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Impact of the Invasive *Ipomoea carnea* Jacq. on Plant Diversity Along the Canal and Drain Banks of Nile Delta, Egypt

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ABSTRACT

In Nile Delta of Egypt, the introduced invasive species *Ipomoea carnea* Jacq. occupies pure and/or mixed stands with poor associates along the banks of canals and drains forming a dense above ground patches. In this study, the impact of *I. carnea* on floristic diversity and soil chemical properties evaluated. The plant community attributes including species richness and evenness were compared between invaded and uninvaded stands. The allelopathic potential of the aqueous extracts of root, stem, leaf and fruit of *I. carnea* were examined on seed germination and seedling growth of *Echinochloa crus-galli* and *Portulaca oleracea* weeds. Results showed that, the inhibitory effect of *I. carnea* extracts could be related to the presence of phenolics, flavonoids, tannins and alkaloids, and followed a gradient: leaf> fruit> root> stem. The allelopathic activity of *I. carnea* coupled with its competitive effect for soil nutrients could contribute to the invasion success and attainment of pure population.
Keywords: Species diversity, Invasive species, Allelopathy.

INTRODUCTION

Invasive plant species pose a great threat that negatively impacts biodiversity and/or abundance of native plant communities and ecosystems. They, also exerts a significant depressive effect on associated flora and results in extensive economic and ecological damage; needed to be managed (McGeoch *et al*., 2010). A prime example in Egypt is the *Ipomoea carnea* Jacq. *I. carnea* is a perennial pantropical dicot shrub belongs to family Convolvulaceae.

It is native to Tropical South America and was introduced to Egypt in 1932 as an ornamental plant for its luxuriant vegetative growth and attractive large pink flowers (Shaltout *et al*., 2010). It represents a troublesome weed along banks of canals and drains in the Nile Delta region and it has the potential to become an ecological invasive disaster in the Egyptian water bodies. This plant has an extended growing season which encompasses most of the year. It spreads rapidly along littorals of water courses and occasionally blocks water flow in the drainage and irrigation system. It also interferes with fishing, navigation and increases sedimentation. Moreover, *I. carnea* has been reported to be poisonous and cause severe nervous disorders when ingested by cattles and goats or sheep (Tokarnia et al., 2000). Shaltout et al., (2010) reported that mechanical management is very useful in removal of this plant especially when the plant has a reduced capacity to re-sprout. However, such management method is intensive and expensive.

Allelopathy of *I. carnea* and other invasive plants have been proposed as a strong mechanism for their remarkable success over the native species, which may be devoid of these innate allelopathic potentials (Callaway and Aschehoug, 2000; and Rice, 1984). It been suggested that a direct or indirect inhibitory or stimulatory effects of the invasive plants secondary metabolites regulate the structures of plant communities (Smith and Martin, 1994). Generally, the agro-ecological applications of allelopathy has provided alternatives to develop more environmentally friendly synthetic herbicides for weed control (Vyvyan, 2002) with lower impact on the environment (Duke *et al*., 2002 and Uddin *et al*., 2013).

Therefore the study of this weed allelopathy is going to reveal a lot of interesting invasiveness ability in Egypt. The objectives of this study were set to demonstrate the impact of *I. carnea* invasion on species diversity and on some soil chemical properties along the canal and drain banks in Nile Delta. Moreover, the assessment of its allelopathy role as a mechanism for its remarkable domination and invasion success in Nile Delta region.

MATERIALS AND METHODS

Study Area

Nile Delta starts 20 km north of Cairo and it is embraced by the Rosetta and Damietta branches of the Nile River. It covers about 22,000 km^2 representing about 63% of the fertile Egyptian lands (Abu Al-Izz, 1971). The climatic conditions is warm with an average temperature range of 20–30^oC in summer, while winter is mild with an average temperature range of 10–20^oC. Most of the rain occurs during winter, ranging between 100 mm/year in the north and 23 mm/year in the south. Four governorates namely El-Dakahlia (N 31^o 04$^/$, E 31^{o}42$^\backslash$), Damietta (N 31^o 07$^/$, E 32^o 35$^\backslash$), Kafr El-Sheikh (N 31^o 12$^/$, E 30^o 96$^\backslash$) and El-Behira (N 31^o 03$^/$, E 30^o 43$^\backslash$) are the designated areas of this study (Figure 1). These four governorates belong to the arid and/or semiarid climatic belts of the northern coastal region of Egypt (Zahran and Willis, 2009). The field studies on the distribution of *I. carnea* were carried out seasonally during the 2013 in the designated sites.

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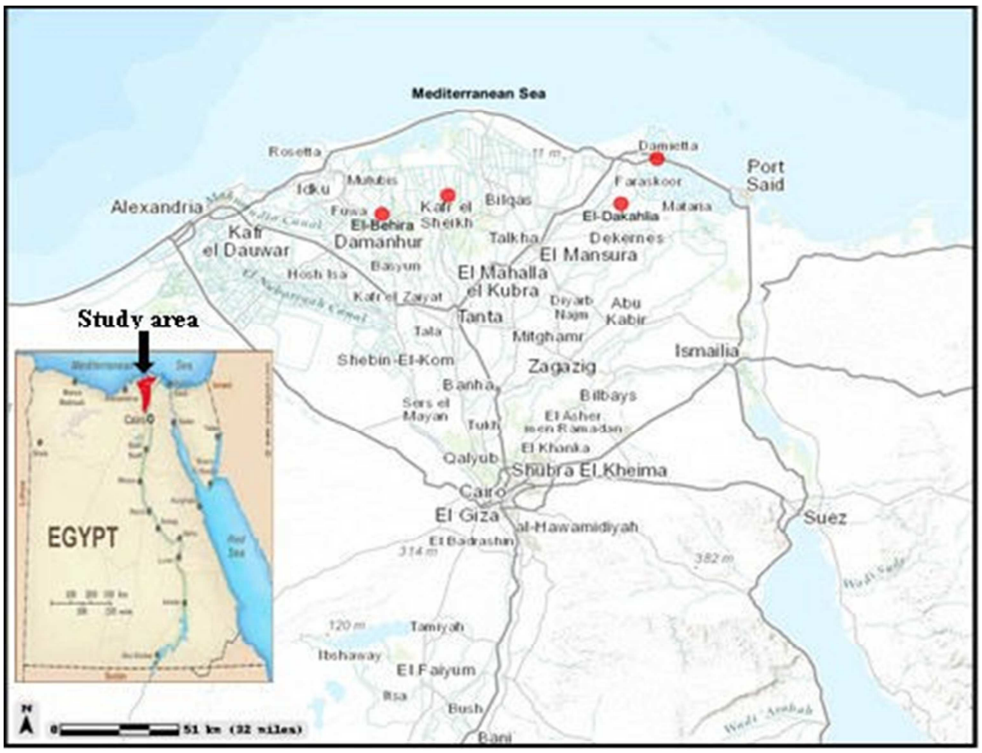

Figure (1): Map of Nile Delta region, Egypt indicated the location of sampling sites.

Plant species diversity

Forty stands of 25 m^2 each for both invaded and uninvaded patches were selected randomly along the banks of irrigation and drainage canals of the study area to determine the possible floristic changes due to invasion by *I. carnea* shrub. The uninvaded stands are at least three meters away from the *I. carnea* community. Furthermore, monospecific stands of *I. carnea* were frequent in the study area, but they were excluded from the present surveys. A list of the associated species was compiled in each surveyed stand, the number of individuals was recorded and presence percentage was calculated for invaded and uninvaded patches. Other community diversity attributes were also estimated, including species richness (estimated by Simpson's diversity index) and species evenness (estimated by Shannon-evenness index). Identification and nomenclature of the plant species in the study area were according to Boulos (1999–2005). The voucher specimens were deposited in the Herbarium of Botany Department, Faculty of Science, Mansoura University.

Soil analysis

For each invaded and uninvaded stands, five soil samples were randomly collected at a profile depth of 0–50 cm in clean plastic bags. Organic carbon and sulphates were determined according to Piper (1947). Calcium carbonate was determined by titration against 1 N NaOH (Jackson, 1962).The total soluble nitrogen was determined by the micro-Kjeldahl method (Pirie, 1955). Each soil sample was extracted by making a 1:5 soil/distilled water suspensions. The following measurements were carried for each soil sample extract. The electrical conductivity (salinity) was measured using conductivity meter and soil reaction (pH) using pH meter (Model Corning, YN 14831 USA). Chloride was determined by direct titration method against silver nitrate solution (N/35.5) using 5% potassium chromate indicator (Jackson, 1962) and bicarbonates was determined by titration method using 0.1N HCl (Pierce *et al*., 1958). Total dissolved phosphorus was determined by digestion and followed by direct stannous chloride method (APHA, 1998). Na^+ and K^+ were determined using a flame photometer (Model PHF 80 Biologie Spectrophotometer), while Ca^{++} and Mg^{++} were estimated according to Allen *et al*. (1974) using an atomic absorption spectrometer (Perkin Elmer Model 2380).

Assessment of allelopathic potential of *I. carnea*

I. carnea shrubs were collected in the period between September and November, 2013, when the plant produced most reproductive organs. Different parts of the whole plant were separated (root, stem, leaf and the fully mature fruit), washed with distilled water, and left until complete dryness at room temperature, in a shaded place. The dried samples were ground to pass 1- mm sieve. Ten grams of air dried materials from all samples were extracted in 100 ml distilled water and left for 24 h at room temperature. Filtration was carried out through a double layer filter paper (Whatman No.1).

Filtrates were served as stock solutions of 10% concentration. By subsequent dilutions with distilled water, root, stem, leaf and fruit extracts of 2%, 4%, 6% and 8% concentrations were prepared.

Seeds of two weeds, *Portulaca oleracea* L. and *Echinochloa crus-galli* (L.) P. Beauv were collected from the study area. *Portulaca oleracea* (family: Portulacaceae) is the common dicotyledonous weed competing for maize crop, vegetables and orchards; while *Echinochloa crus-galli* (family: Poaceae) is considered the worst monocotyledonous weed affecting rice cultivations. Twenty uniform seeds of each tested plant species were placed in separate Petri dishes (9 cm diameter) lined with two layers of filter papers and moistened with 10 ml aqueous extracts (root, stem, leaf, and fruit).

A control sample was assigned with sterile distilled water and left at room temperature (25 ^{o}C). Radical emergence was the criterion of germination. Germinated seeds were counted, removed daily and the final percentage of germination was calculated after 5 days of treatment. For seedling growth bioassay, fifteen uniform germinated seeds were transferred to Petri dishes, which lined with two layers of filter papers; and 10 ml of each aqueous tested extract (2%, 4%, 6%, 8%, and 10% w/v) was added. In addition, a control sample was added to the experiment without any treatment. The shoot and root lengths of the seedlings were measured after 15 days of treatment. The experimental design was carried out as a completely randomized design with 3 replications and was repeated twice (Rice, 1984).

Phytochemical analyses of *I. carnea*

The total phenolic contents of the root, stem, leaf and fruit extracts were determined spectrophotometrically (Sadasivam and Manickam, 2008), tannins were determined using the method of Van Burden and Robinson (1969). Flavonoids were estimated according to Böhm and Kocipai-Abyazan (1994), while alkaloids were determined according to Harborne (1973).

Statistical analysis

Two-way analysis of variance ANOVA were used to evaluate the effect of *I. carnea* invasion on soil chemical properties and also to assess the impact of *I. carnea* organs and extract concentration on final germination percentage and seedling growth of the two assayed weed plants. The significance between mean values was determined on the basis of LSD at the 0.05 probability level using the COSTAT 6.3 program.

RESULTS

Effect of *I. carnea* on species diversity

The data collected from 40 stands in the studied sites, exhibited a low plant species number (27 species) of the invaded stands with *I. carnea* compared with uninvaded ones (50 species) (Table 1).

Similarly, species richness and evenness were lower in the invaded stands than the uninvaded ones. Furthermore, the common associated species within *I. carnea* are *Cynodon dactylon* (P%= 72.5%) and *Phragmites australis* (P%= 67.5%).

Effect of *I. carnea* on soil chemical characters

Two-way ANOVA analysis of the measured values of pH, EC, organic C, Cl, SO_4, HCO_3, P, N, Na, K, Ca and Mg indicated the significant effects of *I. carnea* invasion on sulphates, phosphorus and sodium ($P \leq 0.05$). Moreover, the measured values of pH, EC, organic carbon, Cl, HCO_3, N, K, Ca and Mg were lowered beneath the canopy of *I. carnea* as compared with the outside *I. carnea* canopy (Table 2).

Effect of aqueous extracts of *I. carnea* on seed germination and seedling growth of *P. oleracea* and *E. crus-galli*

All aqueous extracts of *I. carnea* significantly ($P \leq 0.05$) inhibited the seed germination of *P. oleracea* and *E. crus-galli* after 5 days of treatment (Table 3). The aqueous extracts of *I. carnea* either low and high concentrations showed significant reduction ($P \leq 0.05$) in root and shoot growth of the tested species (Table 3). While, similar concentration of extracts showed noticeable inhibitory effect on the root length than shoot growth.

Interestingly, comparison of similar concentrations of the aqueous extracts of root, stem, leaf and fruit on germination percentage of the tested species revealed that the leaf aqueous extract was the most effective one. It completely inhibited the germination of *P. oleracea* at the concentrations 6, 8 and 10 gl^{-1}, and at concentration of 10 gl^{-1} for *E. crus-galli*, where seed germination of *P. oleracea* was more sensitive than that of *E. crus-galli*. At 10 gl^{-1} aqueous leaf extract, the shoot length of *P. oleracea* was reduced by 63.6% while that of *E. crus-galli* was reduced by 48%. The same concentration reduced the root lengths of *P. oleracea* and *E. crus-galli* by 53.4% and 69.4% respectively.

Bioactive chemical compounds of *I. carnea*

The data presented in Table (4) show that the leaf extract of *I. carnea* contained the highest values of phenol contents, flavonoids, tannins and alkaloids, while stem extract showed the lowest contents of these compounds. The lowest value of alkaloids (24.3 mg g^{-1} dry weight) was measured in fruit extract. Phenol contents ranged from 63.5 to 110.2 mg g^{-1} dry weight, flavonoids increased from 7.6 to 39.1 mg g^{-1} dry weight, while tannins varied from 20.3 to 39.3 mg g^{-1} dry weight.

Table (1): Presence percentage of the species in the invaded and uninvaded stands (out of a total 40 stands). Species richness and species evenness are indicated.* A= annuals, B=biennials, P= perennials.

Species	Life span*	Presence (%)	
		Invaded stands	Uninvaded stands
Amaranthus lividus L.	A	10	20
Arundo donax L.	P	5	22.5
Bassia indica (Wight) A.J.Scott	A	2.5	2.5
Chenopodium murale L.	A	32.5	42.5
Cichorium endivia L.	A	2.5	5
Convolvulus arvensis L.	P	7.5	17.5
Cynodon dactylon (L.) Pers.	P	72.5	82.5
*Cyperus alopecuroides*Rottb.	P	12.5	25
Cyperus rotundus L.	P	20	27.5
Echinochloa colona (L.) Link	A	7.5	22.5
Echinochloa stagnina (Retz.) P. Beauv.	P	10	22.5
Eclipta prostrata (L.) L.	A	35	42.5
Imperata cylindrica (L.) Raeusch.	P	15	27.5
Cyperus difformis L.	A	10	10
Leersia hexandra Sw.	P	5	20
Malva parviflora L.	A	30	42.5
Mentha longifolia (L.) Huds.	P	5	25
Persicaria salicifolia Brouss. exWilld.	P	17.5	45
Phragmites australis (Cuv.) Trin. Ex Steud.	P	67.5	87.5
Plantago major L.	P	5	15
Pluchea dioscoridis (L.) DC.	P	22.5	27.5
Portulaca oleracea L.	A	5	20
Rumex dentatus L.	A	42.5	47.5
Sesbania sericea (Willd.) Link	A	2.5	5
Solanum nigrum L.	A	5	7.5
Sonchus oleraceus L.	A	7.5	17.5
Symphyotrichum squamatum (Spreng.) Nesom	P	7.5	10
Alternanthera sessilis (L.) DC.	P	0.0	2.5
Atriplex halimus L.	P	0.0	5
Avena fatua L.	A	0.0	2.5
Beta vulgaris L.	B	0.0	12.5
Bidens pilosa L.	A	0.0	10
Chenopodium album L.	A	0.0	7.5
Conyza bonariensis (L.) Cronquist	A	0.0	15
Cynanchum acutum L.	P	0.0	10
Cyperus laevigatus L.	P	0.0	2.5
Echinochloa crus-galli (L.) P. Beauv.	A	0.0	5
Euphorbia peplus L.	A	0.0	7.5
Lactuca serriola L.	A	0.0	10
Lotus creticus L.	P	0.0	2.5
Lotus glaber Mill.	P	0.0	5
Melilotus indicus (L.) All.	A	0.0	7.5
Panicum repens L.	P	0.0	5
Paspalidium geminatum (Forssk.) Stapf.	P	0.0	30
Saccharum spontaneum L.	P	0.0	12.5
Sisymbrium irio L.	A	0.0	15
Stellaria pallida (Dumort.) Murb.	A	0.0	12.5
Torilis arvensis (Huds.) Link	A	0.0	5
Typha domingensis (Pers.) Poir ex Steud.	P	0.0	12.5
Urospermum picroides (L.) F.W. Schmidt	A	0.0	2.5
Number of species		27	50
Species richness		0.905	0.940
Species evenness		0.813	0.861

Table (2): Effect of *I. carnea* on soil chemical properties (Mean value± standard error) in invaded and uninvaded stands.

Soil parameter		Invaded stands	Uninvaded stands
pH		7.22±0.12	7.56±0.28
EC (mmhos/cm)		2.07±0.28	3.38±1.31
$CaCO_3$ (%)		7.5± 1.58	7.5± 0.67
Organic carbon (%)		1.08±0.21	1.34±0.32
Cl^- (%)		0.35±0.15	0.39±0.11
SO_4^{--} (%)		0.73±0.19*	1.54±0.14
HCO_3^- (%)		0.25± 0.07	0.29± 0.08
Total phosphorus	**mg/100 g dry soil**	4.20±1.08*	9.84±1.48
Total nitrogen		141.79±4.86	150.06±8.36
Na^+		39.48±0.73*	65.07±1.00
K^+		1.70±0.16	2.57±0.74
Ca^{++}		26.72±3.52	32.27±3.95
Mg^{++}		27.13±2.69	40.32±6.05

* Significantly different at 0.05 level.

Table (3): Effect of aqueous extracts of *I. carnea* organs (root, stem, leaf and fruit) on the germination percentage after 5 days and seedling growth (mm) after 15 days of the tested species. Data are mean values± standard error of three replicates; different superscripts in a column indicate significant difference at P≤0.05 as compared to control.

Treatment	Extract concentration (gl^{-1})	*Portulaca oleracea*			*Echinochloa crus-galli*		
		Germination (%)	Shoot length (mm)	Root length (mm)	Germination (%)	Shoot length (mm)	Root length (mm)
Control	0	91.7^{a}±1.7	24.4^{a}±0.2	16.8^{a}±0.3	87.7^{a}±1.5	34.6^{a}±0.1	32.3^{a}±0.1
Root extract	2	71.7^{bc}±1.2	17.5^{cd}±1	12^{bcdef}±0.6	65^{c}±1.1	33.7^{ab}±0.4	23.7^{bc}±0.2
	4	63.3^{cde}±0.7	12.6^{fgh}±1.3	11.3^{defgh}±0.9	50.0^{e}±0.6	32.1^{bc}±0.7	21^{defgh}±0.6
	6	58.7^{de}±0 7	12^{ghi}±1.5	10.7^{fghi}±0.9	43.3^{ef}±0.7	31.5^{bcd}±0.5	20.9^{defgh}±0.9
	8	45^{gh}±0.6	11^{ghij} ±1	10^{ghi}±1.2	31.7^{gh}±0.9	30.6^{cde}±0.5	19^{hi}±1.5
	10	36.7^{h}±0.3	10.3^{hij}±0.3	9.8^{hi}±0.2	21.7^{hij}±0.3	24.7^{h}±0.4	17^{j}±1
Stem extract	2	78.3^{b}±0.9	20.4^{b}±0.4	13.8^{b}±1.4	80^{ab}± 0.6	33.7^{ab}±0.2	24.1^{b}±0.1
	4	73.3^{bc}±0.7	18.8^{bc}±0.9	13.3^{bc}±0.8	75^{b}±0.6	32.8^{abc}±0.2	22.3^{bcde}±1.3
	6	65^{cde}±1.1	16.8^{cde}±0.2	13.1^{bcd}±0.2	51.7^{de}±0.3	32.2^{bc}±0.7	21.8^{cdef}±0.4
	8	55^{efg}±0.6	16^{de}±0.6	11.6^{cdefgh}±0.2	41.7^{ef}±0.3	28.6^{ef}±1.3	21.3^{defg}±0.4
	10	41.7^{h}±0.9	13.3^{fg}±1.3	9.9^{hi}±1	38.3^{fg}±0.7	26.1^{gh}±1.2	20.2^{fgh}±0.1
Leaf extract	2	38.3^{h}±0.3	17.3^{cd}±0.4	13.4^{bc}±0.7	51.7^{de}±0.9	29.5^{def}±0.8	23.4^{bc}±1.4
	4	10^{i}±0.6	16.7^{cde} ±1.8	12.1^{bcdef}±0.6	30^{ghi}±0.6	24.2^{h}±1.7	22.8^{bcd}±0.4
	6	0^{i}	15.7^{de}±0.4	11.7^{cdefgh}±0.4	21.7^{hij}±0.3	20.3^{i}±0.9	17.2^{ij}±0.5
	8	0^{i}	13.2^{fg}±0.6	11^{efgh}±0.3	15^{j}±0.6	19.9^{ij}±0.4	10.5^{l}±0.3
	10	0^{i}	8.9^{j}±0.3	7.8^{j}±0.4	0^{k}	18^{j}±0.3	9.9^{l}±0.4
Fruit extract	2	68.3^{bcd}±0.9	18.9^{bc}±0.4	13.1^{bcd}±1	60^{cd}±0.6	32.8^{abc}±0.4	23.9^{bc}±0.4
	4	56.7^{ef}±1.2	17.8^{cd}±0.4	12.9^{bcde}±0.5	48.3^{e}±0.3	31.7^{bcd}±1	20.5^{efgh}±0.4
	6	46.7^{fgh}±0.9	14.8^{ef}±0.4	12.3^{bcdef}±0.1	28.3^{hi}±0.3	27.6^{fg}±0.4	19.7^{gh}±0.4
	8	8.3^{i}±0.9	11.2^{ghij}±0.3	11.9^{bcdefg}±0.28	25^{hi}±0.6	24.6^{h}±0.6	13.2^{k}±1
	10	6.7^{i}±0.3	9.9^{ij}±0.3	9^{ij}±0.3	20^{ij}±1.2	20.5^{i}±0.5	10.6^{l}±0.3
$LSD_{0.05}$		10.3	2.3	1.9	8.9	2.1	2.1

Table (4): Bioactive chemical constituents (secondary metabolites) of *I. carnea*

Plant organ	Phenolics	Flavonoids	Tannins	Alkaloids
	concentration (mg g^{-1} dry weight plant material)			
Root	70.5±0.5	7.8±0.5	22.6±0.8	41.9±0.8
Stem	63.5±1	7.6±0.7	20.3±0.4	38.4±0.4
Leaf	110.2±0.8	39.1±0.3	39.3±0.5	50.5±0.7
Fruit	79.2±1.4	12.3±0.5	30.7±0.3	24.3±0.6

Discussion

Biological invasion of alien plants is considered one of the most serious threats to the native biological diversity, habitat destruction, pollution and climate change (Millennium Ecosystem Assessment, 2005**)**. In Egypt, the introduced invasive species *I. carnea* Jacq. becomes in pure and/or mixed stands with poor associates along banks of canals and drains forming a dense above ground mass and dominating the other woody and herbaceous native plants.

The results of this study emphasized the potential threat of *I. carnea* invasion on plant diversity and certain soil chemical properties along the banks of canals and drains in the Nile Delta. *I. carnea* causes a negative impact on species richness, evenness and total number of associated species beneath, as compared with uninvaded stands. This negative impact was due to the dominance of *I. carnea* in the studied sites, where it greatly nullified the abilities of native plant community and/or individuals to compete with it. This dominance and presence of pure population of *I. carnea* could lie in high rate of reproduction both vegetatively and/or by seeds, rapid growth rate, quick spread and adaptability for the local habitats, unpalatability to livestock and its wide ecological amplitude (Shaltout *et al*., 2010), and also its high competitive ability and high contents of some inhibitory chemicals that affect the growth of associated species (Bhalerao, 2010b). The rapid spread of *I. carnea* indicates a successful invasion capability (Chaudhuri *et al*., 1994). Other studies also reported that, the successful invasion of alien plants could lie in either, effectively capture available resources (water, nutrients and light) (MacArthur, 1970), rapid growth and reproduction to form pure population with large individuals (Hierro *et al*., 2005), modifying the invaded environment through production of allelochemicals as a novel weapons to increase their competitive ability (Bais *et al*., 2003) or have resistance to generalist enemies as insects, fungi or viruses (Keane and Crawley, 2002).

The present study demonstrated that, the highly growth and dense mass of the invasive *I. carnea* have modified its environment in several ways. It significantly lowered the soil pH, the amount of sulphates, total dissolved phosphorus and sodium and hence the nutrient availability to the native plant community. These findings coincided with those results obtained by Callaway and Aschehoug (2000)**,** and Drenovsky and Batten, (2007). They reported that, some invasive species, in addition to production of allelochemicals, can also lower soil pH and alter nutrient cycling and lead to decreased native plant growth, particularly in nutrient poor sites. Collins and Jose (2008) also reported that *Imperata cylindrica* decreased soil pH in recently invaded areas in the southeastern U.S *Pinus* forests. In this study, within *I. carnea* community, two perennial associated grasses: *Cynodon dactylon* and *Phragmites australis* showed the highest presence with regard to the total associated species. Orcutt (2000) attributed the coexistence of some plants with the invasive species to their abilities to tolerate the allelochemicals released by invasive species by reduction the root uptake of allelochemicals, detoxification and compartmentalization of allelochemicals away from the target position into depository sites and their excretion. Generally, alien and invasive species are the major cause of declining abundance and plant diversity. Therefore, determining the mechanism through which these plants are became invasive could help in the control/ management of these species and also provide insight into organization and interaction of the plant species in specific communities spatially and temporally (Jarchow and Cook, 2009). Several studies have suggested that allelopathy might contribute to the ability of particular exotic species to become dominant in invaded plant communities (Callaway and Ridenour, 2004).

The present results demonstrated that the root, stem, leaf and fruit of *I. carnea* extracted in water have inhibitory effects upon seed germination and seedlings growth of the tested species, *P. oleracea* and *E. crus-galli*. These results agree with Bhalerao (2010a) who investigated the allelopathic potential of *Ipomoea carnea* on *Xanthium strumarium*. The basis for inhibitory action of *I. carnea* may be the role of specific chemicals alone or in combination. The allelopathic compounds were designated bioactive chemical or allelochemicals (Blum, 2011; Cheema *et al*., 2012). The phytochemical analysis of *I. carnea* revealed the presence of several classes of these allelochemicals such as phenolic compounds, flavonoids, tannins and alkaloids. However, different investigators have reported the presence of extra chemicals such as glycosides, the nortropane alkaloids calystegines and indolizidine alkaloid swainsonine in *I. carnea* extracts (Afifi *et al*., 1995 and Haraguchi *et al*., 2003). Other studies have reported the presence of hexadecanoic acid, stearic acid, 1,2 diethyl phthalate, n-octadecanol, octacosane,hexatriacontane, tetracontane and 3-diethyl amino-1- propanol in leaf of *I. carnea* (Tirkey *et al*., 1988; Vaishali *et al*., 2009).

Despite of the long list of allelochemicals of *I. carnea* , Li *et al*., (2010) stressed the importance of only the phenolic compounds as the most important for all of them affecting the ecosystem. As phenolics and flavonoids have been reported to be not only be essential for the normal growth and reproduction of plants, but also plays significant role in plant's defense system against infection, injury and stress conditions **(**Kähkönen *et al*., 1999).

In laboratory settings, the inhibitory effects of *I. carnea* extracts followed a gradient: leaf > fruit > root >stem. Also, the degree of inhibition was dependent on the concentration of extracts. The aqueous leaf extract (10 gl^{-1}) was the most potent inhibitor of seed germination and seedling growth of the assayed species. The high allelopathic activity of leaf extract may be attributed to the presence of many inhibitory bioactive secondary metabolites in higher concentration compared to fruit, root and stem extracts as shown in the results.

From the present results, it is obvious that the inhibitory effects of *I. carnea* are species specific and

vary with plant organ used in extraction as well as extract concentration. The probable reason for the significant inhibition caused by fruit, root and stem extracts on seed germination and seedling growth of the tested species may be explained by their content of bioactive compounds, particularly phenolics, flavonoids, tannins and alkaloids.

In conclusion, *I. carnea* currently dominates the plant communities and forms a characteristic population along the canal and drain banks in Nile Delta of Egypt. It existed in pure population and eliminated all wild plants associates. Its successful invasion and attainment of pure population is mainly due to its allelopathic effect coupled with its competitive for soil nutrients. Therefore, to encourage the reemergence of natural biodiversity a changes in habitat conditions must be exercised through a management strategy. This strategy must be focused on eliminating the population of *I. carnea* from the canal and drain banks for prevention of biodiversity loss and changes in ecosystem function and services. This would be in accordance of the strong warning issued by Sharma and Bachheti (2013). They stated that, plant invasion is considered as the second most important threat to biodiversity after habitat destruction.

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