



Full Length Article

Demography of *Ipomoea carnea*: An Invasive Species in the Nile Delta, Egypt

YASSIN M. AL-SODANY¹, KAMAL H. SHALTOUT† AND EBRAHIM M. EID

Biological and Geological Sciences Department, Faculty of Education, Kafr El-Sheikh University, Kafr El-Sheikh, Egypt

†Botany Department, Faculty of Science, Tanta University, Tanta, Egypt

¹Corresponding author's e-mail: yalsodany@yahoo.com

ABSTRACT

Ipomoea carnea was introduced to Egypt for ornamental purpose. It naturalized as a species along canals and drains, road sides, railways, waste lands and field edges in the Nile Delta. The rapid growth rate, spread and adaptability from aquatic to xerophytic habitats indicate that this invasive plant may potentially become another ecological disaster like water hyacinth. The present work monitored the demography of *I. carnea* populations at two locations in Nile Delta in terms of size structure (natality, mortality, survival & demographic flux) and assessed its standing crop and the correlation between its population characters and the prevailing environmental variables. Fifty permanent stands were established to represent the microvariations in seven habitats, where *I. carnea* occurs at both locations. The height from the ground and average diameter of the canopy for each permanent marked ramet (4355 ramets) were estimated monthly and its volume was calculated as a cylinder. The results revealed that sexual propagation of *I. carnea* from seeds is less common than vegetative propagation from decumbent branches. The variation in population natality varied in relation to habitat and time. *I. carnea* sprouts suffered relatively higher mortality rates than adult plants, indicating the sensitivity of the sprouts to temporal variation in some environmental factors. Months of July and January indicated negative values of demographic flux as a result of the increasing mortality and decreasing natality. In contrast, June had maximum value as no sprout and adult mortalities was noted in this month. The size distribution of *I. carnea* populations had negative skewed shape, where the big individuals (i.e., mature) exceeded the small ones (i.e., juveniles). The biomass of *I. carnea* was higher than the other species in the same habitats in the Nile Delta.

Key Words: Size structure; Biomass; Natality; Mortality; Invasive plants; Demographic flux

INTRODUCTION

Many studies on plant invasion have focused on the life history traits responsible for the invasive nature of a species (Roy, 1990; Rejmánek & Richardson, 1996). Others have examined the invasibility of habitats and communities (Lonsdale, 1999; Levine & D'Antonio, 1999). Several reports have hypothesized that successful establishment of an alien species depends on complex interactions between the species and its target community, so that biological invasions are context-specific processes (Thébaud *et al.*, 1996; Levine, 2000; Alpert *et al.*, 2000). The previous theory implies that small differences in life-history traits of certain species, such as germination, establishment ability, length of the juvenile period (Rejmánek & Richardson, 1996; Dietz *et al.*, 1999) and competitive ability (Thébaud *et al.*, 1996), may interact with habitat characteristics to produce distinct distribution and abundance patterns over a new range. Considerable evidence shows that the emergence and establishment of plant invaders are generally favored when communities are subject to disturbance

(Crawley, 1986, 1987; Burke & Grime, 1996). Moreover, disturbance can produce nutrient enrichment or a release of resources in the disturbed habitat, thus favoring the proliferation of the invading species (Davis & Pelsor, 2001). Most exotic species grow in disturbed and nutrient rich ecosystems (Fox & Fox, 1986; Hobbs & Huenneke, 1992; Meiners *et al.*, 2002).

Clonal plants are those that spread vegetatively by producing a number of similar functional units (such as shoots) that are potentially able to live on their own if physically separated from the parent plant. Such vegetative units are termed ramets, whereas the entire plant is termed genet. Clonal species can be found among vascular plants (Klimes *et al.*, 1997). The term 'genet' was originally defined for clonal vascular plants as the genetic individual that develops from a seed and that produces a number of ramets (Harper & White, 1974; Kays & Harper, 1974). More recently, the zygote was specifically defined as the initial cell of the genet (De Kroon & Van Groenendael, 1997; Andrews, 1998). In light of recent developments in plant genetics, there is a problem with the existing definition

of genet. Additionally, the current definition cannot be applied adequately to clonal bryophytes and seaweeds (Scrosati, 2002).

Size variation is a feature of virtually all wild plant populations (Weiner, 1990). Since fecundity is generally correlated with individual plant size, this variation can result in a few large plants of one generation contributing disproportionately to the next, with a consequent reduction in effective population size (Gottlieb, 1977). Size variation in plants is a result of the ecological process of competition, especially intraspecific competition for light and thus its potential influence upon effective population size forms a bridge between ecology and population genetics (Dodd & Sil Vertown, 2000).

Ipomoea carnea was introduced to Egypt for ornamental purpose (Afifi *et al.*, 1988). It was recorded as a naturalized species along canals and drains, road sides, railways, waste lands and field edges in the Nile Delta (Boulos, 1995; El-Sheikh, 1996; Al-Sodany, 1998). This plant propagates vegetatively by stems, which are capable of rooting within a few days. The farmers use it as ornamental and hedge plant along the banks of irrigation and drainage canals. The ornamental uses and reproduction by seeds often lead to increase the plant dissemination into new regions (Chaudhuri *et al.*, 1994). Recently, it is observed that this species becomes widely spread in other terrestrial habitats and may cause difficulties to many habitats in the Nile Delta. The rapid growth rate, spread and adaptability from aquatic to xerophytic habitats indicate that this invasive plant may potentially become ecological problem.

The present work aims to study the demography of *I. carnea* in different habitats in the Nile Delta in terms of size structure (natality, mortality, survival & demographic flux). It also aims at to assess its standing crop and the correlation between its population characters and the prevailing environmental conditions. This will help to understand the invasive ability of this species in different habitats, which enables monitoring and managing its populations in Egypt.

MATERIALS AND METHODS

Study area. The study area was a part of the Nile Delta, Egypt. It is bounded by the main tributaries of the Nile: Rosetta branch at the west and Damietta branch at the east, the Mediterranean Sea at the north and Menoufia Governorate at the South (Fig. 1). The area of the Nile Delta is about 22,000 km² compared with 13,000 km² for the Valley area. It comprises about 63% of Egypt's productive agricultural area. The surface of the Nile Delta in the south is relatively smoother than that in the north. This may be due to long time absence of agriculture in the north. This has permitted the old branches of the Nile Delta to run freely over the surface, building natural levees and dikes. The region of the mid-Delta slopes, generally from east to west, makes the level of the Damietta branch higher than that of

the Rosetta branch by two meters (Abu Al-Izz, 1971).

The Nile Delta is like the Mediterranean climatic zone. According to global map of the world distribution of arid regions (UNESCO, 1977) the north of the Nile Delta lies in an arid region, while the southern part lies in the hyper-arid region. The climatic conditions are warm summer (20 to 30°C) and mild winter with mean temperature above 10°C. Days are mostly sunny and dry. The annual mean of air temperature decreases from 20.7°C at north (Baltim) to 19.9°C at south (Tanta). The relative humidity decreases in the same direction from 69 to 65%. There is an obvious gradient in the average daily evaporation from north of the study area at Baltim (4.6 mm day⁻¹) to its south at Tanta (6.8 mm day⁻¹). This is associated with an inverse gradient of annual precipitation, which indicates the increase of aridity from north to south. Monthly rainfall varies between 14.6 mm month⁻¹ at Baltim and 4.6 mm month⁻¹ at Tanta. The wind speed varies between 23.8 km h⁻¹ at Baltim and 10.4 km h⁻¹ at Sakha (Anonymous, 1980).

Demography and population structure. Fifty permanent stands were established to represent the microvariations in seven habitats, where *I. carnea* occurs in El-Gharbieya and Kafr El-Sheikh Governorates. The height from the ground (H) and average diameter (D) of the canopy (based on three measures) for each permanent marked ramet (4355 ramets) were estimated monthly and its volume was calculated as a cylinder: volume = $\pi r^2 H$ (r. radius & H. height of the ramet). Because the ratio of height to diameter varies from one habitat to another the estimation of ramet volume using both variables seems to be the best for expressing the shrub size (Shaltout & Ayyad, 1990). The volume estimates were then used to classify the population in each habitat into 7 size classes. The absolute and relative frequencies of ramets and mean height and diameter per ramet in each size class were calculated. Ten randomly distributed quadrates (1 m × 2 m) were laid down in each stand at the end of the calendar year. The number of *I. carnea* ramets in each quadrate was counted and used to calculate its density per stand (ramets m⁻²).

At the start of the taking observation, a map was drawn indicating the spatial distribution of *I. carnea* ramets in each stand. Each month the emerged sprouts were recorded in each stand and added to the map. The means of sprout natality (the percentage of new sprouts in relation to the total number of sprouts), mortality (the percentage of dead sprouts in relation to the total number of sprouts) and survival (the number of sprouts present at the end of the month as a percent of the total number of sprouts) were determined monthly.

At the end of the calendar year, the new successfully established sprouts for each habitat were considered as input to its population. This was referred to as the annual population natality. The annual mortality of the different ramets was also determined. The estimation of annual change or demographic flux (Fr) occurring in *I. carnea* population was calculated according to Peter (1980) (cf.

Shaltout & El-Beheiry, 1991) as: $Fr = (N - M)/(N + M) = \text{change/flux}$ [N. the number of established individual ramets (natality) and M. number of dead individual ramets (mortality) in the permanent stands during the year of study]. The increase/decrease ratio (demographic flux: Fr) varied from 1.0 when there was no mortality, to -1.0 when there was no natality and 0.0 value when mortality and natality are equal.

At the end of the calendar year, three randomly marked individual ramets were harvested in each stand and their stems and leaves were separated and weighted to determine their fresh weight. The stems and leaves were oven dried at 60°C for 3 days to determine the dry weight. Mean of the fresh and dry weights of the stems, leaves and shoot of the ramets of each habitat were determined (gm ramet^{-1}) and multiplied by the number of ramet m^{-2} in the corresponding habitat to give their standing crop (kg m^{-2}) in that habitat (Shaltout & Ayyad, 1988).

Soil analysis. In each stand, a composite soil sample was collected as a profile from three holes each of 50 cm depth, air dried and passed through a 2 mm sieve to separate gravel and debris. Soil water extracts at 1:5 ratio were prepared for the determination of electric conductivity (EC: mS cm^{-1}) and soil pH. Chlorides were estimated by direct titration against silver nitrate using 5% potassium chromate as indicator (Ryan *et al.*, 2001). Sulphates were determined using the gravimetric with ignition of residue method, where sulphates were precipitated in 1% HCl solution as barium sulphate (Ryan *et al.*, 2001). Soil texture analysis was carried using the Bouyoucos hydrometer method, whereby the percentage of sand, silt and clay were determined. Calcium carbonate was estimated using Bernard's calcimeter. Total organic matter was determined by loss-on-ignition at 450-500°C for 2 h. Glacial acetic acid (2.5% v/v) was used for the extraction of K, Mn, Na, Fe and P. Semi-micro Kjeldahl apparatus was used for total nitrogen determination. Atomic absorption was used for the determination of Mn and Fe. Estimation of Na and K was carried out by flame photometer. Molybdenum blue and indo-phenol blue methods were applied for the determination of P and N, respectively using a spectrophotometer (Jackson 1960; Allen *et al.*, 1974; Bear, 1975).

Statistics. Simple linear correlation coefficient was calculated between the population and environmental variables in order to assess their relationships. Regression was calculated to predict the relationship between ramet height and diameter and between the flower and fruit production. SAS software was used to achieve the previous statistics (SAS, 1989).

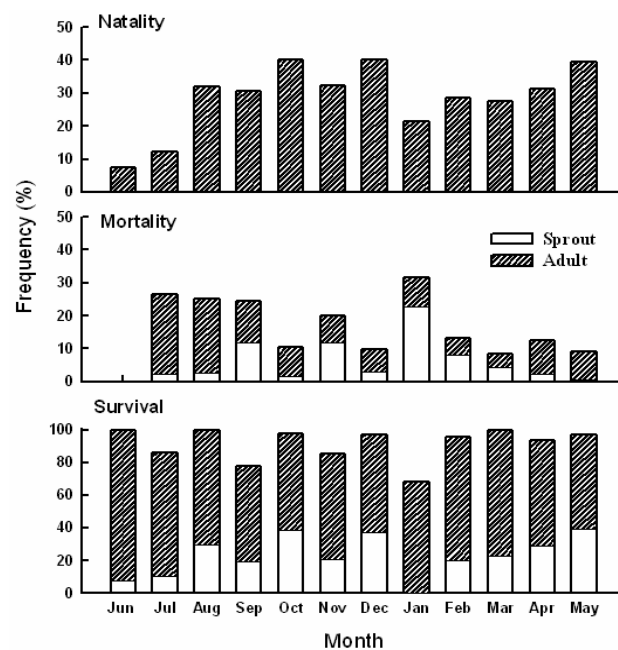
RESULTS

December, October and May had the maximum monthly natality (40.2, 40.0 & 39.6%, respectively), while June had the lowest (7.4%) (Fig. 2). The habitat variation

Fig. 1. Map of the Nile Delta showing the study area (El-Gharbiya & Kafr El-Sheikh Governorates) and its boundaries



Fig. 2. Monthly variation in the natality, mortality and survival of *Ipomoea carnea* populations in Nile Delta



(Fig. 3) indicated that the waste lands had the maximum natality (52.6%), while the road sides and drain banks had the lowest (0.3 & 0.4%, respectively). For sprout mortality, January had the highest (22.7%), while May had the lowest (0.7%). On the other hand the field edges had the highest sprout mortality (12.5%), while drain banks and road sides had the lowest (0.4 & 0.3%, respectively). Adult mortality had the maximum value in July and August (24.3 & 22.5%, respectively) with no adult mortality observed in June. The drain banks had the maximum adult mortality (30.4%), while the road dividers had the lowest (2.1%). The variation in the population mortality expressed as a percentage of all *I. carnea* ramets (including the adults & new established

sprouts) varied per habitat and time. The population of field edges, drain banks and road sides suffered the highest mortality (30.8, 30.7 & 23.7%, respectively), while the road dividers experienced the lowest (10.6%). The monthly variation was the highest during January (31.8%), while no mortality occurred during June (Figs. 2 & 3).

The maximum sprout survival was in December, October and May (37.3, 38.5 & 38.9%, respectively), while the minimum in June and July (Fig. 2). The maximum adult survival was in June (92.7%) and the minimum was in September and May (59.0 & 58.0%, respectively). July and January had negative values of demographic flux as a result of the increasing mortality and decreasing natality, while June had the maximum value as it was the only month with no sprout and adult mortalities (Fig. 4).

The size-class frequency distributions of *I. carnea* population in almost all habitats approximated the negative skewed shape towards the relative preponderance of the big ramets. On an average, the biggest three size classes contributed 51.6% of the total ramets comparing with 21.1% for the smallest three ones. Along the road sides, the biggest three size classes contributed 75.1% comparing with 6.7% for the smallest three classes, while in the field edges they contributed 42.3% comparing with 35.3% for the smallest three ones (Fig. 5).

The ramet height in each-size class varied between 43.8 cm ramet⁻¹ for the smallest class and 303.0 cm ramet⁻¹ for the biggest class (Table I). In general, there was a continuous increase in the diameter with the increase of size class it ranged from 3.1 to 87.6 cm ramet⁻¹ with a mean of 35.3±21.1 cm ramet⁻¹. In contrast, the height to diameter ratio had a continuous decrease from 31.1 in the smallest class to 3.7 in the largest class.

The stem and leaf dry weight of ramet, were 98.8 and 31.1 g ramet⁻¹, respectively (Table II). The canal banks and road dividers had the highest dry stem weight (155.3 & 152.9 g ramet⁻¹), while the field edges had the lowest (36.0 g ramet⁻¹). The drain banks and road sides had the highest dry leaf weight (42.0 & 39.4 g ramet⁻¹), while the railway sides and waste lands had the lowest (20.5 & 16.1 g ramet⁻¹). Regarding the variation in the ramet density, the railway sides and road sides had the highest values (32.8 & 32.6 ramet m⁻²), while field edges the lowest (23.4 ramet m⁻²). On the other hand, the canal banks and road dividers had the highest biomass (5.76 & 5.54 kg m⁻²), while the field edges the lowest (1.49 kg m⁻²) (Table II).

Soils of railway sides had the highest value of sodium (63.6 mg 100 g⁻¹) but were lowest in organic matter (5.6%), P (7.1 mg 100 g⁻¹), Fe (9.3 mg 100 g⁻¹) and Mn (34.3 mg 100 g⁻¹). The soil of waste lands had the highest percentage of clay (6.0%), silt (15.9%) and P (19.5 mg 100 g⁻¹) and the lowest of sand (78.1%) and Na (26.9 mg 100 g⁻¹). The road sides had the highest of pH (8.3), calcium carbonate (5.7%) and Fe (53.1 mg 100 g⁻¹) and the lowest of clay content (3.9%). The soil of canal banks had the highest of N (320.6 mg 100 g⁻¹) and the lowest of K (10.1 mg 100 g⁻¹). The road

Fig. 3. Habitat variation in the annual natality and mortality of *Ipomoea carnea* populations in Nile Delta, RW: railway sides, WL: waste lands, RS: road sides, CB: canal banks, RD: road dividers, FE: field edges and DB: drain banks

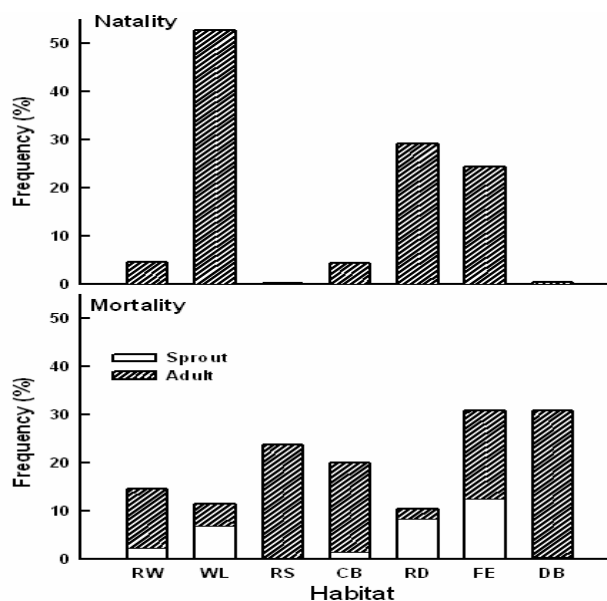
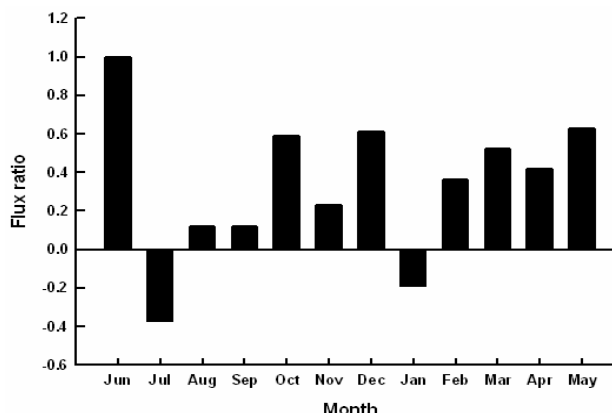


Fig. 4. Monthly change in demographic flux (Fr) of *Ipomoea carnea* populations in Nile Delta



dividers had the highest of EC (5.1 mS cm⁻¹), sand (83.9%), organic matter (17.4%), Cl (753.7 mg 100 g⁻¹), sulphates (336.8 mg 100 g⁻¹), K (31.7 mg 100 g⁻¹) and Mn (90.1 mg 100 g⁻¹), but the lowest N (142.3 mg 100 g⁻¹). Soil of drain banks had the lowest of silt (11.2%) and calcium carbonate (1.6%) (Table III).

DISCUSSION

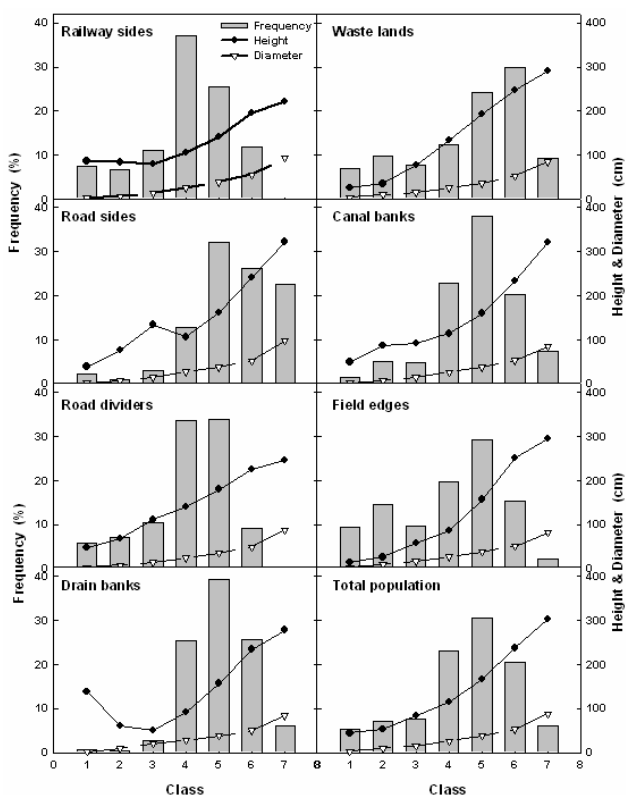
The present study indicated that the sexual propagation of *I. carnea* from seeds is less common, than the vegetative propagation from the decumbent branches. This may be a strategy for avoiding intraspecific competition, which is from findings of Hartnett and Bazzaz

Table I. Mean of the ramet variables of the different size classes of *Ipomoea carnea* population in Nile Delta

Size class	Height (cm ramet ⁻¹)	Diameter (cm ramet ⁻¹)	H/D	Size index (cm ramet ⁻¹)	Volume (dm ³)
1	43.8	3.1	30.1	23.4	0.2
2	52.0	8.7	12.5	30.3	2.1
3	82.8	15.2	7.7	49.0	11.6
4	113.7	25.9	5.1	69.8	56.6
5	166.5	37.5	4.7	102.0	180.8
6	236.6	52.6	4.7	144.6	513.4
7	303.0	87.6	3.7	195.3	1921.4
Mean ± SD	155.7±88.8	35.3±21.1	6.8±13.5	95.5±51.8	288.6±540.0
F-Value	1126.6	4178.4	161.3	1987.9	1534.5

The size classes are coded as follows: 1: < 0.5, 2: 0.5–5, 3: 5–20, 4: 20–100, 5: 100–300, 6: 300–1000, 7: >1000 dm³. All F-Values are significant at P ≤ 0.0001

Fig. 5. Size-class frequency distribution of *Ipomoea carnea* populations in Nile Delta, The range of size classes are: 1: < 0.5, 2: 0.5-5, 3: 5–20, 4: 20-100, 5: 100-300, 6: 300-1000 and 7: > 100 dm³



(1985) who supported our interpretation, as they report that interconnected ramets of golden-rod (*Solidago canadensis*) were less affected by intraspecific competition at high density than individual shoots grown from seeds. This could be interpreted in the view that the connected shoots possessed a stolon, which contained stored assimilates unavailable for the single shoots. Storage allows a clone to fairly tide over the adverse conditions (Silvertown & Franco, 1993).

The spatial structure and distribution of clones is

influenced by the efficiency of seed dispersal and the subsequent seed recruitment. The spatial structure of clones is also influenced by the dynamics of ramets. Lovett Doust (1981) distinguished the phalanx and the guerilla growth forms in clonal plants. In typical phalanx species, the ramets of a clone are closely aggregated and clones are juxtaposed. In typical guerilla species, the ramets of a clone are loosely associated and clones can be more intermingled. However, most clonal species have a growth form that falls between these two extreme types. The general characteristics and size structure of *I. carnea* in the present study indicated that this species was characterized by a typical phalanx growth form, where its ramets belonging to the same clone tended to be closely aggregated and clones formed distinct clumps (Lovett Doust, 1981). This clonal propagation results in population structuring at the ramet level. According to theoretical prediction (Charpentier, 2002) the species with the larger clones and the more phalanx growth form are expected to be the more selfing species because of a higher probability of geitonogamy (Albert *et al.*, 2005). This prediction holds for *I. carnea* that had the larger clones and more phalanx growth form and was the more selfing species.

The population dynamics and regeneration capacity of any plant species depends on a variety of biotic and abiotic factors (Shaltout, 1983). Gray (1975) reported that topography, age of the plants, relative abundance of the plants with a dense crown and broad leaves, frequency and abundance of rainfall are among the important variables to be accounted for in an attempt to quantify the regeneration capacity of species. In this study the variation in population natality varied in relation to habitat and time. The population of waste lands experienced the highest natality, which may be due to the excess of nutrients and organic matter that characterize this habitat compared with the others. Phosphorus content of the soil seemed to play an apparent a role in enhancing natality as the present study indicated positive correlation between both variables. *I. carnea* sprouts suffered relatively higher mortality rates than the adult plants, which may be due to sensitivity of the sprouts to the temporal variations in some environmental factors (e.g., temperature, moisture content). The possible cause of sprouts death is drought, as they had low ability to utilize moisture due to their shallow root system, shortage of nutrients, competition and pathogens (Augsburger & Kelly, 1984; Lonsdale & Abrecht, 1989). The population of field edges having the highest sprout and adult mortality can be explained by severe human impact such as agricultural practices, firing, cutting and trampling along field edges.

A relatively high change in the growth of *I. carnea* population in a certain habitat was a measure of what is going on the demographic flux. The demographic flux (Fr) had negative values during January and July, because mortality was higher than natality and reached a maximum value during May, June, October and December as a result of the increasing natality and decreasing mortality.

Table II. Mean of the density (ramet m⁻²), biomass (gm ramet⁻¹) and standing crop phytomass (kg m⁻²) of *Ipomoea carnea* population in Nile Delta

Habitat	Habitats							Mean±SD	F-value	
	RW	WL	RS	CB	RD	FE	DB			
Density (ramet m ⁻²)	32.8	30.9	32.6	30.0	29.4	23.4	28.4	29.6±3.0	2.17*	
Biomass (g ramet ⁻¹)	Stem	82.1	63.8	111.5	155.3	152.9	36.0	90.3	98.8±41.1	1.68
	Leaf	20.5	16.1	39.4	36.7	35.7	27.5	42.0	31.1±9.2	1.27
Standing crop phytomass (kg m ⁻²)	Shoot	102.6	79.9	150.9	192	188.6	63.5	132.3	130±46.9	1.82
	Stem	2.69	1.97	3.63	4.66	4.50	0.84	2.56	2.98±1.28	---
	Leaf	0.67	0.50	1.28	1.10	1.05	0.64	1.19	0.92±0.29	---
	Shoot	3.37	2.47	4.92	5.76	5.54	1.49	3.76	3.90±1.50	---

The habitat types are: RW: railway sides, WL: waste lands, RS: road sides, CB: canal banks, RD: road dividers, FE: field edges and DB: drain banks. *: P ≤ 0.05

Table III. Soil variables of the habitats supporting *Ipomoea carnea* populations in Nile Delta

Soil variable	Habitats							Mean±SD	F-value
	RW	WL	RS	CB	RD	FE	DB		
pH	8.1	7.9	8.3	8.2	8.0	8.1	7.7	8.0±0.3	5.6***
EC (mS cm ⁻¹)	1.7	2.1	1.6	0.5	5.1	3.6	2.1	2.0±1.9	5.3***
Clay	5.2	6.0	3.9	4.9	4.3	4.6	5.6	5.1±1.7	1.1
Silt	12.0	15.9	14.3	15.4	11.8	14.7	11.2	13.8±5.1	1.1
Sand	82.8	78.1	81.9	79.7	83.9	80.8	83.3	81.1±5.1	1.1
O.M.	5.6	14.2	15.5	13.6	17.4	15.2	15.6	13.9±4.6	5.1***
CaCO ₃	3.0	3.9	5.7	2.6	2.9	2.6	1.6	2.9±1.5	7.8***
P	7.1	19.5	13.0	7.2	19.4	9.7	11.0	11.3±8.4	3.0*
N	156.4	178.6	197.4	320.6	142.3	147.5	152.9	202.6±297.6	0.5
Cl	132.2	260.8	105.8	29.1	753.7	467.8	124.0	203.7±314.7	4.8***
SO ₄	224.6	266.2	193.1	55.5	336.8	238.5	306.9	210.7±166.1	4.1**
Na	63.6	26.9	53.8	27.5	59.7	41.8	59.3	44.1±24.4	4.5***
K	11.4	15.0	18.7	10.1	31.7	18.0	10.9	14.2±7.7	7.5***
Fe	9.3	17.1	53.1	19.1	16.2	33.3	18.0	22.1±19.3	3.6**
Mn	34.3	85.6	80.9	50.9	90.1	75.0	67.9	65.0±27.0	4.6***

The habitat types are: RW: railway sides, WL: waste lands, RS: road sides, CB: canal banks, RD: road dividers, FE: field edges and DB: drain banks. *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001

The structure of plant population can be assessed in terms of the ages, sizes and forms of the individuals that compose it (Harper & White, 1974; Lusk, 2003; Witt, 2004) and are functions of recruitment, growth and mortality (Baker & Wilson, 2003). Since fecundity and survival of plants is often much more closely related to size than age. Some authors have argued that it is better to classify the plant life history by size rather than age (Kirkpatrick, 1984; Caswell, 1986; Shaltout & Ayyad, 1988). Size differences in plant populations may be caused directly by differences in growth rates due to age difference, genetic variation, heterogeneity of resources, herbivory and competition (Harper, 1977; Weiner, 1985). Study of size variability is important for understanding not only the population structure but also the process and mechanism of interaction between individuals.

Size variability also plays an important role in evolutionary biology. The size distribution of an even-aged population of plants is a function of the distribution of initial sizes the distribution of relative growth rates and length of time the plants grow (Weiner & Thomas, 1985 & 1986). The size distribution of *I. carnea* populations as revealed from the present study had negative skewed shape, where the big (mature) individuals exceed the small (juveniles)

ones. This was because the large plants grew larger, while the small plants grew little and lead to un-equal size distribution. A negative skewness of the size distribution may also be the result of variation in the exponential growth rates due to interference or other factors.

Knowledge of biomass is essential in the study of nutrient cycling and biogeochemistry. The higher productivity of a community the greater the amount of biomass that is likely to accumulate (Lieth, 1975). Variations in the amount of biomass at different sites may be related to topography, soil permeability and fertility (Sharma, 1982). *I. carnea* population that inhabits the canal banks, road dividers and road sides attained the highest shoot standing crop per unit area, whereas the field edges had the lowest values. It is most likely that severe human disturbances along the field edges, such as agricultural practices, firing, cutting and trampling caused such findings. Comparing the biomass of *I. carnea* in the present study with that of other species in the same habitats in Nile Delta, it turns out that biomass of *I. carnea* (3.90 kg m⁻²) was higher than those of *Imperata cylindrica* (1.00 kg m⁻²), *Desmostachya bipinnata* (1.17 kg m⁻²), *Phragmites australis* (1.05 kg m⁻²), *Tamarix nilotica* (0.39 kg m⁻²), *Pluchea dioscoridis* (0.36 kg m⁻²) and *Bassia indica* (1.18

kg m⁻²). This can be attributed by cutting, firing or trampling of these species by farmers and their grazing animals (e.g., buffallos, cows, sheep, goats & donkeys). In addition, the rapid vegetative and sexual developments of *I. carnea* may enable the photosynthetic apparatus to be active for longer period under favorable conditions.

The present study concluded that: (1) the sexual propagation of *I. carnea* from seeds is less common than the vegetative propagation from the decumbent branches, (2) this species was characterized by a typical phalanx growth form, (3) the variation in population natality varied in relation to habitat and time, (4) *I. carnea* sprouts suffered relatively higher mortality rates than the adult plants, (5) The demographic flux had negative values during January and July and reached a maximum value during May, June, October and December, (6) the size distribution of *I. carnea* populations had negative skewed shape, where the big (mature) individuals exceed the small (juveniles) ones and (7) the biomass of *I. carnea* was higher than that of other species in the same habitats in Nile Delta.

REFERENCES

- Abu Al-Izz, M.S., 1971. *Land Forms of Egypt*. The American University in Cairo press, Dar Al Maaref, Cairo, Egypt
- Afifi, M.S., M.M.A. Amer and S.A. El-Khayat, 1988. Macro-and micromorphology of *Ipomoea carnea* Jacq. growing in Egypt. Part I. Leaf and flower. *Mansoura J. Pharm. Sci.*, 3: 41–57
- Albert, T., O. Raspe and A.L. Jacquemart, 2005. Diversity and spatial structure of clones in *Vaccinium uliginosum* populations. *Canadian J. Bot.*, 83: 211–218
- Allen, S., H.M. Grimshaw, J.A. Parkinson and C. Quarmby, 1974. *Chemical Analysis of Ecological Materials*. Blackwell Scientific Publications, London
- Alpert, P., E. Bone and C. Holzapfel, 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Persp. Plant Eco. Evolu. Syst.*, 3: 52–66
- Al-Sodany, Y.M., 1998. Vegetation Analysis of the Canals, Drains and Lakes of the Northern Part of Nile Delta. *Ph. D. Thesis*, Faculty of Science, Tanta University, Tanta, Egypt
- Andrews, J.H., 1998. Bacteria as modular organisms. *Annl. Rev. Microbiol.*, 52: 105–126
- Anonymous, 1980. *Climatic Normals for the Arab Republic of Egypt up to 1975*. Ministry of Civil Aviation, Meteorological Authority, Cairo, General Organization for Governmental Printing Offices
- Augsburger, C.K. and C.K. Kelly, 1984. Pathogen mortality of tropical tree seedlings: experimental studies of the effects of dispersal distance, seedling density and light conditions. *Oecologia*, 61: 211–217
- Baker, P.J. and J.S. Wilson, 2003. Coexistence of tropical tree species. *Nature*, 422: 581–582
- Bear, F.E., 1975. *Chemical of the Soil*. Oxford and IBH Publishing Co., New Delhi
- Boulos, L., 1995. *Flora of Egypt, Checklist*. Al-Hadara Publishing, Cairo, Egypt
- Burke, M.J.W. and J.P. Grime, 1996. An experimental study of plant community invasibility. *Ecology*, 77: 776–790
- Caswell, H., 1986. Life cycle models for plants. *Lectures Math. Life Sci.*, 18: 171–233
- Charpentier, A., 2002. Consequences of clonal growth for plant mating. *Evol. Ecol.*, 15: 521–530
- Chaudhuri, H., T. Ramaprabhu and V. Ramachandran, 1994. *Ipomoea carnea* Jacq. A new aquatic weed problem in India. *J. Aquat. Plant Manag.*, 32: 37–38
- Crawley, M.J., 1986. *Plant Ecology*. Blackwell Science, Oxford
- Crawley, M.J., 1987. What makes a community invisable? In: Gray, A.J., M.J. Crawley and P.J. Edwards (eds.), *Colonisation, Succession and Stability*, pp: 429–453. Blackwell Science, Oxford, UK
- Crawley, M.J., 1987. What makes a community invisable? In: Gray, A.J., M.J. Crawley and P.J. Edwards (eds.), *Colonization, Succession and Stability*, pp: 429–453. Blackwell Science, Oxford, UK
- Davis, M.A. and M. Pelsor, 2001. Experimental support for a resource-based mechanistic model of invasibility. *Ecol. Lett.*, 4: 421–428
- De Kroon H. and J. Van Groenendael, 1997. *The Ecology and Evolution of Clonal Plants*. Backhuys Publishers, Leiden
- Dietz, H., T. Steinlein and I. Ullmann, 1999. Establishment of the invasive perennial herb *Bunias orientalis* L: an experimental approach. *Acta Oecol.*, 20: 621–632
- Dodd, M. and J. Sil Vertown, 2000. Size-specific fecundity and the influence of lifetime size variation upon effective population size in *Abies balsamea*. *Heridity*, 85: 604–609
- El-Sheikh, M.A., 1996. Ruderal plant communities of the Nile Delta Region. *Ph.D. Thesis*, Faculty of Sciences, Tanta University, Tanta, Egypt
- Fox, M.D. and B.J. Fox, 1986. The susceptibility of natural communities to invasion. In: Groves, R.H. and J.J. Burdon (eds.), *Ecology of Biological Invasions: An Australian Perspective*, pp: 57–66. Australian Academy of Science, Australia
- Gottlieb, L.D., 1977. Genotypic similarity of large and small individuals in a natural population of the annual plant *Stephanomeria exigua* ssp. *coronaria* (Compositae). *J. Ecol.*, 65: 127–134
- Gray, B., 1975. Size-composition and regeneration of *Araucaria* stands in new Guinea. *J. Ecol.*, 63: 273–289
- Harper, J.L. and J. White, 1974. The demography of plants. *Annu. Rev. Ecol. Syst.*, 5: 419–463
- Harper, J.L., 1977. *The Population Biology of Plants*. Academic Press, London
- Hartnett, D.C. and F.A. Bazzaz, 1985. The genet and ramet population dynamics of *Solidago canadensis* in an abandoned field. *J. Ecol.*, 73: 407–413
- Hobbs, R.J. and L.F. Huenneke, 1992. Disturbance, diversity and invasion, implication for conservation. *Conserv. Biol.*, 6: 324–337
- Jackson, M.L., 1960. *Soil Chemical Analysis*. Prentice-Hall, Inc. Inglewood cliffs, New Jersey
- Kays, S. and J.L. Harper, 1974. The regulation of plant and tiller density in a grass sward. *J. Ecol.*, 62: 97–105
- Kirkpatrick, M., 1984. Demographic models based on size, not age, for organisms with indeterminate growth. *Ecology*, 65: 1874–1884
- Klimes, L., J. Klimes'ová, R. Hendriks and J. Van Groenendael, 1997. Clonal plant architecture: a comparative analysis of form and function. In: De Kroon H. and J. Van Groenendael (eds.), *The Ecology and Evolution of Clonal Plants*, pp: 1–29. Backhuys Publishers, Leiden
- Levine, J.M., 2000. Species diversity and biological invasions, relating local process to community pattern. *Science*, 288: 852–854
- Levine, J.M. and C.M. D'Antonio, 1999. Elton revisited, a review of evidence linking diversity and invasibility. *Oikos*, 87: 15–26
- Lieth, H., 1975. Primary production of the major vegetation units of the world. In: Lieth, H. and R.H. Whittaker (eds.), *Primary Productivity of the Biosphere*, p: 339. Springer-Verlag, New York
- Lonsdale, W.M. and D.G. Abrecht, 1989. Seedling Mortality in *Mimosa pigra*, an invasive tropical shrub. *J. Ecol.*, 77: 371–385
- Lonsdale, W.M., 1999. Global patterns of plant invasions and the concept of invasibility. *Ecology*, 80: 1522–1536
- Lovett Doust, L., 1981. Population dynamics and local specialization in a clonal perennial (*Ranunculus repens*) I. The dynamics of ramets in contrasting habitats. *J. Ecol.*, 69: 743–755
- Lusk, C., 2003. Tree-species competition and coexistence. *Nature*, 422: 580–581
- Meiners, S.J., S.T.A. Pickett and M.L. Cadenasso, 2002. Exotic plant invasions over 40 years of old field successions: community patterns and associations. *Ecography*, 25: 215–223
- Peter, B., 1980. The demography of leaves in a permanent pasture. *Ph.D. Thesis*, University Collage of North-Wales, Bangor, UK

- Rejmánek, M. and D. Richardson, 1996. What attributes make some plant species more invasive? *Ecology*, 77: 1655–1661
- Roy, J., 1990. In search of the characteristics of plant invaders. In: Di Castri, F., A.J. Hansen and M. Debussche (eds.), *Biological Invasions in Europe and the Mediterranean Basin*, pp: 335–352. Kluwer Academic Publishers, London
- Ryan, J., G. Estefan and A. Rashid, 2001. *Soil and Plant Analysis Laboratory Manual*, 2nd edition. Jointly published by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the National Agricultural Research Center (NARC), Available from ICARDA, Aleppo, Syria
- SAS, 1989. *SAS/STAT User's Guide Version 6*, 4th edition. SAS Instruction Incorporation, Cary, North Carolina
- Scrosati, R., 2002. An updated definition of genet applicable to clonal seaweeds, bryophytes and vascular plants. *Basic Appl. Ecol.*, 3: 97–99
- Shaltout, K.H., 1983. An Ecological Study of *Thymelaea hirsuta* (L.) Endl In Egypt. *Ph.D. Thesis*, Tanta University, Tanta, Egypt
- Shaltout, K.H. and M.A. Ayyad, 1988. Structure and standing crop of Egyptian *Thymelaea hirsuta* populations. *Vegetatio*, 74: 137–142.
- Shaltout, K.H. and M.A. Ayyad, 1990. Size-phytomass relationships of *Thymelaea hirsuta* (L.) Endl in Egypt. *Egyptian J. Bot.*, 33: 133–140
- Shaltout, K.H. and M.A. El-Beheiry, 1997. Phytomass and nutrient status of *Kochia indica* as promising fodder plant in Egypt. *Flora*, 192: 39–45
- Sharma, B.M., 1982. Plant biomass in the semi-arid zone of India. *J. Arid Environ.*, 5: 29–33
- Silvertown, J. and M. Franco, 1993. Plant demography and habitat: a comparative approach. *Plant Species Biol.*, 8: 67–73
- Thébaud, C., A.C. Finzi, L. Affre, M. Debussche and J. Escarre, 1996. Assessing why two introduced *Conyza* differ in their ability to invade Mediterranean old fields. *Ecology*, 77: 791–804
- UNESCO, 1977. *Map of the World Distribution of Arid Regions*. MAB Technical Notes 7
- Weiner, J., 1985. Size hierarchies in experimental populations of annual plants. *Ecology*, 66: 743–752
- Weiner, J., 1990. Asymmetric competition in plant populations. *Trends Ecol. Evol.*, 5: 360–364
- Weiner, J. and S.C. Thomas, 1985. Size variability and competition in even-aged plant monocultures. *Annl. Bot.*, 57: 885–892
- Weiner, J. and S.C. Thomas, 1986. Size variability and competition in plant monocultures. *Oikos*, 47: 211–222
- Witt, S.M., 2004. Microhabitat Distribution and Demography of Two Florida Scrub Endemic Plants with Comparisons to Their Habitat Generalist Congeners. *Ph.D. Thesis*. Louisiana State University and Agricultural and Mechanical College, Louisiana

(Received 06 April 2009; Accepted 01 May 2009)