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Ludwigia stolonifera (Guill. & Perr.) P.H. Raven, Insight into its Phenotypic Plasticity, Habitat Diversity and Associated Species

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THIRTY-TWO populations of *L. stolonifera* were monitored resulted in detection of 7 morphotypes in 5 different habitats. Wide spectum species included *Phragmites australis*, *Eichhornia crassipes* and *Cyperus alopecuroides*. Cosmopolitan, Paleotropical and Pantropical elements contributed about 56.7% of the total number of the associated species. Therophytes constituted 46.7% while hydrophytes and helophytes 26.7%, hemicryptophytes, chamaephytes, geophytes and epiphytes were moderately represented. The similarity values between each pair of the 7 morphotypes based on the 42 macro and micro morphological characters were carried out. The fresh water morphotypes were correlated with the organic matter and turbidity, while the terrestrial morphotype was affected by carbonates and ammonia while the brackish and saline morphotypes were affected by electric conductivity, salinity, NaCl contents. *L. stolonifera* exhibits high degree of habitat diversity in the leaf shape and size; in the flower from typical bisexual 5-merous flowers with 10 stamens, to bisexual 6-merous flowers with 12 stamens; in size, position of bracteoles from basal to near base or near base and near or aboved; in the seed productivity/fruit from 60-80 seeds/fruit to 35-45 seeds/fruit from basal to near base or above; in the abundance of vesicles from abundant (up to 10 pneumatophores/cluster) to occasional vesicles (up to 3 pneumatophores/cluster); in the position of aperture from planaperturate to angulaperturate

Keywords: Flora, Hydrophytes, Clustering analysis, Morphological variation, Pneumatophore, Egypt.

Introduction

The number of aquatic weeds in the Nile system of Egypt is about 35 species belong to 19 genera and 15 families (Täckholm, 1974 and Zahran & Willis, 1992). These plants are either entirely submerged, free-floating or their roots may penetrate the soil at the bottom stream. *Ludwigia stolonifera* is one of the most dominant species in watercourses in Egypt (Zahran & Willis, 1992).

Genus *Ludwigia* L. is represented in the Egyptian flora by two species, *L. stolonifera* (Guill. & Perr.) P.H. Raven and *L. erecta* (L.) Hara. The latter is very rare in Nile valley and canal banks (Täckholm, 1974). Some members of genus *Ludwigia* are highly invasive and cause significant economic and environmental damage in many parts of the world (Eppo, 2004 and Global Invasive Species Database, 2009). In Egypt, *Ludwigia stolonifera* tends to aggregate so dense to block the whole waterway, retarding the water flow, threaten plant biodiversity leading to habitat degradation. Accordingly, the study of its associated plants may reveal the diversity, environmental behavior and current distribution of these plants. Floristic composition together with life form represented diagnostic characters in distinguish species especially hydrophytes which have wide geographical and ecological distribution.

The ability of an organism to change its phenotype in response to changes in the environment widely referred to phenotypic plasticity. Price et al. (2003) represented a fundamental way in which organisms cope with environmental variation, phenotypic plasticity encompasses all types of environmentally induced changes (e.g. morphological, physiological, behavioral and phenological) that may or may not be permanent throughout an individual's lifespan. Many aquatics occur in habitats characterized by strong environmental gradients so they often display high levels of polymorphism and phenotypic plasticity (Lacoull & Freedman, 2006) and display responses in their vegetative traits (Dorken & Barrett, 2004).

Recently, Amer et al. (2016) studied the macro- and micro-taxonomic characters of *L. stolonifera*, the study revealed the presence of seven

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morphotypes. The current work aims to study the floristic composition associated with those seven morphotypes, the affinities and dissimilarities between each pair of those morphotypes, the phenotypic plasticity of *L. stolonifera* and factors determining this plasticity.

Materials and Methods

An extensive survey was carried out between May 2013 and July 2015 at many localities covering different habitats in Egypt for collecting the available morphotypes of *Ludwigia stolonifera* and the associated plant species. These habitats included fresh, brackish, saline and salt-water habitats using a stratified sampling method (Müller-Dombois & Ellenberg, 1974).

Thirty-two populations (stands) of *Ludwigia stolonifera* were monitored |(Fig. 1). These stands are distributed in 3 phytogeograhical territories: 12 stands in the Mediterranean coast, 10 stands in the Nile valley and 10 stands in the Eastern desert. Each stand is 100m^2 (4x25m). Ecological notes, presence or absence of plant species had been recorded. The presence performance of a species was calculated as a percentage of the total number of stands where species recorded divided by the total number of stands. The stands were distributed as follows: M1 & M7 (8 stands for each), M6 (7 stands), M3 (3 stands) and M2, M4, M5 (2 stands for each) (Fig. 1).

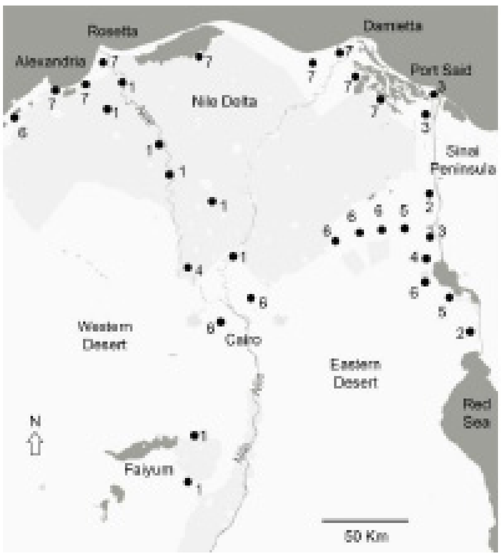

Fig. 1. Distribution map of the 32 populations (stands) representing the seven studied morphotypes (1-7) of *L. stolonifera* in Egypt.

Identification of the associated species was carried out at Cairo University Herbarium (CAI) by the authors. Taxonomic nomenclature was according to Täckholm (1974) and Boulos (1995, 1999, 2000, 2002, 2005 and 2009). Growth or life form of the collected species was according to Raunkiaer's life form system (Raunkiaer, 1937). Analysis of phytogeographical ranges was carried out using Zohary (1947 and 1962). Samples of fresh material of *Ludwigia stolonifera* were collected during flowering and fruiting seasons. From each population, a random sample (at least 10 specimens) of flowering and fruiting plants were examined. For each morphological character, 10-20 samples were monitored. Mean value and standard deviation of each morphological character were calculated. Voucher specimens were kept in Cairo University Herbarium (CAI).

For pollen analysis, pollen grains were extracted from anthers collected from fresh floral buds, mounted on aluminum stubs, gold coated and viewed in a Jeol 1200 Ex II SEM at 20KV. Size measurements were obtained from the average of 10 randomly selected mature grains when possible. Among the investigated pollen morphological characters: pollen shape, pollen size, polarity, aperture position, aperture dimension (LxW), colpus length, exine sculpture and viscin threads diameter. The terminology used in pollen description followed Punt et al. (2007).

Physicochemical analysis of the environmental factors

For water analysis, three water samples were collected from each stand from the top down to 50cm below the water surface, and then integrated as one composite sample. Three replicates were analysed for each sample. For soil analysis, three soil samples were collected from each stand at three depths: 0-10, 10-25 and 25-50cm. These samples were spread over sheets of paper, air dried, thoroughly mixed together, forming one composite sample, passed through 2mm sieve to remove gravel and debris. Three replicates were analysed for each sample. Soil extract were prepared (W/V, 1gm soil: 5ml distilled water) to meet the requirement for different determination.

Sixteen environmental variables were chosen to trace their effect on the phenotypic plasticity of *Ludwigia*. APHA (1995) Standard Methods for the Examination of Water and Wastewater were used in the determination of pH values using Method 4500-

H^+, the electrical conductivity (which expresses the total soluble salts in water and soil extract) using Method 2510 B, salinity using Method 2520 B, turbidity using Method 2130 B, carbonates and bicarbonates using Method 2320 B and organic matter using Method 5220 B. Determination of chlorides, sulfates, phosphates and nitrates were carried out by ASTM (2011) D4327-11 standard test method for anions in water by suppressed ion chromatography. Determination of sodium, potassium, ammonium, magnesium and calcium were carried out using ASTM (2009) D6919-09 standard test method for determination of dissolved alkali and alkaline earth cations and ammonium in water by ion chromatography.

Data analysis

The basic purposes of the multivariate analyses are summarizing large complex data and refining models for habitat structures (Ward et al., 1993). Floristic data matrix (7 morphotypes in the monitored 32 stands and the associated 60 species) was subjected to classification by two-way indicator species analysis (TWINSPAN) using the default settings of the computer program, Community Analysis Package (CAP) for windows version 1.2. An ordered two-way table that expresses succinctly the relationships of the stands and species within the data set was constructed (Hill, 1979 and Økland, 1990). The stands are ordered first by divisive hierarchical clustering, and then the species are clustered based on the classification of stands (Gauch & Whittaker, 1981).

For studying the similarity between each pair of the morphotypes based on the macro- and micro-morphological characters (data matrix of 42 characters and 7 morphotypes) and that based on the associated species (60 species and 7 morphotypes), the data matrices were subjected to Jaccard's Measure of the program SPSS (version 20 for Windows).

In this study, the default options of the computer program CANOCO software version 4.5 (Ter-Braak & Smilauer, 2002) was used to check the magnitude of change in species composition along the first ordination axis (i.e., gradient length in standard deviation units). The canonical correspondence analysis (CCA) was chosen to be the appropriate ordination method to perform direct gradient analysis (Ter-Braak & Prentice, 1988). The relationships between floristic gradients and the studied environmental variables can be indicated on the ordination diagram produced by CCA biplot. All data variables are assessed for normality (stustatw version 5; Berk, 1994) prior to the CCA analysis and appropriate transformations are performed. Sixteen environmental variables were included in this study: pH, electric conductivity (EC), salinity, turbidity, bicarbonates (HCO_3^-), carbonates (CO_3^{-2}), organic matter (OM), sodium (Na^+), ammonium (NH_4^+), potassium (K^+), magnesium (Mg^{+2}), calcium (Ca^{+2}), chloride (Cl^-), nitrate (NO_3^-), phosphate (PO_4^{-3}) and sulfates (SO_4^{-2}). A Monte Carlo permutation test (99 permutations) was used to test for significance of the eigenvalues of the first canonical axis. Interset correlations from the CCAs were therefore used to assess the importance of the environmental variables.

Results

Floristic composition of the associated species

The monitored 32 populations of *Ludwigia stolonifera* (Fig. 1), were categorised in 5 different habitats; four aquatic viz. fresh water (M1 & M2), fresh to brackish (M4 & M6), brackish water (M5), marine water (M7) and one terrestrial wetland habitat (M3). The total number of the monitored associated species were 60 vascular plants belonging to 30 families. These are 29 annuals, 27 perennials and 4 trees or shrubs (Table 1).

The species richest families were Poaceae that was represented by 10 species, followed by Chenopodiaceae (6 species), Polygonaceae (5 species), Amaranthaceae (4 species) and Cyperaceae (3 species); they accounted for 46.7% of the total collected flora. Seven families were represented by 2 species each and 18 monogeneric families. *Amaranthus*, *Chenopodium*, *Cyperus* and *Persicaria* were the most species richest genera that were represented by 3 species each.

The number of associated species differed from one morphotype to another, the highest number was 32 species that were asscociated with the terrestrial wetland morphotype M3, followed by the marine morphotype (22 species), where the least number was recorded in association with the brackish morphotype M5 (6 species) followed by 7 species that were recorded in the fresh to brackish morphotype M4. Also, the presence performance of the associated species differed, it ranged between 75% (recorded in 24 stands out of 32) to about 3% (recorded in one stand). It is to be noted that 44 species were confined to only one stand (i.e, associated with only one of the 7 morphotypes).

TABLE 1. The presence performance % of the associated species within the different monitored morphotypes (M1-M7).

Morphotype Number				**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**T**	**%**
Species/total number of stands	**Chorotype**	**LF**	**Hb**	**8**	**2**	**3**	**2**	**2**	**7**	**8**	**32**	
Phragmites australis (Cav.) Trin. ex Steud.	PAL	HH	P	4	1	2	2	2	6	7	**24**	**75**
Eichhornia crassipes (C. Mart.) Solms	COSM	Hy	P	6	1	0	2	2	5	7	**23**	**72**
Cyperus alopecuroides Rottb.	PAN	HH	P	4	1	1	1	0	2	1	**10**	**31**
Persicaria salicifolia (Brouss. ex Willd.) Assenov	PAL	Hy	P	5	1	0	1	0	1	2	**10**	**31**
Myriophyllum spicatum L.	COSM	Hy	P	0	0	0	1	1	2	1	**5**	**16**
Cynanchum acutum L.	MED+IR-TR+EU-SB	Ep	P	0	1	1	0	0	2	1	**5**	**16**
Ceratophyllum demersum L.	COSM	Hy	P	1	1	0	0	0	2	1	**5**	**16**
Potamogeton nodosus Poir.	MED+IR-TR	Hy	P	1	1	0	0	0	1	0	**3**	**9**
Lemna gibba L.	COSM	Hy	P	2	0	0	0	1	0	6	**9**	**28**
Ranunculus sceleratus L.	MED+IR-TR+EU-SB	HH	A	2	0	0	0	1	0	2	**5**	**16**
Convolvulus arvensis L.	PAL	Ep	P	0	1	1	0	0	2	0	**4**	**13**
Chenopodium ambrosioides L.	COSM	Ch	P	1	0	1	0	0	0	0	**2**	**6**
Nymphaea lotus L.	PAL	Hy	P	1	0	0	0	0	0	1	**2**	**6**
Cyperus rotundus L.	PAN	G	P	0	0	2	0	0	1	0	**3**	**9**
Typha domingensis (Pers.) Poir. ex Steud.	PAN	HH	P	0	0	1	0	0	0	4	**5**	**16**
Juncus acutus L.	MED+IR-TR+EU-SB	H	P	0	0	1	0	0	0	1	**2**	**6**
Hordeum murinum L. subsp. *leporinum* (Link) Arcang.	MED+SA-AR+EU-SB	Th	A	0	0	0	0	0	0	1	**1**	**3**
Mesembryanthemum nodiflorum L.	MED+SA-AR+EU-SB	Th	A	0	0	0	0	0	0	1	**1**	**3**
Pistia stratiotes L.	PAN	Hy	P	0	0	0	0	0	0	1	**1**	**3**
Cakile maritime Scop. subsp. *aegyptiaca*	MED+SA-AR	Th	A	0	0	0	0	0	0	1	**1**	**3**
Spergularia marina (L.) Griseb.	MED+IR-TR+EU-SB	H	P	0	0	0	0	0	0	1	**1**	**3**
Atriplex semibaccata R. Br.	AUST	H	P	0	0	0	0	0	0	1	**1**	**3**
Halocnemum strobilaceum (Pall.) M. Bieb.	MED+IR-TR+SA-AR	Ch	TS	0	0	0	0	0	0	1	**1**	**3**
Ipomoea cairica (L.) Sweet	SA-AR	Ep	P	0	0	0	0	0	0	1	**1**	**3**
Imperata cylindrica (L.) Raesch.	MED+IR-TR+SA-AR	H	P	0	0	0	0	0	0	1	**1**	**3**
Polygonum bellardii All.	MED+IR-TR+EU-SB	Th	A	0	0	0	0	0	0	1	**1**	**3**

TABLE 1. Cont.

Morphotype Number				**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**T**	**%**
Species/total number of stands	**Chorotype**	**LF**	**Hb**	**8**	**2**	**3**	**2**	**2**	**7**	**8**	**32**	
Zaleya pentandra (L.) C. Jeffrey	S-Z	Th	A	0	0	0	0	0	1	0	**1**	**3**
Cyperus laevigatus L.	PAL	G	P	0	0	0	0	1	0	0	**1**	**3**
Alhagi graecorum Boiss.	PAL	Th	P	0	0	0	1	0	0	0	**1**	**3**
Wolffiella hyalina (Delile) Monod	SA-AR+S-Z	Hy	P	0	0	0	1	0	0	0	**1**	**3**
Pluchea dioscoridis (L.) DC.	SA-AR+S-Z	Ph	TS	0	0	1	0	0	0	0	**1**	**3**
Chenopodium album L.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Chenopodium murale L.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Eclipta prostrata (L.) L.	PAN	Th	A	0	0	1	0	0	0	0	**1**	**3**
Cynodon dactylon (L.) Pers.	PAN	G	P	0	0	1	0	0	0	0	**1**	**3**
Rumex dentatus L.	MED+IR-TR	Th	A	0	0	1	0	0	0	0	**1**	**3**
Conyza bonariensis (L.) Cronquist	MED	Th	A	0	0	1	0	0	0	0	**1**	**3**
Echinochloa crusgalli (L.) P. Beauv.	PAN	Th	A	0	0	1	0	0	0	0	**1**	**3**
Amaranthus hybridus L.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Amaranthus viridis L.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Bassia indica (Wight) A. J. Scott	S-Z+IR-TR	Th	A	0	0	1	0	0	0	0	**1**	**3**
Malva parviflora L.	MED	Th	A	0	0	1	0	0	0	0	**1**	**3**
Polypogon monspeliensis (L.) Desf.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Sisymbrium irio L.	MED+IR-TR+EU-SB	Th	A	0	0	1	0	0	0	0	**1**	**3**
Portulaca oleracea L.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Digitaria sanguinalis (L.) Scop.	PAL	Th	A	0	0	1	0	0	0	0	**1**	**3**
Setaria viridis (L.) P. Beauv.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Amaranthus graecizans L.	MED+IR-TR	Th	A	0	0	1	0	0	0	0	**1**	**3**
Melilotus indicus (L.) All.	PAL	Th	A	0	0	1	0	0	0	0	**1**	**3**
Ricinus communis L.	PAN	Ch	TS	0	0	1	0	0	0	0	**1**	**3**
Dactyloctenium aegyptium (L.) Willd.	PAL	Th	A	0	0	1	0	0	0	0	**1**	**3**
Tamarix nilotica (Ehrenb.) Bunge	SA-AR+S-Z	Ph	TS	0	0	1	0	0	0	0	**1**	**3**
Datura innoxia Mill.	PAN	Th	A	0	0	1	0	0	0	0	**1**	**3**

TABLE 1. Cont.

Morphotype Number				M1	M2	M3	M4	M5	M6	M7	T	%
Species/total number of stands	**Chorotype**	**LF**	**Hb**	**8**	**2**	**3**	**2**	**2**	**7**	**8**	**32**	
Solanum nigrum L.	COSM	Th	A	0	0	1	0	0	0	0	**1**	**3**
Panicum coloratum L.	S-Z	H	P	0	1	0	0	0	0	0	**1**	**3**
Alternanthera sessilis (L.) DC.	PAN	HH	A	1	0	0	0	0	0	0	**1**	**3**
Glinus lotoides L.	PAL	Th	A	1	0	0	0	0	0	0	**1**	**3**
Plantago major L.	COSM	Th	A	1	0	0	0	0	0	0	**1**	**3**
Persicaria lanigera (R. Br.) Sojāk	TRP	HH	P	1	0	0	0	0	0	0	**1**	**3**
Persicaria senegalensis (Meisn.) Sojāk	S-Z	HH	P	1	0	0	0	0	0	0	**1**	**3**
Total number of species				**15**	**9**	**32**	**7**	**6**	**11**	**22**		

T= Total number of populations. Chorotype: COSM= Cosmopolitan, PAL= Palaeotropical, PAN= Pantropical, EU-SB= Euro-Siberian, IR-TR= Irano-Turanian, MED= Mediterranean, SA-AR=Saharo-Arabian, S-Z= Sudano-Zambezian, TRP= Tropical, AUST= Australia. LF= Life Form: Ep= Epiphytes, G= Geophytes, HH= Helophytes & Hydrophytes, Th= Therophytes, H= Hemicryptophyte, Ch= Chamaephyte, Hy= Hydrophyte, Ph= Phanerophyte. Hb= Plant Habit: A= Annual, P= Perennial, TS= Tree or shrub. Figures are the number of stands where the corresponding species is recorded.

Only the amphibious *Phragmites australis* was monitored to associate the 7 studied morphotypes, two species viz, the hydrophyte *Eichhornia crassipes* and the helophyte *Cyperus alopecuroides* were recorded in 6 of the studied morphotypes. The former was absent in the terrestrial wetland morphotype (M3), while the later was not recorded in the association of the brackish morphotype (M5). The distribution of the 44 confined species was as follows: 24 species (about 54.5% of the confined species) were confined to the terrestrial wetland morphotype (M3). Most of the latter were therophytes that can grow in the banks of canals, rivers and drains. 10 species in M7, 5 species in the fresh habitat of M1, two species in M4, one species (*Zaleya pentandra*) in M6, one species (*Cyperus laevigatus*) in M5, one species (*Panicum coloratum*) in M2.

Table 2 summarizes the chorological analysis of the associated species. Cosmopolitan, Paleotropical and Pantropical elements were represented by relatively high numbers 14, 10 and 10 species, respectively, that contributes about 56.7% of the total number of the associated species. Mediterranean element either mono, biregional and pluri-regional elements were represented by 2, 4 and 10 species, respectively that collectively represented 26.7%. Sudano-zambezian elements either mono or biregional were very poorly represented (3 and 4 species, respectively), while pure Saharo-Arabian element was also poorly represented by only one species.

The growth or life form of these associated species differed, The therophytes were relatively, highly represented by 28 species that constituted about 46.7% of the total number of associated species, followed by the hydrophytes and helophytes that were represented by 16 species about 26.7%. Hemicryptophytes were represented by only 5 species followed by chamaephytes, geophytes and epiphytes that were represented by 3 species each. *Tamarix nilotica* and *Pluchea dioscorides* were only the two phanerophytes recorded in the association of *Ludwigia stolonifera* in our study (Fig. 2).

The proximity matrix or the similarity between each pair of the 7 morphotypes based on their associated species (Table 3), scored its highest value in the combination between the two fresh to brackish morphotypes M4 & M6 (84%), and in the association between the marine (M7) and brackish morphotype (M5). At the contrary, the least similarity values were recorded between the terrestrial wetland habitat M3 with the marine M7 (20%), the fresh water morphotype M1 (21%), the brackish M5 (21%) and the fresh to brackish M4 (23%) (Table 3).

The clustering analysis carried out by the CAP (community analysis Package), using agglomerative Ward's technique by Euclidean distance measure, on the macro and micro morphological matrix (42 characters) of the 7 studied morphotypes revealed that the 7 morphtypes were clearly distributed in 3 groups (Fig. 3). Group I included the fresh morphotypes M1 and M2, Group II included the brackish and marine the morphotypes M4-M7 and group III included the terrestrial morphotype M3.

In addition, Table 4 showed the similarity values between each pair of the 7 morphotypes based on the 42 macro and micro morphological characters. It was obvious that he highest similarity was recorded between the two fresh to brackish morphotypes M4 and M6 (66.7%) and between the two fresh morphotypes M1 and M2 (53.1%). At the contrary, terrestrial wetland morphotype recorded the least similarity values with the two fresh water morphotypes M1 and M2 (29.7% & 14.7%, respectively). The marine morphotype M7 recorded high similarity values; with other morphotypes ranged between 53.3% to 66.7% except for the terrestrial one M3 (32.4%).

TABLE 2. Chorological analysis of the associated species.

Chorotype	Number of species
Cosmopolitan	14
Palaeotropical	10
Pantropical	10
Mediterranean	
Monoregional	2
Biregional	4
Pleuroregional	10
Sudano-Zambezian	
Monoregional	3
Biregional	4
Tropical	1
Australian	1
Saharo-Arabian	1
Total	**60**

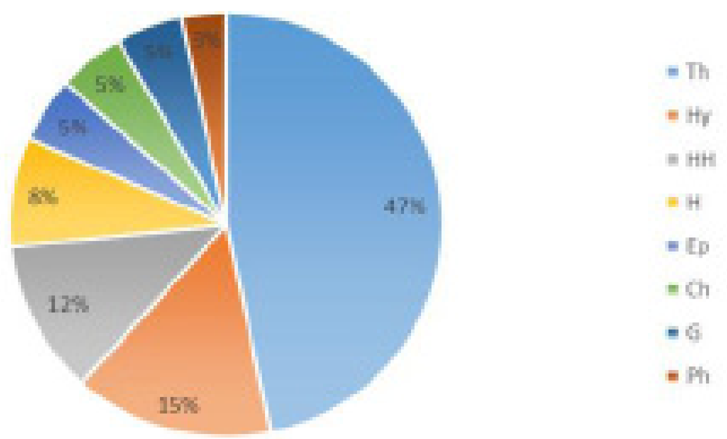

Fig. 2. Different growth form of the recorded species (for abbreviations see Table 1).

TABLE 3. Proximity Matrix or the similarity between each pair of the 7 morphotypes (M1-M7) depending on their associated species.

	M1	M2	M3	M4	M5	M6	M7
M1	100	74	**21**	80	73	80	78
M2		100	**26**	62	49	**81**	55
M3			100	**23**	**21**	40	**20**
M4				100	76	**84**	72
M5					100	80	**84**
M6						100	77
M7							100

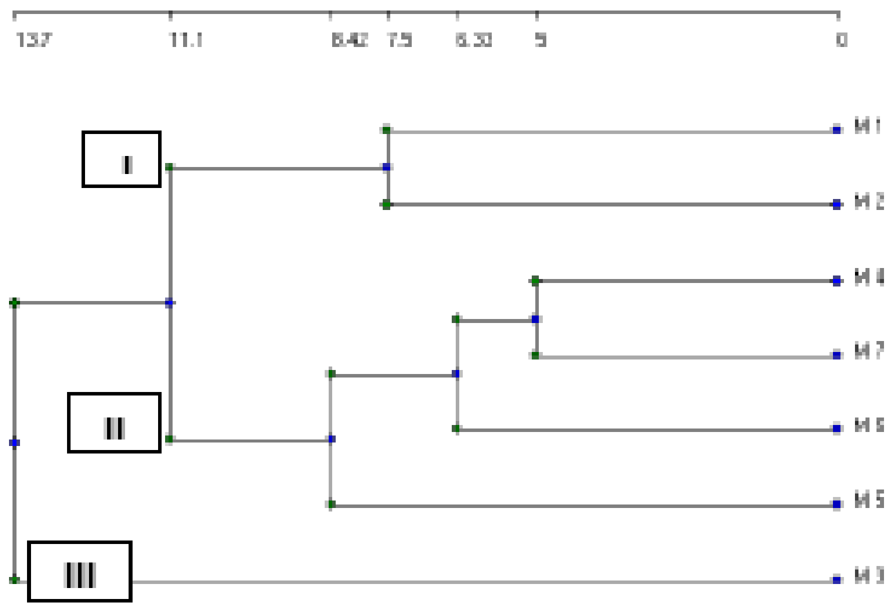

Fig. 3. Cluster analysis of the 7 morphotypes (M1-M7) by using agglomerative Ward's technique by Euclidean distance measure based on their macro and micro morphological data. I, II and III are the resultant groups.

TABLE 4. Similarity between morphotypes based on macro & micro morphological characters using Jaccard's Measure.

	M1	M2	M3	M4	M5	M6	M7
M1	100						
M2	**53.1**	100					
M3	**29.7**	**14.7**	100				
M4	47.2	41.9	34.4	100			
M5	38.9	46.4	37.9	50	100		
M6	52.8	43.8	45.2	**66.7**	51.6	100	
M7	**61.8**	53.3	**32.4**	**66.7**	51.6	**57.6**	100

Environmental variables-vegetation relationships

Table 5 demonstrated the mean values, standard errors (SE) and ANOVA values (F-ratio & P=sig.) of the studied soil and water variables in each morphotype. Clearly, the water reaction (pH) of all samples is generally alkaline. Chlorides exhibited the most highly significant value (P=0.0007). In addition, electric conductivity, salinity, organic matter, potassium, magnesium, nitrates and sulfates were of high significant values. It also displayed that the stands of the saline morphotype M7 had the highest values of pH, EC, salinity, HCO_3^-, Na^+, K^+, Mg^{+2}, Ca^{+2}, Cl^-, NO_3^- and SO_4^{-2}. Whereas, the organic matter and turbidity attained their highest values in the stands of the fresh morphotype M1, NH_4^+ and CO_3^{-2} in stands of the terrestrial morphotype M3 and finally PO_4^{-3} in M4.

The application of CCA in the present data set demonstrated that electric conductivity, salinity, organic matter, potassium, magnesium, nitrates and sulfates were among the most important factors that affect the spatial distribution of the associated species of each morphotype. The relationship between the associated flora and water-soil analyses values in the 32 studied stands of the 7 morphotypes using CCA analysis was performed in Fig. 4. CCA ordination biplot of *L. stolonifera* morphotypes (1-7), with arrows represented the examined water-soil variables. Preliminary analysis revealed high inflation factors for 3 water variables, K^+, Mg^{+2} and Ca^{+2} that should be excluded from the analysis.

It can be noticed that the stands of the fresh water morphotypes M1 & M2 were correlated the organic matter and turbidity, while the terrestrial morphotype M3 was affected by carbonates and ammonia while the brackish and saline morphotypes (M4, M5, M6 and M7) were affected by electric conductivity, salinity, NaCl contents.

The successive decrease of eigenvalues of the four CCA axes (0.2888, 0.4805 and 0.1092 for axes 1, 2 and 3, respectively) illustrated in Table 6, suggesting a well-structured data set. The species-environment correlations were high for the four axes, explaining 79.7% of the cumulative variance.

The inter-set correlations resulted from CCA of the examined water variables were shown in Table 6. Axis 1 was positively correlated with CO_3^{-2}, NH_4^+, NO_3^-, SO_4^{-2}, pH and negatively correlated with EC, Salinity, turbidity, HCO_3^-, organic matter, Na^+, Cl^- and PO_4^{-3}. Carbonates and ammonia had the highest positive values (0.9951), while turbidity had the highest negative value (-0.7637), thus axis 1 can be interpreted as carbonates & ammonia-turbidity gradient. Axis 2 was positively correlated with pH, EC, Salinity, HCO_3^-, Na^+, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-2} and negatively correlated with Turbidity, CO_3^{-2}, OM and NH_4. The highest positive value was for PO_4^{-3} (0.6942), while the highest negative value was for organic matter (-0.7112), thus axis 2 can be interpreted as phosphate-organic matter gradient. Axis 3 was positively correlated with pH, EC, Salinity, HCO_3, CO_3^{-2}, organic matter, Na^+, NH_4^+, Cl^-, NO_3^-, SO_4^{-2} and negatively correlated with Turbidity, and PO_4^{-3}, thus axis 3 can be interpreted as Chloride-phosphate gradient.

The CCA biplot showed that the terrestrial morphotype M3 was correlated with carbonates and ammonia. This type of soil prefers the co-association of therophytes as *Chenopodium album, Chenopodium murale, Rumex dentatus, Amaranthus hybridus, Bassia indica, Malva parviflora* and *Melilotus indicus.* At the contrary, the increase in the electric conductivity, salinity and NaCl contents may result in presence or even dominance of tolerant species at the expense of less tolerant species as in the sites of the brackish and saline morphotypes (M4, M5, M6 and M7) that prefer the co-association of halophytes as *Spergularia marina, Atriplex semibaccata*; hydrophytes as *Pistia stratiotes, Zaleya pentandra, Wolffiella hyalina* and canal bank species as *Imperata cylindrica, Polygonum bellardii, Cyperus laevigatus.*

A test for significance with an unrestricted Monte Carlo permutation test found the F-ratio for the eigenvalue of CCA axis 1 and the trace statistics to be significant (P=0.04), indicating that the observed patterns did not arise by chance.

Phenotypic plasticity of L. stolonifera

Habitat diversity

Ludwigia stolonifera exhibits high degree of habitat diversity, this plasticity enables it to expand its ecological range from fresh water habitats as in morphotypes M1 and M2, wetlands M3, to brackish water M5 as well as marine habitats M7.

TABLE 5. Mean value, standard error and ANOVA F-ratio & Sig. (P) values of the soil & water variables in the 7 morphotypes.

Var	M1	M2	M3	M4	M5	M6	M7	*F*	*Sig.*
PH	7.71±.08	6.29±.10	7.89±.02	7.85±.03	8.30±.03	8.06±.03	8.66±.04	1.410	0.2861
EC	463.33±.88	553.61±1.32	619.12±34.81	775.61±8.34	1227.12±1.15	702.16±1.2	5436.56±4066.41	14.310	0.0030**
Sal	.24±.01	.39±.02	.41±.22	.89±.34	5.65±2.42	1.3±.63	38.33±3.12	12.620	0.0034**
Tur	4.22±.06	1.71±.02	.00	1.01±.12	2.11±.070	2.38±.08	2.00±.08	3.190	0.0925
HCO_3	203.78±2.04	183.03±2.03	69.85±1.74	299.17±32.24	137.44±4.31	113.65±5.04	352.25±4.11	.642	0.5218
CO_3	.00	.00	86.31±2.61	.00	.00	.00	.00	.897	0.6945
OM	253.4±2.24	9.84±.10	21.06±.53	11.09±.58	19.12±.59	44.22±.40	134.04±.58	16.603	0.0026**
Na	41.06±1.16	95.27±1.47	145.82±.43	172.94±.58	297.48±.29	178.73±2.03	2457.42±9.81	5.212	0.0216*
NH_4	.00	.00	41.05±3.46	.00	.00	.00	.00	1.498	0.2791
K	5.65±.33	7.48±.29	14.36±.32	17.55±.29	6.34±.33	5.53±.29	79.34±.33	16.739	0.0021**
Mg	12.61±.31	17.54±.29	49.61±.31	23.48±.29	15.62±.31	13.39±.31	294.55±.29	11.797	0.0038**
Ca	31.53±.29	45.52±.29	138.43±.30	55.43±.30	50.52±.29	36.93±.58	181.58±.30	2.2794	0.1623
Cl	25.56±.29	57.38±.31	360.36±.32	324.6±.31	655.42±.30	324.66±.33	4154.24±1.75	19.450	0.0007***
NO_3	.15±.01	.13±.00	33.49±.29	25.57±.30	.24±.01	1.20±.02	6.55±.29	13.713	0.0032**
PO_4	.00	.00	.00	.37±.03	.00	.00	.00	.195	0.2127
SO_4	34.4±.29	185.83±.58	632.37±.88	216.16±.48	239.53±1.44	201.74±1.11	889.09±.58	15.126	0.0027**

* = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, EC= Electric conductivity, OM=Organic matter (ppm), Sal = Salinity (ppt) and Tur = Turbidity (NTU). Other variables are measured in mg/L.

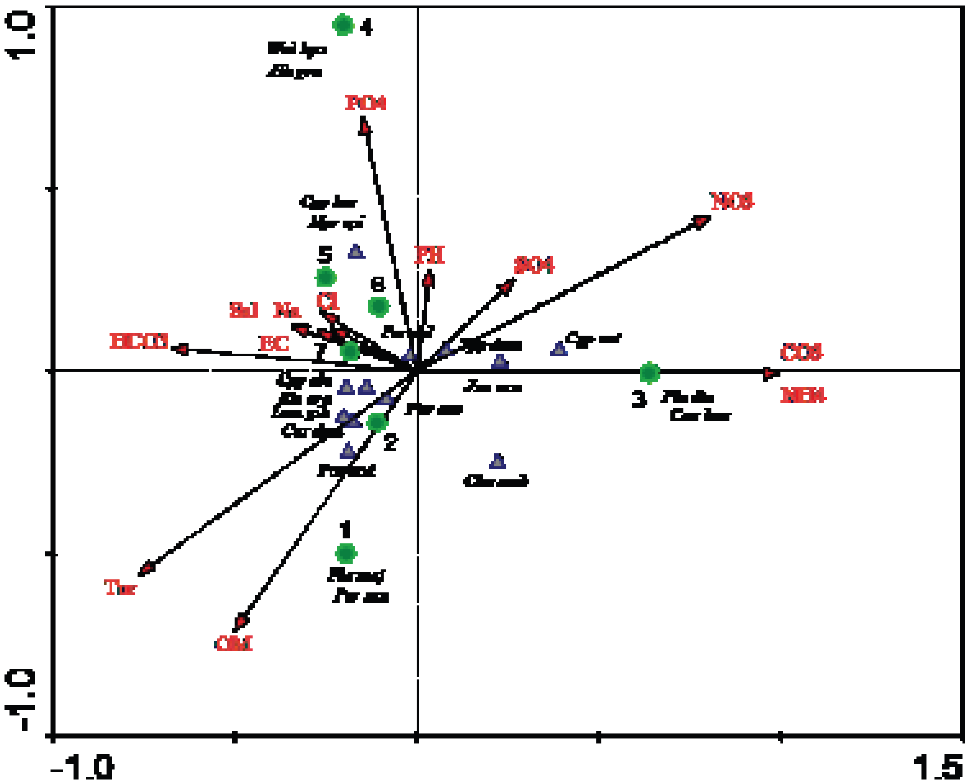

Fig. 4. The CCA ordination biplot of the first 2 axes showing the distribution of 7 morphotypes, with the examined environmental variables. **Characteristic species are given with the 3 initial letters, for species names see Table 1.**

TABLE 6. CCA analysis results showing the inter-set correlations of the water variables, together with eigenvalues and species-environment correlation of the studied morphotypes.

Axes	Ax1	Ax2	Ax3
Eigenvalues	0.2888	0.4805	0.1092
Species-environment correlations	44.5	64.5	79.7
pH	0.0359	0.2745	0.5199
EC	-0.3423	0.1245	0.9115
Salinity	-0.3419	0.1211	0.9123
Turbidity	**-0.7637**	-0.5572	-0.2049
HCO_3^-	-0.6722	0.0626	0.6264
CO_3^{-2}	**0.9951**	-0.0060	0.0309
OM	-0.4998	**-0.7112**	0.1414
Na^+	-0.3145	0.1251	0.9215
NH_4^+	**0.9951**	-0.0060	0.0309
Cl^-	-0.2738	0.1104	**0.9366**
NO_3^-	0.8045	0.4255	0.0095
PO_4^{-3}	-0.1492	**0.6942**	**-0.3448**
SO_4^{-2}	0.2651	0.2493	0.9205

Leaf diversity

Phenotypic plastisity reflected on the leaf shape and size of the studied morphotypes of *L. stolonifera* varied from narrowly elliptic-lanceolate in fresh water habitat as in M1, spathulate-narrowly elliptic in wetland habitat M3 to lanceolate in marine habitat (M7). Morover, diversity was clear in leaf sizes from relatively very small with mean value 0.9±0.11 cm in wetland morphotype M3 to relatively large with mean value 11.3±1.7 cm in fresh aquatic morphotype M1 (Fig. 5).

Fig. 5. Leaf diversity of different morphotypes (M1-M7) of *L. stolonifera*, each square =1cm.

Flower diversity

The studied morphotypes revealed notable variation in the flower from typical bisexual 5-merous flowers with 10 stamens as in M1 and M7, to bisexual 6-merous flowers with 12 stamens as in M3. Female flowers was traced also on some individuals with the bisexual flowers as in M2, M4, M5 and M6. In addition, the ovary shows variation in number of locules from typical 5-locules as in M1, M4, M6 and M7, to 5-8 locules in the other morphotypes (Fig. 6).

Fruit diversity

The fruit morphology of *L. stolonifera* showed notable variation in size, position of bracteoles and number of seeds/fruit among the different morphotypes from small fruit that may reach 2.5cm in M3 to relatively large fruit that may reach 3.5 in other morphotypes except M5. The position of bracteoles varied from basal in M1, M2 and M5 to near base in M4 and M6, at or near base in M3 and near or aboved in M7 (Fig. 7). Also, the seed productivity / fruit varies from 60-80 seeds/fruit in M1, M2 & M7 to 35-45 seeds/ fruit in others.

Pneumatophores diversity

The studied morphotypes showed variation in the production of the pneumatophores (vesicles) at the nodes of floating stem, from abundant vesicles (up to 10 pneumatophores/cluster) as in M1, M2, M4 and M7 (Fig. 8.a & b) to occasional vesicles (up to 3 pneumatophores/cluster, Fig. 8c) in the other morphotypes. Abundant Pneumatophores varied from conical to cylindrical (2.0-4.5(-9.0) cm) in M1, to conical to fusiform (2.0-4.5cm) in M2, fusiform (2.0-6.0cm) in M4 and conical to fusiform or cylindrical (2.0-4.5(-15.0)cm) in M7 where conical and cylindrical pneumatophores can be seen in the same cluster with branched pneumatophores on the roots (Fig. 8d). Occasional pneumatophores appeared fusiform in M5. The density of pneumatophores (number of pneumatophores at each node) differed. It was abundant (from 6 to 10) in M1, M2, M4 and M7 and occasional (up to 3) in others.

Pollen grains

The ratio of the pollen length in the saline morphotype M7, P/E= 0.89 was relatively small compared with the fresh morphotypes P/E= 1.03. As well, M7 represented characteristic position of aperture, planaperturate while others were angulaperturate. Another example of plasticity is the colpus length that might reach 31 µm in M4 and the aperture was covered by an operculum while in others (M2, M5 and M7), the colpus length might be less than 7µm and the aperture was without that operculum. In addition, the crystal-like elements on exine surface were observed in M3 and M5, and were absent in the other morphotypes. Moreover, family Onagraceae is characterized by the presence of viscin threads that were observed in all morphotypes except M5.

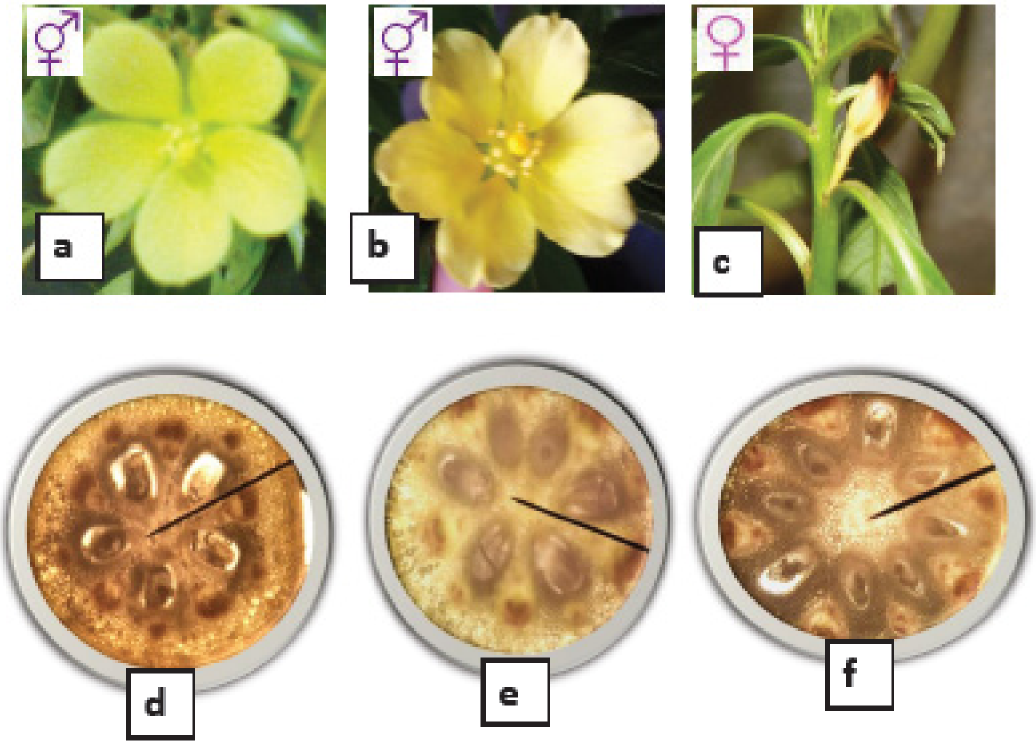

Fig. 6. Flower diversity of *L. stolonifera*, (a) Typical bisexual 5-merous flower with 10 stamens, (b) Bisexual 6-merous flower with 12 stamens, (c) Female flower, (d) 5-locules ovary, (e) 6-locules ovary and (f) 8-locules ovary.

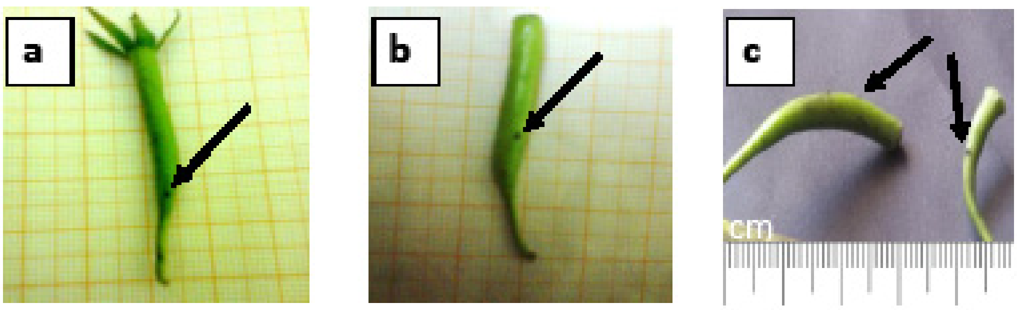

Fig. 7. Fruit diversity in bracteoles position of *L. stolonifera*, (a) Basal in M1, (b) Near base in M4 and (c) Near base or above in M7.

Discussion

Irrigation and drainage system of River Nile as well as the northern natural lakes in the Nile Delta are highly infested by different communities of aquatic macrophytes, which spread so rapidly and easily fill up the whole of many water bodies, cause negative effects on the environment, human health and economic development (Fernàndez et al., 1990; Epstein, 1998; LVEMP, 1999 and Mailu, 2001). The field observation revealed that *Ludwigia stolonifera* is one of the most dominant macrophyte in water courses at least in the area of study.

Fig. 8. Pneumatophores diversity of *L. stolonifera*, (a&b) Abundant pneumatophores, (c) Occasional pneumatophore and (d) Mixed cluster of conical and cylindrical pneumatophores.

Clearly, the expansion of *L. stolonifera* in different habitats may threaten plant biodiversity in Egypt. The floristic composition of a community is an indication of species coexistence. Accordingly, the study of the associated plants was necessary. Moreover, floristic composition together with life form represented diagnostic characters to distinguish species especially hydrophytes which have wide geographical and ecological distribution.

In line with our results, Abu Ziada et al. (2008) recognized Poaceae, Chenopodiaceae, Polygonaceae, Amaranthaceae and Cyperaceae to constitute the major part of the floristic composition in their studies on the aquatic vegetation in the north Nile delta. In addition, the two former families were reported to be among the most frequent plant families in Egypt (Shaheen, 2002 and Abd El-Ghani & Fawzy, 2006). Moreover, Poaceae and Chenopodiaceae were found to be the most frequent families containing many weed species in other studies in the tropics (Åfors, 1994; Becker et al., 1998 and Tamado & Milberg, 2000). Furthermore, these families represent the most common in the Mediterranean North African flora (Quézel, 1978). These families are characterized by high number of genera and subsequently they are represented by relatively quite number of species.

The main bulk of the associated species were annuals (29 species) that constitued about 48.3% of the total flora of the study area. The dominance of annuals could be related to their high reproductive capacity under high level of disturbance (Grime, 1979). The low number of perennials especially in trees (3 species) might be related to the intensive management used in the canals and the continuous mechanical weed control that could affect their vegetative structures.

Based on Raunkiaer's life form system (1937), therophytes were relatively highly represented by 28 species, that constituted about 46.7% of the total number of the associated species, followed by the hydrophytes and helophytes that were represented by 16 species about 26.7%. Similar results were conducted by Abu Ziada et al. (2008) who stated that the therophytes predomintes over other life forms.

Phragmites australis, Eichhornia crassipes and *Cyperus alopecuroides* were the wide ecological spectrum species in the area of study. These results were also conducted by Khedr & El-Demerdash (1997). Mashaly & El-Amier (2007) recognized these species as indicator species in the irrigation and drainage canals system in egypt. Moreover, Hutchinson (1975) cleared that *Eichhornia crassipes* having high ecological tolerance and large-scale ability to disperse in the fresh and alkaline courses of water.

It is to be noticed that the dense canopy of tall growing species along water edge (e.g. *Phragmites australis*) makes the germination and growth of other species more difficult, this often leads to the reduction in the species diversity. In addition, the human impact, especially the mechanical control of weeds, might be the main reason for the low number of species in association with the brackish morphotype M5 and the fresh to brackish morphotype M4, 6 species and 7 species respectively; this is in line with the result conducted by Shaltout & El-Sheikh (1993).

The high number of species, 32 species (about 53.3% of the collected species), associated with the marine morphotype (M7) may be attributed to the nutrient budget of the saline lakes that is mostly dependent upon the amount of nutrients transported through the waste water drains as the water in these drains contain large amounts of suspended solids (Dowidar & Abdel-Moati, 1983 and Abdel-Moati, 1990). These conditions favor the growth of floating and emergent hydrophytes.

In the present study, a suite of chorotypes such as Cosmopolitan, Paleotropical, Pantropical, Mediterranean, Sudano-zambezian and Saharo-Arabian had been represented. This could be attributed to human impact and the ability of certain phytochoria to penetrate the study area from several adjacent phytogeographical regions (Shalaby, 1995).

Water invadors (Simpson, 1932) are land weeds that grow near water, usually with their root systems below water (helophytes *sensu* Raunkiaer, 1937). These weeds invade the water, either from the bank or from more or less shallow water, some are rooted at the normal water level and their stems and branches spread out over the water. The field observation cleared that form in *Echinocloa crusgalli.* Most of the recorded water species in the present study had relatively maximum occurrence in the wetlands along lake Manzala and Edku and other water courses, belong to Poaceae, Cyperaceae and Polygonaceae (Zahran & Wills, 2003). This might support the abundace of some species like *Persicaria salicifolia.* Njambuya & Triest (2010) showed that *Ludwigia stolonifera*, a native species, outperformed the invasive species in all measures of performance studied under nutrient non-limited conditions. These findings are consistent with the conclusion drawn by Daehler (2003) that invasive species do not always have higher growth rate and neither do they often competitively outperform co-occurring native species. Some native species have the same attributes as invasive species (Thompson et al., 1995). Our study confirmed that wherever populations of *L. stolonifera* grown, it outperformed other invadors.

In addition, Njambuya & Triest (2010) indicated that *Ludwigia stolonifera* as a creeping emergent macrophyte, had a higher average relative growth rate that could accumulate more biomass. Rejmànkovà (1992) pointed out that the so-called creeping emergent species accumulate more biomass to above than belowground part. This meets our observations in the field.

Comparison of macro and micro morphological characters among the studied populations of *L. stolonifera* revealed seven morphotypes. The similarities between each pair of the 7 morphotypes was elaborated using Jaccard's Measure. Frankel et al. (1995) and El-sadek & Ayyad (2000) demonstrated that genetic diversity within species gives the opportunity to evolve under changing environments and selection pressure. This may explain the least similarities between the terrestrial wetland morphotype M3 and the other aquatic morphotypes and the relatively high values of similarity between the two fresh to brackish morphotypes M4 & M6 (66.7%) and between the two fresh morphotypes M1 & M2 (53.1%). In addition, this may clarify the response to variations of environmental factors to survival and growth in the heterogeneous environments (Dorken & Barrett, 2004). Similar observation was noticed in the invetigation of Khedr & Hegazy (1998) on *Nymphaea lotus* around Manzala lake where this hydrophytic species invaded the rice fields causing a serious problem. However, the high similarity values between marine morphotype M7 and the three morphotypes M1 (fresh morphotype), M4 and M6 (fresh to brackish morphotypes) cleared the high polymorphism of this morphotype, this come in line with Bidak & Marzouk (2005) who observed high degree of acclimation and plasticity accompanied with *L. stolonifera* populations of certain northern lakes especially lake Manzala. This postulate was confirmed by our result on the similarity between each pair of the 7 morphotypes depending on their associated species using the proximity matrix.

The application of CCA in the present data set agreed with Khedr & El-Demerdash (1997) as they showed that water salinity, EC, potassium ions and total phosphates contents were the environmental factors associated with macrophytic distribution, concluded that the distribution of emergent and floating species was best correlated with water salinity, potassium and total phosphates.

The correlation between fresh water morphotypes M1 & M2 and organic matter & turbidity, agreed with the gradual pollution of most of our water resources by the addition of foreign materials from the surroundings. These included organic matter of plant and animal origin, land surface washing, industrial, agricultural and sewage effluents which containing large amount of dissolved ions and high amount of organic and inorganic constituents. This may agree with Elewa & Mahadi (1988).

The results of the CCA biplot is in agreement with the findings conducted by Corre (1985) and Winter (1990) who stated that halophytes have the ability to grow and dominate in habitats with high concentrations of cations, salinity, pH and moisture contents

High cumulative variance (93.5%) of the species-environment correlations suggested an association between the flora and the measured water variables presented in the study area.

Ludwigia stolonifera is a fresh water amphibious plant can grow in both terrestrial and aquatic conditions. This feature may be attributed to its phenotypic pasticity, recorded earlier in some species of this genus as in *L. grandiflora* (Ruaux et al., 2009 and Haury et al., 2014a) and *L. octavalvis* (Chauhan & Abugho, 2012).

Hutchinson (1975) demonstrated that the distribution of species of aquatic plants is associated with their large-scale ability to disperse sexual or vegetative propagules that can establish in novel habitats, clonal growth and broad ecological tolerance (Darwin, 1859; Sculthorpe, 1967; Grace, 1993; Les et al., 2003 and Charalambidou & Santamària, 2005); these qualities allow them to occur over a wide range of conditions (Lacoull & Freedman, 2006).

Bar & Ori (2014) indicated that plants are able to change quickly in response to environmental cues; leaf shape exemplifies this principle well and represents a classic example of developmental plasticity (Arber, 1920; Schmalhausen, 1949; Sculthorpe, 1967; Cook & Johnson, 1968 and Cook, 1968). The variation in the length and shape of leaves among the studied morphotypes ranged from short, spathulate to narrowly elliptic in M3 to relatively long, lanceolate leaves in M2, M4, M5 and M7 morphotypes which reflects the plastic changes in leaf shape that are considered to be an adaptation of the presence or absence of water in the plant's environment (Morisset & Boutin, 1984). This feature come in line with Peng (1988), Lavania et al. (1990) and Scremin-Dias (2009).

Aquatic plants display a remarkable range of reproductive strategies, including diverse sexual systems and means of clonal propagation (Barrett et al., 1993). Reproductive strategies affect the response of populations to environmental heterogeneity (Ronce & Olivieri, 1997; Barrett & Pannell, 1999; Heilbuth et al., 2001 and Crowley & McLetchie, 2002). Moreover, the variation in reproductive traits will influence the ability of populations to colonize and persist in different types of aquatic habitats and these can explain the variation in flower sex of aquatic morphotypes of *L. stolonifera* when compared with the terrestrial morphotype M3.

Bradshow (1965) and Schlichting (1986) reported that differences in production of seeds is known to occur between populations of many species. This is in line with our study that reflects variations in the fruit morphology and seed productivity/fruit of *L. stolonifera* morphotypes. These may attributed to the variation in the flower which in turn reflect on fruit morphology and seed productivity among the studied morphotypes and come in line with Bidak & Marzouk (2005) who reported variation in seed productivity among *L. stolonifera* populations.

Within the seven morphotypes, the bracteoles are located either at, near the base or higher up on the sides of the capsules which reflect their phenotypic plasticity of the studied morphotypes. This variability may be detected in the same plant. Peng (1989) recorded that variability within the individual of the same plant as in *L. linifolia,* the bracteoles range from (1.5-) 2.5-9 (-13)mm long. Few species including *L. sphaerocarpa* and *L. microcarpa* consistently have shorter bracteoles (less than 1.5mm long) than other species,

As a member of water living, the morphological constructions of *L. stolonifera* morphotypes vegetative organs especially pneumatophores which contains the ability to strengthen the plant oxygen supply and support the plant up grown may have a kind of plasticity to be able to grow and survive in different habitats as fresh water morphotypes (M1 and M2) to brackish (M4 and M6) to marine morphotypes (M7), while the terrestrial morphotype (M3) has fibrous roots attache to the substrate as it is found along the edges of water bodies. This result is aligned with the observation of Sen (1959) in the floating and land forms of *L. adscendens,* confirmed by Fuchen et al. (2005) who demonstrated that production of pneumatophores in *Ludwigia stolonifera* may differ in response to water depth as populations living in deep water are in need of oxygen as than that living in wetland or shallow water. As well, Haury et al. (2014b) stated that *L. peploides* had a lower percentage of roots compared to *L. grandiflora* present in aquatic habitats.

Clearly, the pollen grains of the studied morphotypes showed notable plasticity on many palynological characters such as the P/E ratio, position of aperture, presence of operculum, presence of crystal-like elements on exine surface and the presence of viscin threads. Habitat diversity was clearly reflected on the recorded plasticity where the morphotype inhabiting the saline habitat can easily differeniated by its planaperturate pollen from others inhabiting fresh water habitats by their angulaperturate pollen. On the same way, the morphotypes inhabiting brackish habitat characterized by long colpus and presence of operculum, similar results were observed by Torabi et al. (2013) who detected various abnormalities and unusual adhesion of pollen grains in saline condition when compared with those in normal conditions.

Jain (1978) cleared that such interspecific variabilities could be of adaptive significance and could affect population fitness, particularly in inhabiting fluctuating and unpredictable environments. In addition, Frankel et al. (1995) and El-sadek & Ayyad (2000**)** demonstrated that genetic diversity within species gives the oppourtunity to evolve under changing environments and selection pressure. So we can conclude that further cytological and molecular studies need to elucidate the impact of such genetic diversity on plasticity among *L. stolonifera* morphotypes.

Conclusion

The studied populations of *Ludwigia stolonifera* exhibit high phenotypic plasticity in relation to the different habitats (terrestrial, fresh water, brackish and saline) in the leaf shape and size, the flower characters, number of carpels and stamens, the size and position of bracteoles, the seed productivity per fruit, the abundance of vesicles and the position of aperture. The study revealed that this plasticity is correlated with the habitat diversity and the water characteristics. Accordingly, the associated species shows great dissimilarities among the different morphotypes.

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لودويجيا ستولونيفرا نظرة موضوعية فى المرونة الظاهريه وتنوع الموائل والنباتات المصاحبة

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بمتابعة اثنين وثلاثين عشيرة نباتية لنبات المديد (اللودويجيا ستولونليفرا) تم رصد سبعة أنماط مورفولوجية مختلفة تنتمي هذه الأنماط إلى خمسة موائل مختلفة. وكان أكثر النباتات مصاحبة لنبات المديد هي الحجنة وياسنت الماء والسمر الحلو.مثلت النباتات واسعة الأنتشار ونباتات الإستوائية للعالم القديم والحديث حوالي 56.7% من مجموع النباتات المصاحبة للمديد. وكذلك مثلت النباتات الحولية ما يقرب من 46.7%ونباتات المائية حوالي 26.7% بينما تواضع تواجد النباتات الأخرى. تم رصد معامل التماثل بين الأنماط السبعة المختلفة معتمدا على 42 من الخصائص المورفولوجية الدقيقة والكبيرة.

ومما هو جدير بالذكر أن نبات المديد للمياة العذبة تأثر بتواجد المادة العضوية ومعامل عكارة الماء بينما تأثر مديد مناطق الأراضي الرطبة بتواجد الكربونات والأمونيا، وتأثر نبات المديد لمناطق المياه المالحة بمعامل التوصيل الكهربائي والملوحة ومحتوى كلوريد الصوديوم. وقد أظهرت الدراسة مرونة مظهرية متباينة لنبات المديد في الموئل المختلفة، وقدرصدت الدراسة ذلك في اختلاف شكل الأوراق وحجمها، وفي الزهرة من زهرة خماسية بها عشرة أسدية إلى زهرة سداسية بها أثني عشرة من الأسدية، وفى حجم وموضع الوريقة القنابية من قاعدية إلى قرب قاعدية أو تحت طرفية، وفى إنتاجية البذور من 60-80 إلى فقط 35-45 بذرة للثمرة، وفي الجذور من 10 جذور للعنقود الواحد إلى فقط ثلاثة جذور، وأخيرا في وضع فتحات حبوب اللقاح من سطحية إلى ذات الزوايا.