken within 10 quadrats (5 x 5 m^2). From these list and counts, the mean relative density and relative frequency of the species were calculated as the fraction of sample quadrats containing the species [1, 17]. Plant cover as percentage of ground surface was determined by the line intercept method [18]. Five line intercept transects, randomly placed within every quadrat were studied [17]. The sum of the relative density, relative frequency and relative cover gave the importance value (IV) out of 300. The importance value of species was calculated as:

Density = (number of individuals/ area sampled)
Relative density = (density for a species)/(total density for all species) x 100
Frequency = (number of sampled quadrats in which species occurs)/(total number of quadrats sampled)
Relative frequency = (frequency value for a species)/(total of frequency values for all species) x 100
Cover = (total of intercept lengths for a species)/(total transect length) x 100
Relative cover = (total of intercept lengths for a species)/(total of intercept lengths for all species) x100
Importance value = Relative density + Relative frequency + Relative cover

Soil analysis: Five soil samples were collected from profile (0-50 cm depth) of each vegetation stand. Soil texture was determined by Bouyoucos hydrometer method. Soil porosity was determined as described by [19]. Calcium carbonate was estimated gravimetrically according to [20], while organic carbon was determined by Walkely and Black rapid titration method described by [21]. Soil water extracts of 1:5 were prepared for determinations of soil reaction using pH meter Model HI 8519 and soil salinity (EC) using CMD 830 WPA conductivity meter. Soluble chlorides were determined by direct titration against silver nitrate solution (N/35.5) using 5% potassium chromate indicator [20].

Sulphates were obtained by the difference between cations and anions of soil extract according to [20]. Soluble carbonates and bicarbonates were determined by titration method using H_2SO_4 (0.1N), phenol phthalein and methyl orange indicators for carbonates and bicarbonates, respectively [22]. The extractable sodium and potassium cations were estimated using flame photometer [23]. The extractable calcium and magnesium cations were determined using EDTA (0.01N) as described by [20].

Multivariate analyses and statistical testing: Vegetation classification and ordination techniques were employed. The stand-species data matrix was classified into groups using the importance values (IV) of species by means of the Two Way Indicator Species Analysis (TWINSPAN) computer program [24]. The ordination techniques applied were the Detrended Correspondence Analysis (DCA) to check the magnitude of change in species composition along the first ordination axis and the Canonical Correspondence Analysis (CCA) that was used to examine the relationships of the floristic composition and the measured environmental variables [25]. The following soil variables were included: % organic carbon, % calcium carbonate, % chlorides, % sulphates, % soluble carbonates, % bicarbonates, sodium (meq./L.), potasium (meq./L.), calcium (meq./L.), magnesium (meq./L.), pH value, electric conductivity (mmhos/cm), % coarse sand, % fine sand, % silt, % clay and % porosity.

Species diversity: The Shannon-Wiener index H' and Shannon-evenness index E_1 were determined as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where $p_i = n_i / N$ = proportional abundance of species i in a habitat made up of s species, n_i = the number of stands containing species i and $N = S\ n_i$. The Shannon-evenness index was applied to quantify the evenness component of diversity and was calculated as: $E_1 = H' / \ln s$

RESULTS

Floristic composition: A total of 19 species belonging to 11 families were recorded in this study (Table 1). They constituted 12 annual and 7 perennial species. The graminaceous species showed the highest contribution to the total flora (21.1%) followed by members of Chenopodiaceae and Compositae (15.8% each), Leguminosae (10.5%), while the other 7 families; Boraginaceae, Juncaceae, Cyperaceae, Aizoaceae, Caryophylaceae, Mulvaceae and Polygonaceae, shared total of 36.8% (5.3% each). The most common species recorded were *Chenopodium ambrosioides, Chenopodium murale, Heliotropium curassavicum, Spergularia maritima, Melilotus indicus* and

Table 1: Average importance values (IV) out of 300 of the common perennial species in the five vegetational groups resulting from the TWINSPAN technique. Species are arranged in every group in descending order according to the importance value

Group A	IV	Group B	IV	Group C	IV
Heliotropium curassavicum	92.0	*Heliotropium curassavicum*	102.3	*Chenopodium ambrosioides*	71.9
Melilotus indicus	52.4	*Chenopodium murale*	46.9	*Melilotus indicus*	64.7
Chenopodium ambrosioides	39.6	*Spergularia maritima*	39.0	*Chenopodium murale*	51.4
Chenopodium murale	37.0	*Chenopodium ambrosioides*	38.8	*Heliotropium curassavicum*	38.5
Mesembryanthemum crystallinum	14.4	*Polypogon monspeliensis*	15.5	*Sonchus oleraceus*	30.3
Spergularia maritima	14.1	*Lotus pedunculatus*	15.1	*Spergularia maritima*	15.2
Bassia indica	12.3	*Mesembryanthemum crystallinum*	10.6	*Lotus pedunculatus*	9.3
Sonchus oleraceus	11.6	*Aster squamatus*	10.2	*Rumex cyprius*	5.3
Cyperus rotundus	8.9	*Sonchus oleraceus*	9.3	*Polypogon monspeliensis*	4.7
Senecio glaucus	8.8	*Melilotus indicus*	7.2	*Cyperus rotundus*	4.4
Polypogon monspeliensis	5.4	*Lolium multiflorum*	3.6	*Lolium multiflorum*	4.3
Lotus pedunculatus	2.5	*Juncus rigidus*	1.4		
Phragmites australis	2.4				

Group D	IV	Group E	IV
Phragmites australis	76.3	*Heliotropium curassavicum*	166.7
Heliotropium curassavicum	56.8	*Cynodon dactylon*	61.4
Bassia indica	44.9	*Chenopodium ambrosioides*	41.8
Mesembryanthemum crystallinum	33.4	*Melilotus indicus*	24.1
Chenopodium ambrosioides	31.4	*Bassia indica*	6
Melilotus indicus	16.7		
Malva parviflora	12.4		
Rumex cyprius	5.0		
Cynodon dactylon	2.8		
Sonchus oleraceus	2.6		

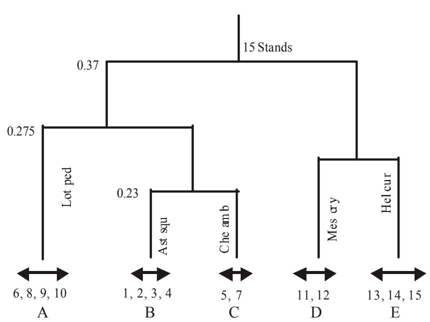

Fig. 1: TWINSPAN dendrogram of 15 stands based on the importance value of the species. Indicator species names are abbreviated to the first three letters of both genus and species

Phragmites australis. Each of these species attained maximum importance value (IV) greater than 50 (out of 300 for all species in a stand).

Vegetation classification: The application of TWINSPAN based on the importance value of the recorded species in 15 stands produced five vegetational groups represent and coincide with different habitat types. The five groups are labeled A, B, C, D and E (Table 1 and Fig. 1). Each group comprises a set of stands, which are similar in their vegetation and are characterized by specific indicator species.

Group A: This group comprises four stands; numbers 6, 8, 9 and 10 representing the fallow land habitat type and contain 13 species. *Lotus pedunculatus* is the indicator species of this group. *Heliotropium curassavicum* and *Melilotus indicus* are the dominant species that attained the highest IVs of 92 and 52.4, respectively. *Chenopodium ambrosioides, Chenopodium murale, Mesembryanthemum crystallinum, Spergularia maritima, Bassia indica, Sonchus oleraceous* are common species with IVs ranged from 11.6 to 39.6. *Cyperus rotundus, Senecio glaucus, Polypogon monspeliensis, Lotus pedunculatus* and *Phragmites australis* represent the associated species of this group with IVs ranged from 2.4 to 8.9.

Group B: This vegetational group comprises the four stands numbered 1, 2, 3 and 4 and represents the desert habitat type. Twelve species are found in this group

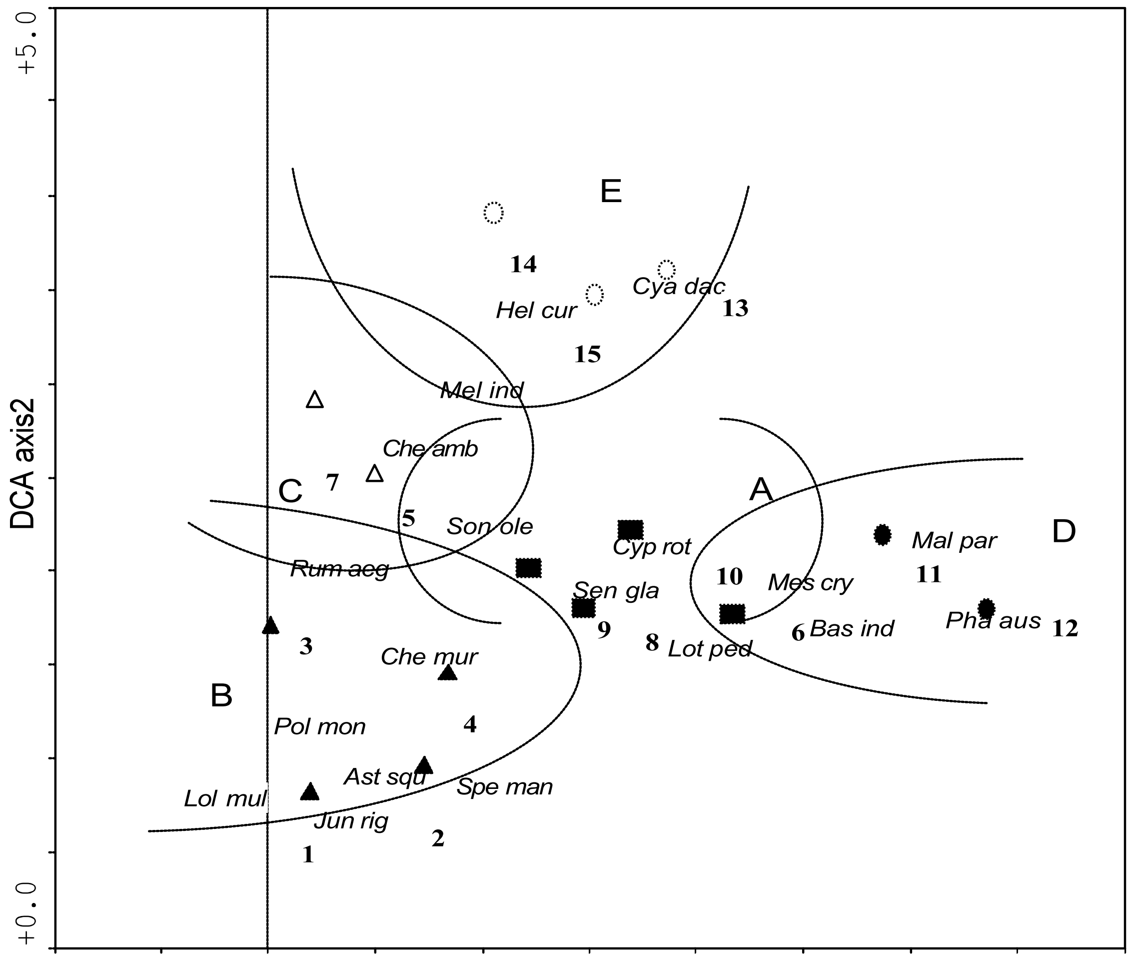

Fig. 2: DCA ordination of species in different habitat types of the study area. A = (▪) = fallow land, B = (▲) = desert, C = (Δ) = newly reclaimed land cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, D = (■) = canal bank and E = (▫) = old cultivated land with *Citrullus lanatus.* Species names are abbreviated to the first three letters of both genus and species

including *Aster squamatus* as indicator species, while *Heliotropium curassavicum* is the dominant species recording maximum IV of 102.3. *Chenopodium murale, Spergularia maritima, Chenopodium ambrosioides, Polypogon monspeliensis, Lotus pedunculatus, Mesembryanthemum crystallinum* and *Aster squamatus* are common species with IVs ranged from 10.2 to 46.9. *Sonchus oleraceus, Melilotus indicus, Lolium multiflorum* and *Juncus rigidus* are the associated species with IV < 10.

Group C: Two stands number 5 and 7 represent this vegetational group and occur in the newly reclaimed land cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, respectively. Total number of species of this group is 11 which have *Chenopodium ambrosioides* as an indicator and one of dominant species, while in the same time recording IV of 71.9. *Melilotus indicus* and *Chenopodium murale* attained maximum IVs of 64.7 and 51.4, respectively. *Heliotropium curassavicum, Sonchus oleraceus, Spergularia maritima* are common species with IVs ranged from 15.2 to 38.5. The associated species of this group have IVs ranged between 4.3 and 9.3 and represented by *Lotus pedunculatus, Rumex cyprius, Polypogon monspeliensis, Cyperus rotundus* and *Lolium multiflorum.*

Group D: Stands number 11 and 12 of this vegetational group represent the canal bank habitat type. This group contains 10 species dominated by *Phragmites australis* and *Heliotropium curassavicum* recording IVs of 76.3 and 56.8, respectively. *Mesembryanthemum crystallinum* is the indicator species of this group, while *Chenopodium ambrosioides, Melilotus indicus* and *Malva parviflora* (IVs, 12.4-33.4) are common species. *Rumex cyprius, Cynodon dactylon* and *Sonchus oleraceus* are the associated species (IVs, 2.6-5).

Table 2: Soil characteristics of the TWINSPAN groups representing the different habitat types (A = fallow land, B = desert, C = newly reclaimed land cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, D = canal bank and E = old reclaimed cultivated land with *Citrullus lanatus*) in the study area. Values are mean ± standard deviation. EC = Electric conductivity

	TWINSPAN groups				
Soil properties	A	B	C	D	E
Organic carbon (%)	0.18±0.03	0.06±0.02	0.20±0.05	0.20±0.05	0.31±0.04
Calcium carbonate (%)	8.50±0.17	24.40±0.66	6.20±0.34	7.60±0.59	3.80±0.21
pH value	8.80±0.29	8.10±0.37	8.35±0.31	8.20±0.43	8.60±0.59
EC (mmhos/cm)	4.50±0.29	1.50±0.21	5.80±0.43	6.70±0.56	2.40±0.28
Cl^- (%)	10.86±0.55	8.85±0.51	44.62±0.58	53.56±2.76	49.60±3.81
SO_4^{--} (%)	5.73±0.83	4.83±0.38	18.82±0.52	23.68±2.63	39.80±1.93
Soluble CO_3^{--} (%)	0.08±0.02	0.52±0.12	0.00±0.00	0.00±0.00	0.02±0.01
HCO_3^- (%)	1.69±0.21	1.87±0.09	1.60±0.12	1.93±0.16	1.58±0.59
Sodium (meq./L.)	13.42±0.76	10.30±0.70	42.47±1.09	45.51±1.78	53.50±2.78
Potasium (meq./L.)	0.75±0.04	0.43±0.11	0.77±0.06	0.89±0.05	1.97±0.33
Calcium (meq./L.)	6.29±0.83	2.82±0.29	11.30±0.69	20.37±0.67	23.50±2.10
Magnesium (meq./L.)	3.50±0.22	2.00±0.25	10.50±0.62	17.80±0.99	17.30±0.69
Coarse sand (%)	92.30±4.49	90.80±2.86	86.70±2.57	74.50±1.84	76.80±1.33
Fine sand (%)	4.60±0.16	3.70±0.17	9.50±0.63	6.60±0.19	4.79±0.21
Silt (%)	2.10±0.17	2.75±0.12	2.40±0.37	8.30±0.70	7.91±0.49
Clay (%)	1.00±0.05	2.75±0.22	1.40±0.34	10.60±1.52	10.50±0.62
Porosity (%)	46.60±1.95	49.10±2.13	54.70±2.43	56.30±3.77	53.50±2.78
Soil texture	sandy	sandy	sandy	sandy loam	sandy loam

Group E: This vegetational group represents the old reclaimed land cultivated with *Citrullus lanatus* and comprises three stands number 13, 14 and 15. Only five species were recorded in this group. *Heliotropium curassavicum* is the indicator species of the group which is dominated by *Cynodon dactylon* (IV = 61.4), while *Chenopodium ambrosioides* and *Melilotus indicus* are common species of IVs 41.8 and 24.1, respectively. *Bassia indica* is the associated species attaining IV of 6.

Ordination of stands: The DCA ordination of species (Fig. 2) demonstrates the separation of TWINSPAN groups of different habitat types into five vegetational groups along the plane of the first and second axes. Species of Group E representing the old reclaimed land cultivated with *Citrullus lanatus* are located at the top of the diagram, while species of group B representing the desert habitat type are arranged at the lower left side of the diagram in between the two DCA axes. Species of groups C, A and D which represent the new reclaimed land cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, the fallow land and the canal bank habitat types, respectively, are arranged at the middle of axis 2 of the ordination diagram.

Vegetation-soil relationships: The soil variables of the five groups of stands derived from TWINSPAN classification indicate considerable variation in the edaphic factors among the stands of the different groups (Table 2). The percentage of organic carbon attains maximum value of 0.31% in group E (old reclaimed land) while the minimum value reached 0.06% in group B (desert habitat types). In the remaining vegetational groups, the percentage of organic carbon ranges from 0.18% in group A to 0.2% in groups C and D. The percentage of calcium carbonates attains maximum value (24.4%) in group B while the recorded values in the remaining groups varies between minimum 3.8% in group E and 8.5% in group A. Soil reaction is slightly alkaline in all groups as pH ranges between 8.1 in group B to 8.8 in group A. Electric conductivity attains high values of 5.8 and 6.7 mmhos/cm in groups C and D, respectively, while the minimum value (1.5 mmhos) is recorded in group B. Chloride and sulphates content show the highest values in group C, D and E, while the minimum values are attained in group A and B. On the contrary, soluble carbonate attained its minimum (0.02%) in group E and absent in groups C and E, while group A and B recorded maximum values amounting to 0.08 and 0.52%, respectively. The bicarbonate content showed low fluctuations through all groups and ranged between 1.58% in group E and 1.93% in group D. Sodium, potassium, calcium and magnesium contents attained their maximum values of 53.5, 1.97, 23.5 and 17.3 meq./L., respectively, in group E (old reclaimed

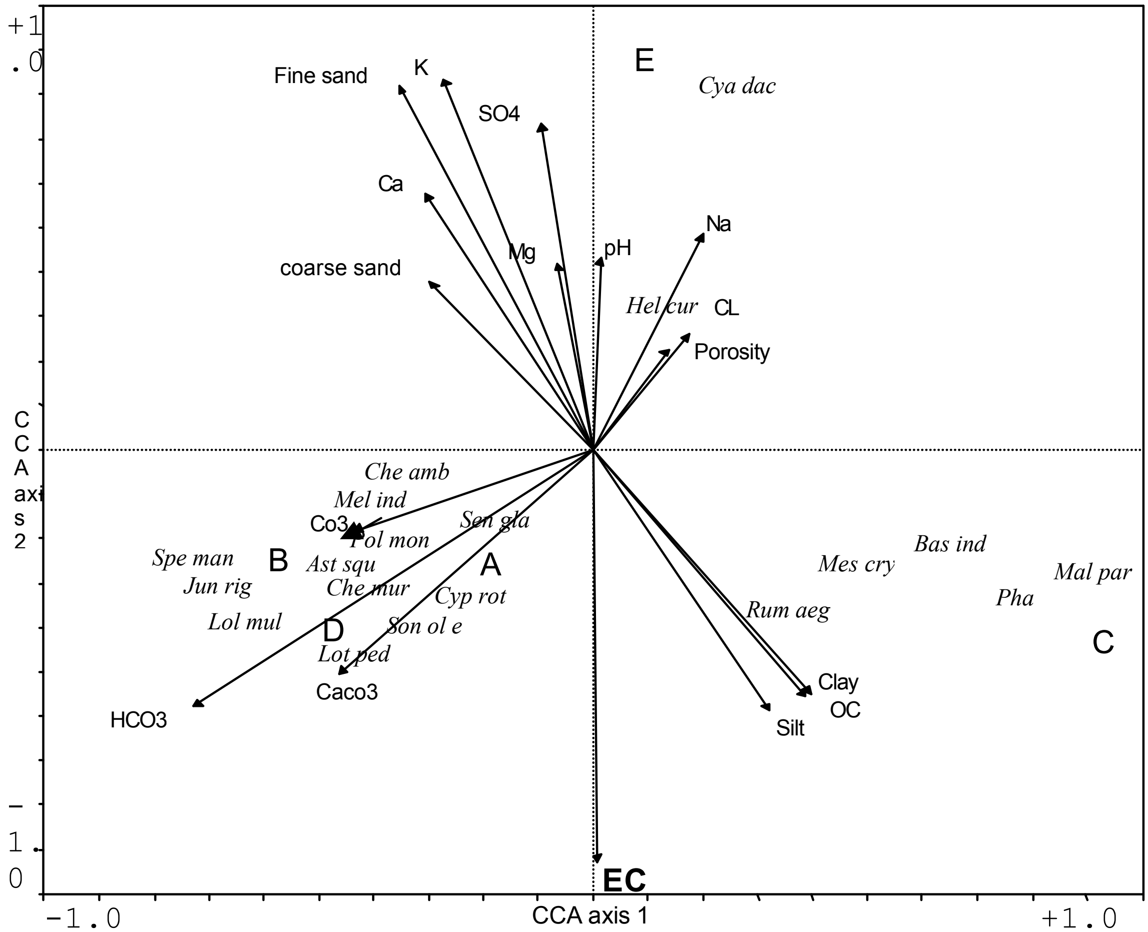

Fig. 3: CCA species-soil variable biplot in different habitat types of the study area. A = fallow land, B = desert, C = newly reclaimed land cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, D = canal bank and E = old cultivated land with *Citrullus lanatus,* with arrows indicating the soil factors and species names are abbreviated to the first three letters of both genus and species. EC = electric conductivity and OC = organic carbon

land) while minimum values of 10.3, 0.43, 2.82 and 2 meq./L. are recorded for the same minerals, respectively, in group B representing the desert habitat.

Significant differences are observed in soil texture among the different vegetational groups. Soil texture in groups A, B and C is formed mainly of coarse sand (92.3, 90.8 and 86.7%, respectively) then fine sand (4.6, 3.7 and 9.5%, respectively) and partly of fine fractions (silt and clay). The soil texture is generally sandy. On the contrary, soil texture in groups D (canal bank) and E (old reclaimed land) is sandy loam where the fine fractions recording 8.3 and 7.9% (for silt) and 10.6 and 10.5% (for clay) in groups D and E, respectively. Soil porosity for all groups ranges between 46.6% in group A and 56.3% in group D.

The correlation between vegetation and soil variables, is seen in the Canonical Correspondence Analysis (CCA) ordination biplot (Fig. 3) in which the soil variables are represented by arrows. The edaphic variables which have long arrows are more important influence on community variation and species distribution. The angle between an arrow and each axis is a reflection of its degree of correlation with that axis. Species in group A (fallow land) exhibit a close relationship with high percentage of Ca CO_3 while species of group D (canal bank) strongly correlated with bicarbonate content and that of group B (desert) demonstrate a close relationship with high percentage of soluble carbonates. High correlation is found between species of group C (newly reclaimed land) and electric conductivity, silt, organic carbon and clay. Species of group E (old reclaimed land) are highly correlated with pH value, sodium, chloride and porosity. Weak correlation is found between species of different groups and sulphates, magnesium, potassium, fine sand, calcium and coarse sand.

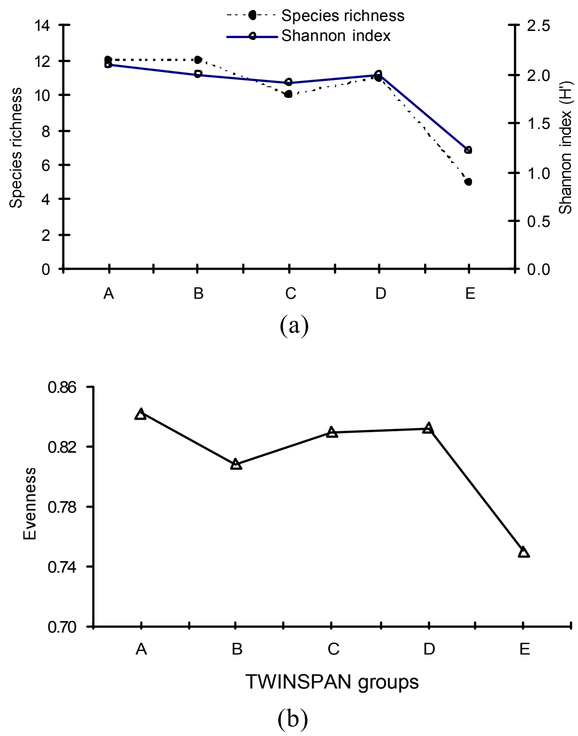

Fig. 4: Species diversity in different habitat types of the study area. A = fallow land, B = desert, C = newly reclaimed land cultivated with *Lycopersicon esculentum* and *Beta vulgaris*, D = canal bank and E = old cultivated land with *Citrullus lanatus*

Species diversity: Vegetational groups demonstrate differences in species richness, diversity and evenness (Fig. 4a). The highest species richness of value 12 is attained in groups A (fallow land) and B (desert habitat), while decreased to 10 in group C (new reclaimed land), followed by slight increase to value of 11 in group D (canal bank). Sharp decrease in richness to a minimum value 5 is found in group E (old reclaimed land).

The Shannon diversity index (*H'*) of the five vegetational groups showed almost parallel trend to that obtained in case of species richness. The highest *H'* value of 2.09 is recorded in group A, then values decreased to 2.01, 1.9 in groups B and C. Slight increase in Shannon index attained value of 1.99 in group D followed by sharp decrease to a minimum value of 1.2 in group E.

Evenness of different vegetational groups (Fig. 4b) showed the highest value of evenness (0.84) in group A, while the minimum value (0.75) recorded in group E. The evenness values of the remaining vegetational groups demonstrate intermediate values amounting 0.81, 0.82 and 0.83 for group B, C and D, respectively.

DISCUSSION

The recognized vegetational groups in the study area named after their dominants and total number of recorded species are *Heliotropium curassavicum-Melilotus indicus*, 13 species (fallow land), *Heliotropium curassavicum*, 12 species (desert habitat), *Chenopodium ambrosioides-Melilotus indicus-Chenopodium murale*, 11 species (newly reclaimed land), *Phragmites australis-Heliotropium curassavicum*, 10 species (canal bank) and *Heliotropium curassavicum-Cynodon dactylon*, 5 species (old reclaimed land). It appears that *Heliotropium curassavicum* is the most dominant species in nearly all habitat types of the present study. That was explained by [26], who carried out biological study of this weedy invasive species in the same study area and reported that the fast spread of *Heliotropium curassavicum* as a weed in the newly reclaimed salt affected sandy lands of the Delta Mediterranean coast represents a serious agricultural problem. The other traditional weeds have become poorly adapted to the prevailing environment where selection pressure is very strong. This view is supported by the dominance of *Heliotropium curassavicum* over the other weedy species in the study area. Vegetation is characterized not only by the preponderance of annuals (63%), but also by the presence of several highly adapted, drought-resistant species [27]. In addition, biotic factors such as allelopathic interactions may play a role in influencing the distribution of vegetation in nature, the yield of various crop species, germination and weed interference [28, 29].

The crop plants have a major effect on the weed flora [8]. This effect may be direct or indirect, where herbicides, soil management and fertilization regimes may vary depending on the crop type and these factors influence most weed species [30]. In addition, the continuous disturbance due to agricultural practices, often bury or expose the seeds to wide range of night/day surface soil temperature [28]. Furthermore, the continuous removal of undesired weed species by farmers in cultivated lands may explain the variability in the number of recorded species among different vegetational group from five in the old reclaimed cultivated land by *Citrullus lanatus* (i.e. highest rate of removal of undesired weeds) to 13 in the fallow land, where there is no removal of weed species. Although vegetation in the old reclaimed land is dominated by *Heliotropium curassavicum* (undesired weed), the species has maximum IV of 166.7 (out of 300) and that explained by the fact that the success of *Heliotropium curassavicum* as a weed can be attributed to a large extent to its ability to produce adventitious root buds which allow for the plant's perennation and spread [26]. In addition, old reclaimed land is rich in minerals and organic carbon which enhance the vigorous growth of this weedy plant as compared to other habitat types.

The habitat type has direct effect on the dominance relations among different vegetational groups. In this respect, the canal bank vegetation is dominated by *Phragmites australis* which is an amphibious plant while *Heliotropium curassavicum* dominates vegetation of the fallow land. The dominance of these species in the abandoned areas may be attributed to their abilities to cope with the significant substrate alterations, which may inhibit the re-establishment of other long-lived species [31]. Moreover, the weedy species replace the natural plant communities and this is a widespread phenomenon [32].

The vegetation-environment relationships as assessed by both DCA and CCA demonstrate the relative positions of species and sites along the most important ecological gradients. Both ordination techniques indicated that organic carbon, calcium carbonate and soil texture are important factors controlling the distribution of vegetation and invasive species in the study area. This was reported in other studies [1, 33].

The variations in species richness, diversity and evenness among the different habitat types may be attributed to the difference in soil characteristics, substrate discontinuities and the allelopathic effect of one or more invasive species depending on their relative dominance among other associated species [26, 34-35]. This is in accordance with the findings of [36] who provide evidence that a high level of species diversity would be brought about by a local differentiation in soil properties around individual plants, since heterogeneity of environments allows satisfaction of the requirements of many species within a community [37]. Species diversity increases as the number of species per sample increases and as the abundance of species within a sample becomes even [38]. Consequently the vegetational groups in the fallow land and in the desert habitat of the present study are more diverse than those of other groups.

In conclusion, the three invasive species; *Heliotropium curassavicum, Bassia indica* and *Chenopodium ambrosioides* dominate the plant communities in the different habitat types of the Nile Delta coast. Species diversity and dominance is related to soil physical characteristics and variation of habitat types. As inferred by variation of invasive species dominance with crop type and associated species in the cultivated lands, biotic factors such seem to play a role in plant invasions.

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